

# The metals

Red Book™

1997 CD-ROM Version

## Nonferrous Metals



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Subject Index



User Guide

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## Dedication

***The Metals Red Book™*** is dedicated to Michael, Jo-Ann, Mary-Ann and Angela-Marie, my brother and sisters, for their love and support.

John E. Bringas, P.Eng.  
Edmonton, Alberta

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# Chapter

# 1

## ***ALUMINUM AND ALUMINUM ALLOYS***

Although aluminum compounds such as alum have been known since antiquity, aluminum metal was first isolated in minute quantities only during the first few decades of the 19th century. By mid-century aluminum had become more widely available but it was an expensive material. In 1884, when the six-pound ornamental pyramid of aluminum was placed on the top of the Washington Monument in Washington D.C., its cost was close to that of silver. However, in 1886 the simultaneous discovery by Hall in the U.S. and Héroult in France of an electrolytic smelting process for aluminum revolutionized its role in industry by making it economically attractive. The Hall-Héroult process, somewhat modified, remains to this day the only commercial aluminum smelting process.

Aluminum is the most abundant metal in the earth's crust, but its most common ore is bauxite, a hydrated oxide of aluminum, iron, and silicon. Alumina (aluminum oxide,  $\text{Al}_2\text{O}_3$ ) is extracted from this ore by the Bayer process in which the bauxite is treated with hot sodium hydroxide. The resultant alumina is then dissolved in a bath of molten cryolite (sodium aluminum fluoride) and electrolyzed in electrolytic cells with carbon anodes and cathodes. The product is molten aluminum, which is degassed, alloyed if desired, and cast into ingots which are suitable for remelting or for mechanical processing, typically by rolling or extrusion. Aluminum is amenable to recycling, and the use of scrap in both primary and secondary production and in fabrication is an increasing trend.

Bauxite is mined in diverse parts of the world, but aluminum smelting is carried out in localities where electricity costs are low, as energy is more important than transportation in the economics of aluminum production. This is because aluminum is such a reactive metal. In alumina, aluminum and oxygen are so strongly bonded that a great deal of energy is required to separate them. When an atomically clean aluminum surface is exposed to air, it reacts immediately forming a thin oxide layer



within seconds. Fortunately, this thin layer is normally adherent and protective, preventing further oxidation of the metal and endowing it with excellent corrosion resistance in most environments. Furthermore, the surface oxide layer can be controlled and even coloured by the anodization process, adding to its esthetic versatility. A less positive consequence of the reactivity of aluminum is that successful welding procedures require effective shielding from the air.

Aluminum and its alloys have face-centered cubic (fcc) crystal structures, and therefore have excellent formability properties, except when these are inhibited by the degree and type of alloying. The strength obtainable by heat treating some alloys can be greater than in many structural steels. The metal has an attractive surface appearance with good reflectivity, good electrical and thermal conductivity, and low density. This latter property, combined with the high strengths available, gives high strength-to-weight ratios which are responsible for these alloys being the primary structural materials in the aerospace industry. The stiffness (elastic modulus) of aluminum is only about one-third as high as that of steel, and this factor must be considered in component design in order to prevent unduly large deflections in service.

The transportation industry and the container and packaging industry are each responsible for more than 20% of the tonnage of aluminum produced, while the building industry provides more than 15% of the market. Consumer durables, electrical products, and the machinery and equipment industry each provide between 5% and 10% of the market.

Unalloyed (commercial purity) aluminum and some 300 commonly recognized alloys are available, in both cast and wrought forms. In most of these, the total alloy content is less than 15%. Some of the alloys are solid solutions, strengthenable by cold work, while others, both cast and wrought, are heat-treatable (i.e., strengthened by a precipitation hardening heat treatment). The alloy classification system developed by The Aluminum Association makes use of a 4 digit system for wrought aluminum and its alloys, while cast alloys are designated by 3 digits plus a period and a supplementary digit. These nomenclatures are followed by an alphanumeric temper designation which provides information on the thermal and mechanical processing. The system is described in Tables 1 and 2.

The major impurities in aluminum are iron and silicon, with common minor contaminants including zinc, gallium, titanium, and vanadium. These impurities are responsible for the presence, in all aluminum-based materials, of nonmetallic inclusions which are intermetallic compounds containing iron and silicon as well as other elements where available.

Coarse intermetallic constituents, such as particles of  $\text{FeAl}_3$  (or its precursor  $\text{FeAl}_6$ ) and  $\text{Al}_{12}(\text{Fe,Mn})_3\text{Si}$  form during solidification and, although they may be broken up by subsequent fabrication, they remain in the size range of 1-10 micrometers. Other intermetallic phases form as smaller (submicrometer) particles during the initial stages of processing; some of these (e.g.  $\text{Al}_{18}\text{Mg}_3\text{Cr}_2$  and  $\text{Al}_{20}\text{Cu}_2\text{Mn}_3$ ) can have the positive effect of retarding recrystallization and grain growth, thus contributing to grain refinement. Coarse, brittle intermetallic compounds are detrimental to the strength and ductility of the alloys, but especially to the fracture toughness and the appearance after anodizing. In casting alloys, they can also be detrimental to castability, since large insoluble particles in the liquid can dramatically reduce its fluidity. To alleviate these problems, some alloys are available in special grades with restricted levels of impurities. Because of the importance of these impurities, grades of unalloyed aluminum which are intended primarily for remelting are designated by a system using the letter P followed by the maximum contents of silicon and iron respectively in hundredths of a percent. Thus P1020 contains no more than 0.10%Si and 0.20%Fe. A letter may follow this term to designate different elemental limits for impurities other than iron and silicon.

Fabrication of wrought aluminum and its alloys can be carried out by virtually all metalworking processes, notably extrusion, forging, drawing, stamping, and machining. About 50% of wrought products are flat rolled (sheet, plate, foil) with more than 15% as extruded shapes and tubes. Combinations of rolling and extrusion are used to produce bar, rod, and wire. Most wrought alloys are available in many of these product forms. The severe deformations associated with the production of beverage cans provides a vivid illustration of the impressive fabrication properties of some aluminum-based materials. An increasing trend is to the continuous production of shapes starting from the liquid state, for example slab, strip, or bar casting with in-line hot rolling.

The Alclad alloys are composite materials in which thin layers of a cladding alloy are bonded to the surfaces of a high strength alloy to provide corrosion protection. The composition of the cladding alloy is chosen to make it corrosion resistant and also anodic to the core alloy. For example commercial purity cladding is used on aluminum-copper (2xxx) high strength alloys, while aluminum-zinc or aluminum-zinc-magnesium cladding is used on high strength aluminum-zinc-magnesium-copper alloys in the 7xxx series.

Castings are produced by sand mold, permanent mold, pressure-die, investment, and plaster casting. A variety of powder metallurgy

processes are also applicable to aluminum and its alloys. In addition, aluminum is a popular matrix material for metal matrix composites.

### **High Temperature Properties**

Pure aluminum melts at 660°C (1221°F), and alloying elements generally lower the range of melting temperatures, hence aluminum and its alloys are not truly high temperature materials in the usual sense. Furthermore, the strength of the precipitation hardened alloys declines rapidly if they are exposed to temperatures much above 100-200°C (212-392°F) as a result of the coarsening of the strengthening precipitates. Some solution strengthened alloys are capable of maintaining useful strengths at temperatures somewhat above 200°C (392°F), but 300°C (572°F) is beyond the useful range for most aluminum alloy applications. Thus when aluminum alloys are described below as useful for "elevated" temperature applications, this refers to temperatures much lower than would be the case in some other alloy systems.

At sub-zero temperatures aluminum alloys are particularly useful since, unlike ferritic steels, they do not undergo a low temperature embrittlement. They are thus used for structural applications at temperatures as low as -270°C (-454°F).

Aluminum and its alloys are discussed below, beginning with the wrought non-heat-treatable alloys, namely unalloyed aluminum, the aluminum-manganese (3xxx) alloys and the aluminum-magnesium (5xxx) alloys. This is followed by considerations of the wrought heat-treatable alloys and the cast alloys.

### **Wrought Non-Heat-Treatable Alloys**

#### **Unalloyed (Commercial Purity) Aluminum (1xxx Series)**

These materials, which contain in excess of 99%Al, have microstructures consisting mainly of the relatively pure aluminum fcc matrix, the only other phases present being nonmetallic inclusions which result from the presence of the impurities iron and silicon. Unalloyed aluminum is not heat-treatable but can be strengthened by cold working. The most common grade is 1100 (UNS A91100), which has 99.0%Al with Si, Fe, and Cu the principal impurities. This material, with its attractive combination of workability and weldability properties finds major applications as sheet metal work and heat exchangers and in the food and chemical storage and handling industries. Other useful 1xxx alloys include 1050 (UNS A91050) and 1060 (UNS A91060), which have higher purity (99.5% and 99.6%Al, respectively), giving them lower strength but excellent corrosion resistance and formability. These alloys find

applications as tubing and containers for the food, chemical and brewing industries. Also in the 1xxx category are 1145 (UNS A91145), which is used for foil, and 1199 (UNS A91199), a super-purity unalloyed grade having a minimum of 99.99%Al which makes it useful for electrolytic capacitor foil and vapour deposited coatings for optical reflectors. Electrical conductor grade aluminum, alloy 1350 (UNS A91350), sometimes referred to as EC grade, is similar in composition to 1050 but it has stricter limits on a number of impurity elements. It is used for wire, stranded and bus conductors, and transformer strip.

### **Aluminum-Manganese Alloys (3xxx Series)**

The 3xxx series alloys are similar to unalloyed aluminum with additions of manganese or manganese plus magnesium totaling between 1% and 2.4%. For example alloy 3003 (UNS A93003) contains 1.2%Mn, while 3004 (UNS A93004) contains 1.2%Mn and 1.0%Mg, and 3105 (UNS A91305) contains 0.5%Mn and 0.5%Mg. The manganese and magnesium serve as solid solution strengtheners but the manganese also becomes involved in the formation of manganese-rich precipitates such as  $(\text{Mn,Fe})\text{Al}_6$  and  $\text{Al}_{12}(\text{Fe,Mn})_3\text{Si}$  which inhibit recrystallization and therefore contribute to grain refinement, for example during hot work. These alloys are used in large tonnages for beverage containers as well as for cooking utensils, chemical equipment, sheet metal work, building products and pressure vessels. Alloys 3003 and 3004 are also available as Alclad 3003 and Alclad 3004, the cladding layer being alloy 7072, an aluminum-zinc alloy containing 1%Zn. These clad alloys find applications as building products such as siding and roofing.

### **Aluminum-Magnesium Alloys (5xxx Series)**

Dissolved in aluminum, magnesium provides good solid solution strengthening and high work hardening; it does not cause appreciable precipitation hardening at concentrations below 7%. This is the basis for the 5xxx series of non-heat-treatable aluminum alloys. There are numerous alloys in this series, with only a few being Al-Mg binary alloys, while most contain a third element such as manganese or chromium for additional strength through solution strengthening and grain refinement. These alloys have the usual combination of good formability and corrosion resistance, but the higher strength alloys in the series have particularly good weldability when argon-shielded welding procedures are used.

These alloys are solid solutions up to about 3.5%Mg, above which there exists the possibility of the formation of magnesium-aluminum intermetallic phase precipitates such as  $\text{Mg}_5\text{Al}_3$  or  $\text{Mg}_5\text{Al}_8$ . These can create susceptibility to stress corrosion cracking if they precipitate at

grain boundaries, as can happen at temperatures in the 120-180°C (248-356°F) range. Other inclusion phases which form in commercial alloys include  $\text{Mg}_2\text{Si}$  and particles containing Mn and/or Cr as well as Fe.

Common binary alloys include 5005 (UNS A95005), 5050 (UNS A95050) and 5252 (UNS A95252) which contain 0.8%, 1.4%, and 2.5%Mg respectively. These are used for appliances, conductors, pipe, hardware and trim for appliances and automobiles. Common ternary alloys include 5052 (UNS A95052) and 5154 (UNS A95154) both of which contain 0.25%Cr along with magnesium at the level of 2.5% and 3.5% respectively. These find applications in marine service and as tanks and pressure vessels. Alloys 5652 (UNS A95652) and 5254 (UNS A95254) are similar but have lower limits on the iron, silicon, copper, and manganese impurity levels, making them useful for hydrogen peroxide and chemical storage vessels. Alloys containing magnesium, manganese, and chromium include 5056 (UNS A95056), 5083 (UNS A95083), and 5086 (UNS A95086) which have 4.0-5.1%Mg, 0.1-0.7%Mn, and 0.12-0.15%Cr; applications of these materials include zipper stock, nails, construction, marine, automotive and aircraft components, and cryogenics. Other aluminum-magnesium-manganese-chromium alloys such as 5454 (UNS A95454) and 5456 (UNS A95456) find uses in welded structures, tanks, and pressure vessels.

A number of these alloys have particularly attractive appearance when anodized (5005, 5252, 5457, 5657). Alloy 5056 is also available as Alclad 5056 (the cladding layer being Alloy 5253, an aluminum-magnesium-silicon-zinc alloy) which is used in wire form as a screening material. Alclad 5052, 5086, and 5154 are also available.

### **Wrought Heat-Treatable Alloys**

In heat-treatable aluminum alloys, the heat treatment provides strengthening by the mechanism of precipitation hardening. Precipitation hardening requires that the alloying element exhibit a strongly decreasing solubility in aluminum with decreasing temperature. For example, in the aluminum-copper system the equilibrium solubility of copper in aluminum falls dramatically from about 5.6% at 548°C (1018°F) to a negligible solubility at room temperature. This permits the development of a finely dispersed distribution of precipitate particles if an alloy containing less than 5.6%Cu is given a two-step heat treatment as follows:

1. The alloy is subjected to a solution treatment in the single phase region, for example 525°C (977°F) to allow the copper and aluminum to

form a solid solution, then quenched rapidly to room temperature in water. This gives a supersaturated solid solution of copper in aluminum.

2. The supersaturated solid solution is unstable and, given an aging treatment at a relatively low temperature, a second phase will precipitate out as a controlled distribution of fine particles. The aging may occur at room temperature (natural aging) or during heating to a low temperature, e.g. 130-190°C (266-374°F), for a number of hours. Normally it is not the equilibrium phase (e.g.  $\text{CuAl}_2$ , also called *theta*-phase, in the Al-Cu system) but rather a series of non-equilibrium transition phases which form progressively during the aging treatment. The presence of a fine dispersion of particles of these transition phases provides the strength to the alloy; however, if the dispersion becomes too coarse (i.e., a smaller number of larger particles) then the strength drops. This phenomenon, known as overaging, occurs if the aging temperature is too high and/or the aging time is too long. For each system there exists an optimum aging time and temperature which gives the maximum strength. In this peak strength condition, the precipitate particles are too fine to be seen in the optical microscope, but are clearly revealed by transmission electron microscopy. In some alloys precipitation can be stimulated and strength raised further by cold work between solution treatment and aging.

In general the formability and corrosion resistance are degraded by the precipitation hardening process, but they remain satisfactory for many purposes. Fabrication in many cases is carried out before aging, and corrosion resistance can be improved by using Alclad versions of the alloys. Some but not all of these alloys are weldable and in those that are it may be necessary to heat treat after welding.

Among the heat-treatable aluminum alloy systems are those whose principal alloying elements are: copper, alone or with magnesium (the 2xxx system); silicon, alone or with magnesium (the 4xxx and 6xxx systems); and zinc, alone or with magnesium and copper (the 7xxx system).

### **Aluminum-Copper and Aluminum-Copper-Magnesium Alloys (2xxx Series)**

Copper is one of the most important alloying elements in aluminum. It contributes solution strengthening, but also with appropriate heat treatment provides the possibility of precipitation hardening as described above. Several binary aluminum-copper alloys have commercial importance, although most commercial aluminum-copper alloys contain other elements as well, notably magnesium.

The important binary aluminum-copper alloys are 2011 (UNS A92011) and 2219 (UNS A92219). All of these heat-treatable alloys can be given a wide range of strengths depending on the exact heat treatment conditions. For example, alloy 2219 (6.3%Cu, 0.3%Mn) in the T87 condition has a yield strength which is nearly six times higher than the same alloy in the O temper condition. The presence of small amounts of Mn, Zr, Ti and V in this alloy raise its recrystallization temperature so that it maintains useful strength at elevated temperatures, i.e. above 300°C (572°F). This is a readily weldable alloy which is used for supersonic aircraft skin and structural components. It is also available as Alclad 2219 with the cladding material being the aluminum-zinc alloy 7072. Alloy 2011 (UNS A92011) contains 6.5%Cu as well as small amounts of bismuth and lead which form chip-breakers during machining making this a common aluminum alloy for screw-machine products.

The presence of as little as 0.5% magnesium in aluminum-copper alloys has a strongly intensifying effect on the precipitation hardening. The exact mechanisms for this are not fully understood despite these alloys having been known since 1911. Among the important aluminum-copper-magnesium alloys are 2014 (UNS A92014), 2024 (UNS A92024), 2124 (UNS A92124), and 2218 (UNS A92218), all of which contain 4-4.5%Cu and 0.5-1.5%Mg with some also containing smaller quantities of manganese, silicon, and nickel. Alloy 2014 is used for heavy-duty forgings, plate and extrusions for structural components on aircraft and motor vehicles. Alloy 2024, one of the most common aluminum alloys, is a higher strength alloy which also finds applications in the aircraft industry for structural components and fasteners, as well as being used for truck wheels and other miscellaneous structural applications. Alclad 2014 and Alclad 2024 are also available, the cladding material on 2014 being alloy 6006 while 2024 is clad with alloy 1230. Alloy 2124 is similar to 2024 but contains lower levels of impurity elements in order to obtain improved fracture toughness; it is used for thick plate for aircraft structures. Alloy 2218, which contains 2% nickel, is used for aircraft engine components such as pistons, compressor rings, and cylinder heads.

Other aluminum-copper-magnesium alloys include 2048 (UNS A92048), which has a lower copper content than the alloys discussed above and is used as sheet and plate structural components for aerospace applications, and 2618 (UNS A92618), which contains small additions of iron, silicon, nickel, and titanium for use as forgings, tire molds, and aircraft engine components.

**Aluminum-Silicon Alloys (4xxx Series)**

This series includes alloy 4032 (UNS A94032), an alloy containing 12%Si, along with about 1% each of magnesium, copper, and nickel. This alloy is used for pistons and other components for service at "elevated" temperatures. The alloy 4043 (UNS A94043) which contains 0.8%Si is used in rod or wire form as a filler metal for the welding of all aluminum alloys other than those rich in magnesium.

**Aluminum-Magnesium-Silicon Alloys (6xxx Series)**

This heat-treatable alloy series contains 0.6-1.2%Mg and 0.4-1.3%Si with manganese, copper, and chromium often present as well to provide solid solution strengthening and control over grain size. These are referred to as "balanced" alloys when the amounts of magnesium and silicon are in the appropriate ratio to form the useful intermetallic compound  $Mg_2Si$ . With its precursor transition phases,  $Mg_2Si$  provides precipitation hardening when the alloy is solution treated and aged. These alloys are typically solution treated at 520-540°C (968-1004°F), and aged at 160-175°C (320-347°F). In some cases, the composition is specified in terms of % $Mg_2Si$ , rather than referring to the individual elements. Unbalanced alloys generally contain excess silicon.

Alloy 6061 (UNS A96061) is a balanced alloy, containing 1.5% $Mg_2Si$ , which is extensively used for intermediate strength, general purpose applications in the transportation and building industries (e.g., for trucks, towers, pipes and rail cars). It is also available as Alclad 6061, the cladding material being 7072 aluminum-zinc alloy. Higher strength modifications of 6061 include 6066 (UNS A96066) and 6070 (UNS A96070). In order to obtain improved extrusion properties, a lower strength alloy such as alloy 6063 (UNS A96063) with 1% $Mg_2Si$  is employed for applications such as structural shapes, pipe, railings, etc. A modification of 6063 is 6463 (UNS A96463), which has a lower iron impurity content in order to give better appearance after anodizing.

Alloy 6005 (UNS A96005), an unbalanced alloy which has good extrusion properties but higher strength, has applications which include ladders and TV antennae. Alloys 6009 (UNS A96009) and 6011 (UNS A96011) are formable sheet alloys used for automobile body sheet. Here the aging reaction which creates the precipitation hardening occurs during the paint baking heat treatment. Alloys 6101 (UNS A96101) and 6201 (UNS A96201) have applications as high strength bus bars and electrical conductors, while 6151 (UNS A96151) is a forging alloy used in automotive and machine applications. Other useful extrusion alloys include 6070 (UNS A96070), for heavy duty welded structures, 6205



(UNS A96205) which also exhibits high impact strength, and 6351 (UNS A96351).

### **Aluminum-Zinc-Magnesium and Aluminum-Zinc-Magnesium-Copper Alloys (7xxx Series)**

This series of wrought heat-treatable alloys is based on aluminum containing 4-8%Zn and 1-3%Mg. Zinc and magnesium are both very effective in developing strong precipitation hardening characteristics, and the addition of 1-2% copper provides further strengthening. The result is that this series includes the strongest of the precipitation hardening aluminum alloys, which are widely used for structural applications, including many in the aircraft industry. The strengthening precipitate here is  $MgZn_2$  and its transition phase precursors. Magnesium in excess of the  $MgZn_2$  balance further increases strength. Double aging treatments are common in developing the desired dispersion of precipitates. In general these alloys are more susceptible to corrosion than many of the other aluminum alloys, in particular to stress corrosion cracking and exfoliation corrosion. Various strategies are used to improve the resistance to stress corrosion, including overaging and careful control over thermal treatment.

The original high strength alloy in the series is 7075 (UNS A97075), which contains 5.6%Zn, 2.5%Mg, 1.6%Cu, and 0.23%Cr, the latter for improved resistance to stress corrosion cracking. Modified versions of this alloy include 7178 (UNS A97178) and 7001 (UNS A97001), with progressively higher zinc, magnesium, and copper contents and progressively higher strengths. Alloys 7175 (UNS A97175) and 7475 (UNS A97475) are comparable to 7075, but with lower limits on impurities to give improved fracture toughness. Both 7075 and 7178 are produced as Alclad alloys, with the cladding being 7072 (aluminum-zinc) or 7011 (aluminum-zinc-magnesium).

Other high strength aluminum-zinc-magnesium-copper alloys include 7049 (UNS A97049), which is used for aircraft forgings and extrusions, 7050 (UNS A97050), which is designed for improved resistance to exfoliation corrosion and stress corrosion cracking as well as for high fracture toughness and fatigue resistance, and 7076 (UNS A97076) which is a forging alloy used for aircraft propellers.

The aluminum-zinc-magnesium alloys without copper addition include 7005 (UNS A97005), which was developed specifically to be weldable. It is used in situations where moderate strength and weldability are required, such as in large heat exchangers and structural members for trucks and trailers. It is also used in sporting equipment.

The alloy 7072 (UNS A97072), a binary aluminum-zinc alloy containing 1%Zn, has a high corrosion potential and finds extensive use as cladding on a wide range of Alclad alloys; it is also used for sacrificial anodes.

## **Cast Aluminum Alloys**

Cast aluminum alloys have compositions which have been developed not only for strength, ductility, and corrosion resistance but also for castability properties such as fluidity in the liquid state. This has resulted in their having different compositions than the wrought alloys, in particular higher silicon contents. Silicon forms a simple eutectic system with aluminum, thus at a late stage of solidification there will be a highly fluid liquid available to feed the normal solidification shrinkage cavities. Thus the presence of silicon in the alloy, at levels ranging from 4% to 12%, permits production of high quality intricate castings with large variations in section thickness while keeping scrap loss minimal by reducing cracking and shrinkage porosity. Aluminum-silicon-based alloys are the most common of the aluminum casting alloys.

Casting alloys (Table 1) are available in a number of alloy systems and in both non-heat-treatable and heat-treatable grades, although here the distinctions are not as clear as in wrought alloys.

## **Aluminum-Copper Alloys**

Aluminum-copper alloys are heat-treatable and capable of high strength, but are relatively difficult to cast, have poor weldability, and can be susceptible to corrosion. Alloy 242.0 (UNS A02420), which contains 4%Cu, 2%Ni, and 2.5%Mg, finds applications in pistons and air-cooled cylinder heads for motorcycle, diesel, and aircraft engines.

## **Aluminum-Copper-Silicon Alloys**

Aluminum-copper-silicon alloys are extensively used, with the copper contributing to strength and the silicon to castability. A wide range of compositions is produced, ranging from high copper to high silicon, thus these alloys fall into both the 2xx.x and the 3xx.x series. These alloys are heat-treatable when the copper content is above 3-4%, especially when magnesium is present as well. Alloys in this category which have 4-5%Cu and 1-3%Si, include 208.0 (UNS A02080) which is used for pressure-tight castings such as manifolds and valve bodies, as well as 295.0 (UNS A02950) and 296.0 (UNS A02960) which are used for wheels, fittings, and housings where strength and machinability are required. Alloys which contain more silicon than copper include 308.0 (UNS A03080) and 319.0 (UNS A03190), which contain 5-6%Si and 3-5%Cu; these are used for

general purpose castings and in automotive applications. Alloys with 8-12%Si and 2-4%Cu include 380.0 (UNS A03800), 383.0 (UNS A03830), and 384.0 (UNS A03840) which are die casting alloys. The 380.0 alloy in particular is very widely used in the automotive and consumer electrical industries, although it has poor weldability and brazeability. Some aluminum-silicon-copper alloys also contain small amounts of magnesium for strengthening purposes; examples include 354.0 (UNS A03540) and 355.0 (UNS A03550). Hypereutectic alloys, i.e. those with more than 12%Si, contain primary silicon particles in their microstructures which impart wear resistance, giving these alloys applications as automotive pistons and engine blocks. A popular example is 390.0 (UNS A03900), which contains 17%Si, 4.5%Cu, and 0.6%Mg.

### **Aluminum-Silicon Alloys**

When a combination of castability and corrosion resistance is deemed more important than strength, aluminum-silicon alloys without copper are used. Examples of this type of alloy include 413.0 (UNS A04130) which has 12%Si and is used for intricate die castings which may require pressure tightness, and 443.0 (UNS A04430) with 5.2%Si which is used mainly for sand and permanent mold castings including cooking utensils and food handling equipment. These non-heat-treatable alloys have good weldability and are among the most important commercial casting alloys.

### **Aluminum-Silicon-Magnesium Alloys**

Magnesium additions to the aluminum-silicon alloys render them heat-treatable, and hence provide increased strength. Alloys 356.0 (UNS A03560), which is very widely used for sand and permanent mold castings, and its stronger variants 357.0 (UNS A03570) and 359.0 (UNS A03590) fall into this category with 7-10%Si plus 0.3-0.6%Mg. So does the alloy 360.0 (UNS A03600), a die casting alloy for use where the corrosion resistance of 380.0 is inadequate. In some alloys, sodium or calcium additions are made to modify the Al-Si eutectic so as to provide a further increment of strength.

### **Aluminum-Magnesium Alloys**

Aluminum-magnesium alloys are not heat-treatable, being mainly single phase solid solutions. They are used where high corrosion resistance is desired, especially in marine environments and food handling. Low impurity content is important here as well. These alloys have poorer castability than the silicon-bearing alloys but have good machinability and attractive appearance when anodized. Examples include 514.0 (UNS

A05140) with 4%Mg, 518.0 (UNS A05180) with 8%Mg, 520.0 (UNS A05200) with 10%Mg, and 535.0 (UNS A05350) which contains 7%Mg.

### **Aluminum-Zinc-Magnesium Alloys**

Aluminum-zinc-magnesium casting alloys have poor castability and poor temperature resistance but can be heat treated to reasonable strength levels and are amenable to brazing and machining. Alloy 712.0 (UNS A07120), 713.0 (UNS A07130), and 771.0 (UNS A07710) contain 6-8%Zn and 0.3-0.9%Mg with minor additions of other elements. One application of 713.0 is cast aluminum furniture.

### **Aluminum-Tin Alloys**

Aluminum-tin alloys, such as 850.0 (UNS A08500), with about 6%Sn and minor amounts of copper and nickel, find applications as cast bearing alloys, for example as connecting rod and crankcase bearings in diesel engines.

Many of these casting alloys are also available with lower specified impurity levels, for example 380.0 (UNS A13800) and 384.0 (UNS A13840). The 443.0 alloy comes additionally as A443.0 (UNS A14430), B443.0 (UNS A24430), and C443.0 (UNS A34430) with different impurity levels specified in each case.

### **Weldability**

Welding of aluminum and its alloys is complicated by the strong tendency of aluminum to react with oxygen in the air to form a thin surface oxide layer. Thus shielding by gas atmosphere or by flux is critical in the welding process. GTAW (gas tungsten arc welding) and GMAW (gas metal arc welding) techniques are standard and most alloys, wrought and cast, are readily weldable. There are, however, a number which require special welding techniques and some for which welding is not recommended.

Generally, the non-heat-treatable alloys are readily weldable as are the heat-treatable 6xxx alloys. Special techniques may be required for the heat-treatable 2xxx and 4xxx series. The 7xxx high strength heat-treatable alloys are generally not recommended for arc welding, with the exception of 7005 and 7039 which were developed specifically for welding. In general, the heat associated with welding has a strong local effect on the microstructure and properties of the material, for example the strength of the weld region of a strain hardened alloy may be similar to that of the alloy in the annealed condition. In the heat-treatable alloys, solution treating, annealing, and overaging can occur in the heat affected

zone, so it may be necessary to re-solution treat and re-age the materials after welding to recover the strength properties; however, the ductility may not be fully recovered.

In addition to arc welding, aluminum and its alloys can in general be resistance welded and can be brazed with an appropriate flux.

### Table 1 Aluminum Alloy Groups

(a) Wrought aluminum and its alloys grouped by major alloying element:

|      |                                   |
|------|-----------------------------------|
| 1xxx | unalloyed aluminum, 99%Al minimum |
| 2xxx | copper                            |
| 3xxx | manganese                         |
| 4xxx | silicon                           |
| 5xxx | magnesium                         |
| 6xxx | magnesium and silicon             |
| 7xxx | zinc                              |
| 8xxx | other elements                    |

In the 1xxx series, where the aluminum content is greater than 99.00%, the last two digits give the minimum aluminum percentage. They are the same as the two digits to the right of the decimal point in the minimum aluminum percentage in the specification (e.g. 1050 contains  $\geq 99.50\% \text{Al}$ ). The second digit is 0 for unalloyed aluminum with natural impurity limits; 1 through 9 for special limits on one or more individual elements.

In the other series, 2xxx to 7xxx, the last two digits have no special significance. The second digit indicates alloy modifications, i.e., it is assigned 0 in the original alloy developed, with 1 through 9 assigned consecutively indicating alloying modifications.

(b) Cast aluminum and its alloys grouped by major alloying element:

|       |                                             |
|-------|---------------------------------------------|
| 1xx.x | unalloyed aluminum, 99%Al minimum           |
| 2xx.x | copper                                      |
| 3xx.x | silicon, with added copper and/or magnesium |
| 4xx.x | silicon                                     |
| 5xx.x | magnesium                                   |
| 7xx.x | zinc                                        |
| 8xx.x | tin                                         |
| 9xx.x | other                                       |

In the 1xx.x series, where the aluminum content is greater than 99.00%, the second and third digits give the minimum aluminum percentage.

They are the same as the two digits to the right of the decimal point in the minimum aluminum percentage. Thus 150.0 contains  $\geq 99.50\% \text{Al}$ . The last digit indicates the product form: 1xx.0 for castings and 1xx.1 for ingot.

In the other series, 2xx.x to 7xx.x, the second and third digits have no special significance. In these series, the final digit defines the product form: xxx.0 for castings, xxx.1 and xxx.2 for ingots suitable for foundry use, where the final digits 1 and 2 refer to composition limits on iron, magnesium, and zinc in the ingots. Prefix letters are used to denote differences in impurity limits (especially iron) in castings (e.g. B443.0).

## **Table 2 Basic Temper Designations**

F - As fabricated, with no special control over thermal or mechanical treatment and no mechanical property limits for wrought products

O - Annealed to obtain lowest strength temper (wrought products) and to improve ductility and dimensional stability (cast products). May be followed by a digit other than zero.

H - Strain hardened (wrought products only). The H is always followed by two or more digits (see below).

W - Solution heat treated. Applicable to alloys which age at room temperature over a period of months or years.

T - Heat treated to produce stable tempers other than F, O, or H. Applicable to alloys that are thermally treated, with or without supplementary strain hardening, to produce stable tempers. The T is always followed by one or more digits (see next page).

## **Strain Hardened Products**

The first digit following the H indicates the specific sequence of basic operations as described below. The second digit indicates the degree of strain hardening on a scale from 1 through 9, where 0 corresponds to full annealing and 8 corresponds to 75% cold work following full annealing. Thus when the second digit is 2 (e.g., alloy 5005-H12) the material is said to be quarter hard, 4 - half hard, 8 - full hard. The numeral 9 is used when the UTS exceeds that of 8 by more than 10 MPa. A third digit, when used, refers to a specific variation of a 2-digit temper. There are special 3 digit designations for patterned or embossed sheet.

H1 - Strain hardened only, with no supplementary thermal treatment.

H2 - Strain hardened and partially annealed, i.e. strain hardened more than the desired final amount, then annealed to reduce the strength. The second digit refers to the strength level after the partial anneal.

H3 - Strain hardened and stabilized by a low temperature thermal treatment, for those alloys which gradually age-soften at room temperature. The second digit refers to the strength level after stabilization.

### **Heat Treated Products**

The T is followed by a number from 1 to 10, indicating a specific sequence of basic treatments as described below. This is followed by one or more additional digits, the first of which cannot be 0, to identify a variation of one of the 10 basic tempers (e.g. alloy 2024-T3, alloy 7075-T651). In this context "naturally aged" means aged at room temperature, and "artificially aged" means aged above room temperature. Specific designations have been assigned for the cases of stress relieving by stretching, compressing, or a combination of the two. These include TX51, TX510, TX511, while TX52 refers to stress relief by compressing and TX54 by stretching and compressing.

T1 - Cooled from an elevated temperature shaping process and naturally aged to a substantially stable condition (not cold worked).

T2 - Cooled from an elevated temperature shaping process, cold worked, and naturally aged to a substantially stable condition.

T3 - Solution treated, cold worked, and naturally aged to a substantially stable condition.

T4 - Solution treated and naturally aged to a substantially stable condition.

T5 - Cooled from an elevated temperature shaping process and artificially aged.

T6 - Solution heat treated and artificially aged.

T7 - Solution heat treated and overaged or stabilized. This applies to wrought products which have been precipitation hardened past the point of maximum strength and to cast products which are artificially aged to provide dimensional and strength stability.

T8 - Solution heat treated, cold worked, and artificially aged.

T9 - Solution heat treated, artificially aged, and cold worked.

T10 - Cooled from an elevated temperature shaping process, cold worked, and artificially aged.

| <b>SAE/AMS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS</b> |                                                                                                  |
|----------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                     | <b>Title</b>                                                                                     |
| 2201                                                           | Tolerances Aluminum and Aluminum Alloy Bar, Rod, Wire, and Forging Stock Rolled or Cold Finished |
| 2202                                                           | Tolerances, Aluminum Alloy and Magnesium Alloy Sheet and Plate                                   |
| 2203                                                           | Tolerances, Aluminum Alloy Drawn Tubing                                                          |
| 2204                                                           | Tolerances Aluminum Alloy Standard Structural Shapes                                             |
| 2205                                                           | Tolerances, Aluminum Alloy and Magnesium Alloy Extrusions                                        |
| 2450                                                           | Sprayed Metal Finish Aluminum                                                                    |
| 2470                                                           | Anodic Treatment of Aluminum Alloys, Chromic Acid Process                                        |
| 2471                                                           | Anodic Treatment of Aluminum Alloys, Sulfuric Acid Process, Undyed Coating                       |
| 2472                                                           | Anodic Treatment of Aluminum Alloys, Sulfuric Acid Process, Dyed Coating                         |
| 2473                                                           | Chemical Treatment for Aluminum Alloys, General Purpose Coating                                  |
| 2474                                                           | Chemical Treatment for Aluminum Alloys Low Electrical Resistance Coating                         |
| 2482                                                           | Teflon-Impregnated or Codeposited Hard Coating Treatment of Aluminum Alloys                      |
| 2672                                                           | Brazing, Aluminum                                                                                |
| 2673                                                           | Aluminum Molten Flux (Dip) Brazing                                                               |
| 2811                                                           | Identification Aluminum and Magnesium Alloy Wrought Products                                     |
| 3412                                                           | Flux, Aluminum Brazing                                                                           |
| 3414                                                           | Flux, Aluminum Welding                                                                           |
| 3415                                                           | Flux, Aluminum Dip Brazing 1030°F (554°C) or Lower Liquidus                                      |
| 4000                                                           | Aluminum Sheet and Plate, (1060) NONCURRENT January 1987, UNS A91060                             |
| 4001                                                           | Aluminum Sheet and Plate 0.12Cu, (1100-0) Annealed, UNS A91100                                   |
| 4003                                                           | Aluminum Sheet and Plate 0.12Cu, (1100-H14) Strained Hardened, UNS A91100                        |
| 4004                                                           | Aluminum Alloy Foil, 2.5Mg - 0.25Cr, (5052-H191) Strain Hardened, UNS A95052                     |
| 4005                                                           | Aluminum Alloy Foil 5.0Mg - 0.12Mn - 0.12Cr, (5056-H191) Strain Hardened, UNS A95056             |
| 4006                                                           | Aluminum Alloy Sheet and Plate 1.25Mn - 0.12Cu - (3003-0) Annealed, UNS A93003                   |
| 4007                                                           | Aluminum Alloy Foil 4.4Cu - 1.5Mg - 0.6Mn (2024-0), UNS A92024                                   |
| 4008                                                           | Aluminum Alloy Sheet and Plate 1.25Mn - 0.12Cu (3003-H14) Strain Hardened, UNS A93003            |
| 4009                                                           | Aluminum Alloy Foil 1.0Mg - 0.6Si - 0.30Cu - 0.20Cr (6061-0) Annealed, UNS A96061                |



| <b>SAE/AMS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                   |
|----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                                                                      |
| 4010                                                                       | Aluminum Alloy Foil 1.2Mn - 0.12Cu (3003-H18), UNS A93003                                                                                                                         |
| 4011                                                                       | Aluminum Foil 99.45Al (1145-0) Annealed, UNS A91145                                                                                                                               |
| 4013                                                                       | Aluminum Sheet, Laminated, Surface Bonded                                                                                                                                         |
| 4014                                                                       | Aluminum Alloy Plate 4.5Cu - 0.85Si - 0.80Mn - 0.50Mg (2014-T651), Superseded by AMS 4029                                                                                         |
| 4015                                                                       | Aluminum Alloy Sheet and Plate 2.5Mg - 0.25Cr (5052-0) Annealed, UNS A95052                                                                                                       |
| 4016                                                                       | Aluminum Alloy Sheet and Plate 2.5Mg - 0.25Cr (5052-H32) Strain Hardened, Quarter-Hard, and Stabilized, UNS A95052                                                                |
| 4017                                                                       | Aluminum Alloy Sheet and Plate, 2.5Mg - 0.25Cr - (5052-H34) Strained Hardened, Half-Hard, and Stabilized, UNS A95052                                                              |
| 4021                                                                       | Aluminum Alloy Sheet and Plate, Alclad 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (Alclad 6061-0) Annealed, UNS A86061                                                                      |
| 4025                                                                       | Aluminum Alloy Sheet and Plate 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-0) Annealed, UNS A96061                                                                                     |
| 4026                                                                       | Aluminum Alloy Sheet and Plate 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061; -T4 Sheet, -T451 Plate) Solution Heat Treated and Naturally Aged, UNS A96061                               |
| 4027                                                                       | Aluminum Alloy Sheet and Plate 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061; -T6 Sheet, -T651 Plate) Solution and Precipitation Heat Treated, UNS A96061                                |
| 4028                                                                       | Aluminum Alloy Sheet and Plate 4.4Cu - 0.85Si - 0.80Mn - 0.50Mg (2014-0) Annealed, UNS A92014                                                                                     |
| 4029                                                                       | Aluminum Alloy Sheet and Plate 4.5Cu - 0.85Si - 0.80Mn - 0.50Mg (2014; -T6 Sheet, -T651 Plate) Solution and Precipitation Heat Treated, UNS A92014                                |
| 4031                                                                       | Aluminum Alloy Sheet and Plate 6.3Cu - 0.30Mn - 0.18Zr - 0.10V - 0.06Ti (2219-0) Annealed, UNS A92219                                                                             |
| 4035                                                                       | Aluminum Alloy Sheet and Plate 4.4Cu - 1.5Mg - 0.60Mn (2024-0) Annealed, UNS A92024                                                                                               |
| 4036                                                                       | Aluminum Alloy Sheet and Plate, Alclad One Side, 4.4Cu - 1.5Mg - 0.60Mn (Alclad One Side 2024, -T3 Sheet; -T351 Plate), UNS A82024                                                |
| 4037                                                                       | Aluminum Alloy Sheet and Plate 4.4Cu - 1.5Mg - 0.60Mn (2024; -T3 Flat Sheet, - T351 Plate) Solution Heat Treated, UNS A92024                                                      |
| 4040                                                                       | Aluminum Alloy Sheet and Plate, Alclad 4.4Cu - 1.5Mg - 0.60Mn (Alclad 2024 and 1½% Alclad 2024-0) Annealed, UNS A82024                                                            |
| 4041                                                                       | Aluminum Alloy Sheet and Plate, Alclad 4.4 Cu - 1.5Mg - 0.60Mn (Alclad 2024 and 1½% Alclad 2024, -T3 Flat Sheet; 1½% Alclad 2024-T351 Plate, UNS A92024                           |
| 4044                                                                       | Aluminum Alloy Sheet and Plate 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-0) Annealed, UNS A97075                                                                                       |
| 4045                                                                       | Aluminum Alloy Sheet and Plate 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075; -T6 Sheet, -T651 Plate) Solution and Precipitation Heat Treated, UNS A97075                                  |
| 4046                                                                       | Aluminum Alloy Sheet and Plate, Alclad one side 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (Alclad One Side 7075; -T6 Sheet, -T651 Plate) Solution and Precipitation Heat Treated, UNS A87075 |

| <b>SAE/AMS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                         |
|----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                                                                                            |
| 4048                                                                       | Aluminum Alloy Sheet and Plate, Alclad 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (Alclad 7075-0) Annealed, UNS A87075                                                                                              |
| 4049                                                                       | Aluminum Alloy Sheet and Plate, Alclad 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (Alclad 7075; -T6 Sheet - T651 Plate) Solution and Precipitation Heat Treated, UNS A97075                                         |
| 4050                                                                       | Aluminum Alloy Plate 6.2Zn - 2.3Cu - 2.2Mg - 0.12Zr (7050-T7451) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97050                                                                       |
| 4056                                                                       | Aluminum Alloy Sheet and Plate 4.4Mg - 0.70Mn - 0.15Cr (5083-0) Annealed, UNS A95083                                                                                                                    |
| 4062                                                                       | Aluminum Tubing, Seamless, Drawn, Round (1100-H14) Strain Hardened, UNS A91100                                                                                                                          |
| 4063                                                                       | Aluminum Alloy Sheet, Clad One Side 1.25Mn - 0.12Cu (No. 11-0 Brazing Sheet) Annealed, UNS A83003                                                                                                       |
| 4064                                                                       | Aluminum Alloy Sheet, Clad Two Sides 1.25Mn - 0.12Cu (No. 12-0 Brazing Sheet) Annealed, UNS 83003                                                                                                       |
| 4065                                                                       | Aluminum Alloy Tubing, Seamless, Drawn 1.2Mn - 0.12Cu (3003-0) Annealed, UNS A93003                                                                                                                     |
| 4066                                                                       | Aluminum Alloy Tubing, Seamless, Drawn 6.3Cu - 0.30Mn - 0.18Zr - 0.10V - 0.06Ti (2219-T8511) (See 8.2) Solution Heat Treated, Stress Relieved by Stretching, and Precipitation Heat Treated, UNS A92219 |
| 4067                                                                       | Aluminum Alloy Tubing, Seamless, Drawn, Round 1.25Mn - 0.12Cu (3003 - H14) Strain Hardened, UNS A93003                                                                                                  |
| 4068                                                                       | Aluminum Alloy Tubing, Seamless, Drawn 6.3Cu - 0.30Mn - 0.18Zr - 0.10V - 0.06Ti (2219-T3511) Solution Heat Treated and Stress Relieved by Stretching, UNS A92219                                        |
| 4069                                                                       | Aluminum Alloy Tubing, Seamless, Drawn, Round Close Tolerance 2.5Mg - 0.25Cr (5052-0) Annealed, UNS A95052                                                                                              |
| 4070                                                                       | Aluminum Alloy Tubing, Seamless, Drawn, Round 2.5Mg - 0.25Cr (5052-0), UNS A95052                                                                                                                       |
| 4071                                                                       | Aluminum Alloy Tubing, Hydraulic, Seamless, Drawn, Round 2.5Mg - 0.25Cr (5052-0) Annealed, UNS A95052                                                                                                   |
| 4077                                                                       | Aluminum Alloy Sheet and Plate, Alclad One Side 4.4Cu - 1.5Mg - 0.60Mn (Clad One Side 2024-0) Annealed, UNS A82024                                                                                      |
| 4078                                                                       | Aluminum Alloy Plate 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T7351) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97075                                                                       |
| 4079                                                                       | Aluminum Alloy Tubing, Seamless, Drawn, Round, Close Tolerance 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-0) Annealed, UNS A96061                                                                           |
| 4080                                                                       | Aluminum Alloy Tubing, Seamless, Drawn, 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-0), UNS A96061                                                                                                           |
| 4081                                                                       | Aluminum Alloy Tubing, Hydraulic, Seamless, Drawn, Round 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T4) Solution Heat Treated and Naturally Aged, UNS A96061                                                |
| 4082                                                                       | Aluminum Alloy Tubing, Seamless, Drawn 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T6) Solution and Precipitation Heat Treated, UNS A96061                                                                   |
| 4083                                                                       | Aluminum Alloy Tubing, Hydraulic, Seamless, Drawn, Round 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T6) Solution and Precipitation Heat Treated, UNS A96061                                                 |
| 4084                                                                       | Aluminum Alloy Sheet 5.7Zn - 2.2Mg - 1.6Cu - 0.22Cr (7475T-61) Solution and Precipitation Heat Treated, UNS A97475                                                                                      |

| <b>SAE/AMS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                                                    |
|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                                                                                                                                                                       |
| 4085                                                                       | Aluminum Alloy Sheet 5.7Zn - 2.2Mg - 1.6Cu - 0.22Cr (7475-T761) Solution Heat Treated and Overaged, UNS A97475                                                                                                                                                                     |
| 4086                                                                       | Aluminum Alloy Tubing, Hydraulic, Seamless, Drawn 4.4Cu - 1.5Mg - 0.60Mn (2024-T3) Solution Heat Treated, Cold Worked, and Naturally Aged, UNS A92024                                                                                                                              |
| 4087                                                                       | Aluminum Alloy Tubing, Seamless, Drawn 4.4Cu - 1.5Mg - 0.60Mn (2024-0) Annealed, UNS A92024                                                                                                                                                                                        |
| 4088                                                                       | Aluminum Alloy Tubing, Seamless, Drawn 4.4Cu - 1.5Mg - 0.60Mn (2024-T3) Solution Heat Treated and Cold Worked, UNS A92024                                                                                                                                                          |
| 4089                                                                       | Aluminum Alloy Plate 5.7Zn - 2.2Mg - 1.6Cu - 0.22Cr (7475-T7651) Solution Heat Treated, Stress Relieved by Stretching, and Precipitation Heat Treated, UNS A97475                                                                                                                  |
| 4090                                                                       | Aluminum Alloy Plate 5.7Zn - 2.2Mg - 1.6Cu - 0.22Cr (7475-T651) Solution Heat Treated, Stress Relieved, and Precipitation Heat Treated, UNS A97475                                                                                                                                 |
| 4094                                                                       | Aluminum Alloy Sheet and Plate, Alclad 6.3Cu - 0.30Mn - 0.18Zr - 0.10V - 0.06Ti Alclad 2219-T81 Sheet Solution Heat Treated, Cold Worked, and Precipitation Heat Treated Alclad 2219-T851 Plate Solution Heat Treated, Stress Relieved and Precipitation Heat Treated), UNS A82219 |
| 4095                                                                       | Aluminum Alloy Sheet and Plate, Alclad 6.3Cu - 0.30Mn - 0.18Zr - 0.10V - 0.06Ti Alclad 2219-T31; Sheet, Solution Heat Treated and Cold Worked Alclad 2219-T351; Plate, Solution Heat Treated and Stress Relieved, UNS A82219                                                       |
| 4096                                                                       | Aluminum Alloy Sheet and Plate, Alclad 6.3Cu - 0.30Mn - 0.18Zr - 0.10V - 0.06Ti (Alclad 2219-0) Annealed, UNS A92219                                                                                                                                                               |
| 4100                                                                       | Aluminum Alloy Sheet, Alclad 5.7Zn - 2.2Mg - 1.6Cu - 0.22Cr (7475- T761) Solution and Precipitation Heat Treated, UNS A97475                                                                                                                                                       |
| 4101                                                                       | Aluminum Alloy Plate 4.4Cu - 1.5Mg - 0.60Mn (2124-T851) Solution Heat Treated, Stretched, and Precipitation Heat Treated, UNS A92124                                                                                                                                               |
| 4102                                                                       | Aluminum Alloy Bars, Rods, and Wire, Rolled or Cold-Finished 99.0Al (1100-F) as Fabricated, UNS A9100                                                                                                                                                                              |
| 4107                                                                       | Aluminum Alloy Die Forgings 6.2Zn - 2.3Cu - 2.2Mg - 0.12Zr (7050-T74) Solution Heat Treated and Overaged, UNS A97050                                                                                                                                                               |
| 4108                                                                       | Aluminum Alloy Hand Forgings 6.2Zn - 2.3Cu - 2.2Mg - 0.12Zr (7050-T7452) (formerly -T73652) Solution Heat Treated, Compression Stress-Relieved, and Overaged, UNS A97050                                                                                                           |
| 4111                                                                       | Aluminum Alloy Forgings 7.7Zn - 2.5Mg - 1.5Cu - 0.16Cr (7049-T73) Solution and Precipitation Heat Treated, UNS A97049                                                                                                                                                              |
| 4113                                                                       | Aluminum Alloy Extruded Structural Shapes 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061- T6) Solution and Precipitation Heat Treated, UNS A96061                                                                                                                                          |
| 4114                                                                       | Aluminum Alloy Bars and Rods, Rolled or Cold-Finished 2.5Mg - 0.25Cr (5052-F) as Fabricated, UNS A95052                                                                                                                                                                            |
| 4115                                                                       | Aluminum Alloy Bars, Rods, and Wire, Rolled or Cold-Finished, and Rings 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-0) Annealed, UNS A96061                                                                                                                                             |
| 4116                                                                       | Aluminum Alloy Bars, Rods, and Wire, Cold-Finished, 1.0Mg - 0.60Si - 0.30Cu - 0.20Cr (6061-T4), UNS A96061                                                                                                                                                                         |
| 4117                                                                       | Aluminum Alloy Bars, Rods, And Wire, Rolled or Cold Finished and Flash Welded Rings 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061; -T6, -T651) Solution and Precipitation Heat Treated, UNS A96061                                                                                        |

| <b>SAE/AMS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                                    |
|----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                                                                                                       |
| 4118                                                                       | Aluminum Alloy Bars, Rods, and Wire, Rolled or Cold Finished 4.0Cu - 0.70Mn - 0.60Mg - 0.50Si (2017; -T4, -T451) Solution Heat Treated, UNS A92017                                                                 |
| 4120                                                                       | Aluminum Alloy Bars, Rods, and Wire, Rolled or Cold Finished 4.4Cu - 1.5Mg - 0.60Mn (2024) Solution Heat Treated and Naturally Aged (T4) Solution Heat Treated, Cold Worked, and Naturally Aged (T351), UNS A92024 |
| 4121                                                                       | Aluminum Alloy Bars, Rods, and Wire, Rolled or Cold Finished 4.5Cu - 0.85Si - 0.80Mn - 0.50Mg (2014-T6) Solution and Precipitation Heat Treated, UNS A92014                                                        |
| 4122                                                                       | Aluminum Alloy Bars, Rods, and Wire Rolled or Cold Finished, and Rings 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T6) Solution and Precipitation Heat Treated, UNS A97075                                                |
| 4123                                                                       | Aluminum Alloy Bars and Rods, Rolled or Cold Finished 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T651) Solution and Precipitation Heat Treated, UNS A97075                                                               |
| 4124                                                                       | Aluminum Alloy Bars Rods and Wire, Rolled, Drawn or Cold Finished 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T7351), UNS A97075                                                                                          |
| 4125                                                                       | Aluminum Alloy Die Forgings, and Rolled or Forged Rings 0.90Si - 0.62Mg - 0.25Cr (6151-T6) Solution and Precipitation Heat Treated, UNS A96151                                                                     |
| 4126                                                                       | Aluminum Alloy Forgings 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T6) Solution and Precipitation Heat Treated, UNS A97075                                                                                               |
| 4127                                                                       | Aluminum Alloy Forgings and Rolled or Forged Rings 1.0Mg - 0.6Si - 0.28Cu - 0.20Cr (6061- T6) Solution and Precipitation Heat Treated, UNS A96061                                                                  |
| 4128                                                                       | Aluminum Alloy Bars, Rolled or Cold Finished 1.0Mg - 0.60Si - 0.30Cu - 0.20Cr (6061- T451) Solution Heat Treated and Stress Relieved by Stretching, UNS A96061                                                     |
| 4130                                                                       | Aluminum Alloy Die Forgings 4.4Cu - 0.85Si - 0.80Mn (2025-T6) Solution and Precipitation Heat Treated, UNS A92025                                                                                                  |
| 4131                                                                       | Aluminum Alloy Forgings 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T74) Solution and Precipitation Heat Treated, UNS A97075                                                                                              |
| 4132                                                                       | Aluminum Alloy Die and Hand Forgings, Rolled Rings, and Forging Stock 2.3Cu - 1.6Mg - 1.1Fe - 1.0Ni - 0.18Si - 0.07Ti (2618-T61) Solution and Precipitation Heat Treated, UNS A92618                               |
| 4133                                                                       | Aluminum Alloy Forgings and Rolled Rings 4.4Cu - 0.85Si - 0.80Mn - 0.50Mg (2014-T6) Solution and Precipitation Heat Treated, UNS A92014                                                                            |
| 4134                                                                       | Aluminum Alloy Die Forgings 4.4Cu - 0.85Si - 0.80Mn - 0.50Mg (2014-T4) Solution Heat Treated, UNS A92014                                                                                                           |
| 4140                                                                       | Aluminum Alloy Die Forgings 4.0Cu - 2.0Ni - 0.68Mg (2018-T61) Solution Heat Treated, UNS A92018                                                                                                                    |
| 4141                                                                       | Aluminum Alloy Die Forgings 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T73) Solution and Precipitation Heat Treated, UNS A97075                                                                                          |
| 4143                                                                       | Aluminum Alloy Forgings and Rolled or Forged Rings 6.3Cu - 0.30Mn - 0.18Zr - 0.10V - 0.06Ti (2219-T6) Solution and Precipitation Heat Treated, UNS A92219                                                          |

| <b>SAE/AMS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                |
|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                                                                                   |
| 4144                                                                       | Aluminum Alloy Hand Forgings and Rolled Rings 6.3Cu - 0.30Mn - 0.18Zr - 0.10V - 0.06Ti (2219-T852) Solution Heat Treated, Stress Relief Compressed, and Precipitation Heat Treated, UNS A92219 |
| 4146                                                                       | Aluminum Alloy Forgings and Rolled or Forged Rings 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T4) Solution Heat Treated and Naturally Aged, UNS A96061                                             |
| 4147                                                                       | Aluminum Alloy Forgings 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T7352) Solution Heat Treated Stress Relieved by Compression, and Overaged, UNS A97075                                             |
| 4148                                                                       | Aluminum Alloy Die Forgings 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7175-T66) Solution and Precipitation Heat Treated, UNS A97175                                                                      |
| 4149                                                                       | Aluminum Alloy Forgings 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7175-T74) (Formerly T736) Solution and Precipitation Heat Treated, UNS A97175                                                          |
| 4150                                                                       | Aluminum Alloy Extrusions and Rings 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T6) Solution and Precipitation Heat Treated, UNS A96061                                                             |
| 4152                                                                       | Aluminum Alloy Extrusions 4.4Cu - 1.5Mg - 0.60Mn (2024-T3) Solution Heat Treated, UNS A92024                                                                                                   |
| 4153                                                                       | Aluminum Alloy Extrusions 4.5Cu - 0.85Si - 0.80Mn - 0.50Mg (2014 -T6) Solution and Precipitation Heat Treated, UNS A92014                                                                      |
| 4154                                                                       | Aluminum Alloy Extrusions 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T6) Solution and Precipitation Heat Treated, UNS A97075                                                                         |
| 4156                                                                       | Aluminum Alloy Extrusions 0.68Mg - 0.40Si (6063-T6) Solution and Precipitation Heat Treated, UNS A96063                                                                                        |
| 4157                                                                       | Aluminum Alloy Extrusions 7.7Zn - 2.4Mg - 1.6Cu - 0.16Cr (7049-T73511) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97049                                                        |
| 4159                                                                       | Aluminum Alloy Extrusions 7.7Zn - 2.4Mg - 1.6Cu - 0.16Cr (7049-T76511) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97049                                                        |
| 4160                                                                       | Aluminum Alloy Extrusions 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-0) Annealed, UNS A96061                                                                                                       |
| 4161                                                                       | Aluminum Alloy Extrusions 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T4) Solution Heat Treated and Naturally Aged, UNS A96061                                                                      |
| 4162                                                                       | Aluminum Alloy Extrusions 6.3Cu - 0.30Mn - 0.18Zr - 0.10V - 0.06Ti (2219-T8511) Solution Treated, Stress Relief Stretched, Precipitation Heat Treated, UNS A92219                              |
| 4163                                                                       | Aluminum Alloy Extrusions 6.3Cu - 0.30Mn - 0.18Zr - 0.10V - 0.06Ti (2219-T3511) Solution Heat Treated and Stress Relieved by Stretching, UNS A92219                                            |
| 4164                                                                       | Aluminum Alloy Extrusions 4.4Cu - 1.5Mg - 0.60Mn (2024-T3510) Stress-Relief Stretched, Unstraightened, UNS A92024                                                                              |
| 4165                                                                       | Aluminum Alloy Extrusions 4.4Cu - 1.5Mg - 0.60Mn (2024-T3511) Stress-Relieved Stretched, Straightened, UNS A92024                                                                              |
| 4166                                                                       | Aluminum Alloy Extrusions 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T73) Solution Treated and Overaged, UNS A97075                                                                                  |
| 4167                                                                       | Aluminum Alloy Extrusions 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T73511) Solution Heat Treated, Stress Relieved by Stretching, and Precipitation Heat Treated Straightened, UNS A97075           |

| <b>SAE/AMS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                               |
|----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                                                                                  |
| 4168                                                                       | Aluminum Alloy Extrusions 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T6510) Solution Heat Treated, Stress Relieved by Stretching, and Precipitation Heat Treated, Unstraightened, UNS A97075        |
| 4169                                                                       | Aluminum Alloy Extrusions 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T6511) Solution Heat Treated, Stress Relieved by Stretching, and Precipitation Heat Treated, Straightened, UNS A97075          |
| 4172                                                                       | Aluminum Alloy Extrusions 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061- T4511) Solution Heat Treated and Stress Relieved by Stretching, UNS A96061                                                  |
| 4173                                                                       | Aluminum Alloy Extrusions 1.0Mg - 0.60Si - 0.30Cu - 0.20Cr (6061-T6511) Solution Heat Treated and Stress Relieved by Stretching, and Precipitation Heat Treated, UNS A96061                   |
| 4174                                                                       | Aluminum Alloy Flash Welded Rings 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T73) Solution and Precipitation Heat Treated, UNS A97075                                                               |
| 4177                                                                       | Core, Flexible Honeycomb, Aluminum Alloy, Treated for Sandwich Construction 5056, 175 (347), UNS A95056                                                                                       |
| 4178                                                                       | Core, Flexible Honeycomb, Aluminum Alloy, Treated for Sandwich Construction 5052, 175 (347), UNS A95052                                                                                       |
| 4179                                                                       | Aluminum Alloy Forgings 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7175-T7452) Solution Heat Treated, Stress Relieved, and Precipitation Heat Treated, UNS A97175                                        |
| 4180                                                                       | Aluminum Wire 99.0Al Minimum (1100-H18), UNS A91100                                                                                                                                           |
| 4181                                                                       | Aluminum Alloy Welding Wire 7.0Si - 0.38Mg - 0.10Ti (4008), UNS A94008                                                                                                                        |
| 4182                                                                       | Aluminum Alloy Wire 5.0Mg - 0.12Mn - 0.12Cr (5056-0) Annealed, UNS A95056                                                                                                                     |
| 4184                                                                       | Filler Metal, Aluminum Brazing 10Si - 4.0Cu (4145), UNS A94145                                                                                                                                |
| 4185                                                                       | Filler Metal, Aluminum Brazing 12Si (4047), UNS A94047                                                                                                                                        |
| 4186                                                                       | Aluminum Alloy Bars, Rods, and Wire, Rolled or Cold Finished 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-F) As Fabricated, UNS A97075                                                                |
| 4187                                                                       | Aluminum Alloy Bars and Rods, Rolled, Drawn, or Cold Finished 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-O) Annealed, UNS A97075                                                                    |
| 4189                                                                       | Aluminum Alloy Welding Wire 4.1Si - 0.2Mg (4643), UNS A94643                                                                                                                                  |
| 4190                                                                       | Aluminum Alloy Welding Wire 5.2Si (4043), UNS A94043                                                                                                                                          |
| 4191                                                                       | Aluminum Alloy Welding Wire, 6.3Cu - 0.30Mn - 0.18Zr - 0.15Ti - 0.10V (2319), UNS A92319                                                                                                      |
| 4193                                                                       | Aluminum Alloy Sheet and Plate 4.4Cu - 1.5Mg - 0.60Mn (2024-T861) Solution Heat Treated, Cold Worked, and Precipitation Heat Treated, UNS A92024                                              |
| 4194                                                                       | Aluminum Alloy Sheet and Plate, Alclad 4.4Cu - 1.5Mg - 0.60Mn (Alclad 2024 and 1½% Alclad 2024-T361 Flat Sheet; 1½% Alclad 2024-T361 Plate) Solution Heat Treated and Cold Worked, UNS A82024 |

| <b>SAE/AMS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                                            |
|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                                                                                                               |
| 4195                                                                       | Aluminum Alloy Sheet and Plate, Alclad 4.4Cu - 1.5Mg - 0.60Mn (Alclad 2024 and 1½% Alclad 2024-T861 Flat Sheet; 1½% Alclad 2024-T861 Plate) Solution Heat Treated, Cold Worked, and Precipitation Heat Treated, UNS A82024 |
| 4200                                                                       | Aluminum Alloy Plate 7.7Zn - 2.4Mg - 1.6Cu - 0.16Cr (7049-T7351) Solution Heat Treated, Stress Relieved, and Precipitation Heat Treated, UNS A97049                                                                        |
| 4201                                                                       | Aluminum Alloy Plate 6.2Zn - 2.3Cu - 2.2Mg - 0.12Zr (7050-T7651) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97050                                                                                          |
| 4202                                                                       | Aluminum Alloy Plate 5.7Zn - 2.2Mg - 1.6Cu - 0.22Cr (7475-T7351) Solution Heat Treated, Stress Relieved by Stretching, and Precipitation Heat Treated, UNS A97475                                                          |
| 4203                                                                       | Aluminum Alloy Plate 6.2Zn - 1.8Cu - 2.4Mg - 0.13Zr (7010-T7351) Solution Heat Treated, Stress Relieved, and Precipitation Heat Treated, UNS A97010                                                                        |
| 4204                                                                       | Aluminum Alloy Plate 6.2Zn - 1.8Cu - 2.4Mg - 0.13Zr (7010-T7651) Solution Heat Treated, Stress Relieved, and Precipitation Heat Treated, UNS A97010                                                                        |
| 4205                                                                       | Aluminum Alloy Plate 6.2Zn - 1.8Cu - 2.4Mg - 0.13Zr (7010-T73651) Solution Heat Treated, Stress Relieved, and Precipitation Heat Treated, UNS A97010                                                                       |
| 4207                                                                       | Aluminum Alloy Sheet, Alclad 5.7Zn - 2.2Mg - 1.6Cu - 0.22Cr (7475-T61) Solution and Precipitation Heat Treated, UNS A87475                                                                                                 |
| 4208                                                                       | Aluminum Alloy Sheet 6.0Cu - 0.40Zr (2004-F) As Rolled, UNS A92004                                                                                                                                                         |
| 4209                                                                       | Aluminum Alloy Sheet, Alclad 6.0Cu - 0.40Zr (2004-F) As Rolled, UNS A82004                                                                                                                                                 |
| 4210                                                                       | Aluminum Alloy Castings Sand 5.0Si - 1.2Cu - 0.50Mg (355.0-T51) Precipitation Heat Treated, UNS A03550                                                                                                                     |
| 4212                                                                       | Aluminum Alloy Sand Castings 5.0Si - 1.2Cu - 0.50Mg (355.0-T6) Solution and Precipitation Heat Treated, UNS A03550                                                                                                         |
| 4214                                                                       | Aluminum Alloy Sand Castings 5.0Si - 1.2Cu - 0.50Mg (355.0-T71) Solution Heat Treated and Stabilized, UNS A03550                                                                                                           |
| 4215                                                                       | Aluminum Alloy Castings 5.0Si - 1.2Cu - 0.50Mg (C355.0-T6P) Solution and Precipitation Heat Treated, UNS A33550                                                                                                            |
| 4216                                                                       | Aluminum Alloy Sheet 1.0Mg - 0.8Si - 0.8Cu - 0.50Mn (6013-T6) Solution Heat Treated and Artificially Aged, UNS A96013                                                                                                      |
| 4217                                                                       | Aluminum Alloy Sand Castings 7.0Si - 0.32Mg (356.0-T6) Solution and Precipitation Heat Treated, UNS A03560                                                                                                                 |
| 4218                                                                       | Aluminum Alloy Castings 7.0Si - 0.35Mg (A356.0-T61P) Solution and Precipitation Heat Treated, UNS A13560                                                                                                                   |
| 4219                                                                       | Aluminum Alloy Castings 7.0Si - 0.55Mg - 0.12Ti - 0.06Be (A357.0 T61) Solution and Precipitation Heat Treated, UNS A13570                                                                                                  |
| 4221                                                                       | Aluminum Alloy Plate 4.4Cu - 1.5Mg - 0.60Mn (2124-T8151) Solution Heat Treated, Stress Relieved and Precipitation Heat Treated, UNS A92124                                                                                 |
| 4223                                                                       | Aluminum Alloy Castings 4.5Cu - 0.70Ag - 0.30Mn - 0.25Mg - 0.25Ti (A201.0-T4) Solution Heat Treated and Naturally Aged, UNS A12010                                                                                         |
| 4224                                                                       | Aluminum Alloy Sand Castings 4.0Cu - 2.1Ni - 2.0Mg - 0.30Cr - 0.30Mn - 0.13Ti - 0.13V (243.0) Stabilized, UNS A02430                                                                                                       |

| <b>SAE/AMS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                 |
|----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                                                                    |
| 4225                                                                       | Aluminum Alloy Sand Castings, Heat Resistant 5.0Cu - 1.5Ni - 0.25Mn - 0.25Sb - 0.25Co - 0.20Ti - 0.20Zr (203.0P) Solution Heat Treated and Stabilized, UNS A02030               |
| 4229                                                                       | Aluminum Alloy Castings, High Strength 4.5Cu - 0.70Ag - 0.30Mn - 0.25Mg - 0.25Ti (A201.0-T7) Solution Heat Treated and Overaged, UNS A02010                                     |
| 4232                                                                       | Aluminum Alloy Extrusions 2.7Cu - 2.2Li - 0.12Zr (2090-T86) Solution Heat Treated, Cold Worked, and Precipitation Heat Treated, UNS A92090                                      |
| 4233                                                                       | Aluminum Alloy Welding Wire 4.5Cu - 0.70Ag - 0.30Mn - 0.25Mg - 0.25Ti For Welding 201 Type Alloys                                                                               |
| 4235                                                                       | Aluminum Alloy Castings 4.6Cu - 0.35Mn - 0.25Mg - 0.22Ti (A206.0-T71) Solution and Precipitation Heat Treated, UNS A12060                                                       |
| 4236                                                                       | Aluminum Alloy Castings 4.6Cu - 0.35Mn - 0.25Mg - 0.22Ti (A206.0-T4) Solution Heat Treated and Naturally Aged, UNS A12060                                                       |
| 4237                                                                       | Aluminum Alloy Sand Castings 4.6Cu - 0.35Mn - 0.25Mg - 0.22Ti (206.0-T71) Solution Heat Treated and Naturally Aged, UNS A02060                                                  |
| 4238                                                                       | Aluminum Alloy Sand Castings 6.8Mg - 0.18Ti - 0.18Mn (535.0-F) As Cast, UNS A05350                                                                                              |
| 4239                                                                       | Aluminum Alloy Sand Castings 6.8Mg - 0.18Ti - 0.18Mn (535.0-0) Annealed, UNS A05350                                                                                             |
| 4241                                                                       | Aluminum Alloy Castings 7.0Si - 0.58Mg - 0.15Ti - 0.06Be (D357.0-T6) Solution and Precipitation Heat Treated, Dendrite Arm Spacing (DAS) Controlled, UNS A43570                 |
| 4242                                                                       | Aluminum Alloy Castings, Sand Composite 4.7Cu - 0.60Ag - 0.35Mn - 0.25Mg - 0.25Ti (B201.0-T7) Solution Heat Treated and Overaged, Aircraft Structural Quality, UNS A02010       |
| 4243                                                                       | Aluminum Alloy Sheet, Alclad 6.2Zn - 2.3Cu - 2.2Mg - 0.12Zr (Alclad 7050-T76) Solution Heat Treated and Overaged, UNS A87050                                                    |
| 4244                                                                       | Aluminum Alloy Welding Wire 4.6Cu - 0.35Mn - 0.25Mg - 0.22Ti for Welding 206 Type Alloys                                                                                        |
| 4245                                                                       | Aluminum Alloy Welding Wire 5.0Si - 1.2Cu - 0.50Mg For Welding 355 Type Alloys                                                                                                  |
| 4246                                                                       | Aluminum Alloy Welding Wire 7.0Si - 0.52Mg For Welding 357 Type Alloys, UNS A03570                                                                                              |
| 4247                                                                       | Aluminum Alloy Hand Forgings 7.7Zn - 2.4Mg - 1.6Cu - 0.16Cr (7049-T7352) Solution Heat Treated, Stress Relieved by Compression, and Precipitation Heat Treated, UNS A97049      |
| 4248                                                                       | Aluminum Alloy Hand Forgings and Rings 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T652) Solution Heat Treated, Stress Relief Compressed, and Precipitation Heat Treated, UNS A96061 |
| 4249                                                                       | Aluminum Alloy Castings 7.0Si - 0.58Mg - 0.15Ti - 0.06Be (D357.0-T6) Solution and Precipitation Heat Treated, UNS A43570                                                        |
| 4251                                                                       | Aluminum Alloy Sheet 2.7Cu - 2.2Li - 0.12Zr (2090-T83) Solution Heat Treated, Cold Worked, and Precipitation Heat Treated, UNS A92090                                           |
| 4252                                                                       | Aluminum Alloy Plate 6.4Zn - 2.4Mg - 2.2Cu - 0.12Zr (7150-T7751) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97150                                               |
| 4253                                                                       | Aluminum Alloy-Aramid Fiber Reinforced-Laminated Sheet 5.7Zn - 2.2Mg - 1.6Cu - 0.22Cr (7475-T61) 3, 5, 7, or 9 Ply                                                              |
| 4254                                                                       | Aluminum Alloy, Aramid-Fiber-Reinforced Laminated Sheet 4.4Cu - 1.5Mg - 0.6Mn (2024-T3) 3, 5, 7, or 9 Ply                                                                       |



| <b>SAE/AMS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                |
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| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                                                                                   |
| 4255                                                                       | Aluminum Alloy Sheet, Clad One Side 0.6Mg - 0.35Si - 0.28Cu (No. 21 Brazing Sheet) As Fabricated                                                                                               |
| 4256                                                                       | Aluminum Alloy Sheet, Clad Two Sides 0.6Mg - 0.35Si - 0.28Cu (No. 22 Brazing Sheet) as Fabricated, UNS A86951                                                                                  |
| 4258                                                                       | Aluminum Alloy, Aramid-Fiber-Reinforced, Laminated Sheet 5.7Zn - 2.2Mg - 1.6Cu - 0.22Cr (Alclad, One Side 7475-T761) 5 or 7 Ply                                                                |
| 4260                                                                       | Aluminum Alloy Investment Castings 7.0Si - 0.32Mg (356.0-T6) Solution and Precipitation Heat Treated, UNS A03560                                                                               |
| 4261                                                                       | Aluminum Alloy Investment Castings 7.0Si - 0.32Mg (356.0-T51) Precipitation Heat Treated, UNS A03560                                                                                           |
| 4280                                                                       | Aluminum Alloy Permanent Mold Castings 5.0Si - 1.2Cu - 0.5Mg (355.0-T71) Solution Heat Treated and Overaged, UNS A03550                                                                        |
| 4281                                                                       | Aluminum Alloy Permanent Mold Castings 5.0Si - 1.2Cu - 0.50Mg (355.0-T6) Solution and Precipitation Heat Treated, UNS A03550                                                                   |
| 4284                                                                       | Aluminum Alloy Permanent Mold Castings 7.0Si - 0.30Mg (356.0-T6) Solution and Precipitation Heat Treated, UNS A03560                                                                           |
| 4285                                                                       | Aluminum Alloy Centrifugal Mold Castings 7.0Si - 0.30Mg (356.0-T6) Solution and Precipitation Heat Treated, UNS A03560                                                                         |
| 4286                                                                       | Aluminum Alloy Permanent Mold Castings 7.0Si - 0.32Mg (356.0-T51) Precipitation Heat Treated, UNS A03560                                                                                       |
| 4290                                                                       | Aluminum Alloy Die Castings 9.5Si - 0.50Mg - (360.0) as Cast, UNS A03600                                                                                                                       |
| 4291                                                                       | Aluminum Alloy Die Castings 8.5Si - 3.5Cu (A380.0) as Cast, UNS A13800                                                                                                                         |
| 4300                                                                       | Boron-Aluminum Composite Sheet 50 v/o 5.6B, 6061-0, For Diffusion Bonding                                                                                                                      |
| 4302                                                                       | Aluminum Alloy, Aramid-Fiber-Reinforced, Laminated Sheet 5.7Zn - 2.2Mg - 1.6Cu - 0.22Cr (7475-T761) 3, 5, 7, or 9 Ply                                                                          |
| 4303                                                                       | Aluminum Alloy Plate 1.7Cu - 2.2Li - 0.12Zr (2092-T81) Solution Heat Treated, Cold Worked, and Aged, UNS A92090                                                                                |
| 4306                                                                       | Aluminum Alloy Plate 6.4Zn - 2.4Mg - 2.2Cu - 0.12Zr (7150-T6151) Solution Heat Treated, Stress Relieved, and Aged, UNS A97150                                                                  |
| 4307                                                                       | Aluminum Alloy Extrusions 6.4Zn - 2.4Mg - 2.2Cu - 0.12Zr (7150-T61511) Solution Heat Treated, Stress Relieved, and Precipitation Heat Treated, UNS A97150                                      |
| 4310                                                                       | Aluminum Alloy Rings, Rolled or Forged 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T651, 7075-T652) Solution Heat Treated, Mechanically Stress Relieved, and Precipitation Heat Treated, UNS A97075   |
| 4311                                                                       | Aluminum Alloy Rings, Rolled or Forged 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075-T7351, 7075-T7352) Solution Heat Treated, Mechanically Stress Relieved, and Precipitation Heat Treated, UNS A97075 |
| 4312                                                                       | Aluminum Alloy Rings, Rolled or Forged 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061-T651, 6061-T652) Solution Heat Treated, Mechanically Stress Relieved, and Precipitation Heat Treated, UNS A96061 |
| 4313                                                                       | Aluminum Alloy Rings, Rolled or Forged 6.3Cu - 0.30Mn - 0.18Zr - 0.10V - 0.06Ti (2219-T351, 2219-T352) Solution Heat Treated and Mechanically Stress Relieved, UNS A92219                      |

| <b>SAE/AMS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                |
|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                                                                                   |
| 4314                                                                       | Aluminum Alloy Rings, Rolled or Forged 4.5Cu - 0.85Si - 0.80Mn - 0.50Mg (2014-T651, 2014-T652) Solution Heat Treated, Mechanically Stress Relieved, and Precipitation Heat Treated, UNS A92014 |
| 4320                                                                       | Aluminum Alloy Forgings 7.7Zn - 2.5Mg - 1.5Cu - 0.16Cr (7149-T73) Solution and Precipitation Heat Treated, UNS A97149                                                                          |
| 4321                                                                       | Aluminum Alloy Forgings 7.7Zn - 2.5Mg - 1.5Cu - 0.16Cr (7049-O1) High Temperature Annealed, UNS A97049                                                                                         |
| 4322                                                                       | Aluminum Alloy Die Forgings 4.0Mg - 1.3Li - 1.2C - 0.45O <sub>2</sub> (5091) Mechanically Alloyed, As Fabricated, UNS A95091                                                                   |
| 4323                                                                       | Aluminum Alloy Hand Forgings 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7075- T7452) Solution Heat Treated, Stress Relieved, and Precipitation Heat Treated, UNS A97075                                   |
| 4333                                                                       | Aluminum Alloy Die Forgings 6.2Zn - 2.3Cu - 2.2Mg - 0.12Zr (7050- T7452) Solution Heat Treated, Compression Stress Relieved, and Overaged, UNS A97050                                          |
| 4340                                                                       | Aluminum Alloy Extrusions 6.2Zn - 2.3Cu - 2.2Mg - 0.12Zr (7050-T76511) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97050                                                        |
| 4341                                                                       | Aluminum Alloy Extrusions 6.2Zn - 2.3Cu - 2.2Mg - 0.12Zr (7050-T73511) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97050                                                        |
| 4342                                                                       | Aluminum Alloy Extrusions 6.2Zn - 2.3Cu - 2.2Mg - 0.12Zr (7050-T74511) (Formerly -T736511) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97050                                    |
| 4343                                                                       | Aluminum Alloy Extrusions 7.7Zn - 2.4Mg - 1.6Cu - 0.16Cr (7149-T73511) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97149                                                        |
| 4344                                                                       | Aluminum Alloy Extrusions 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr (7175-T73511) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97175                                                        |
| 4345                                                                       | Aluminum Alloy Extrusions 6.4Zn - 2.4Mg - 2.2Cu - 0.12Zr (7150-T77511) Solution Heat Treated, Stress Relieved, and Overaged, UNS A97150                                                        |
| 4347                                                                       | Aluminum Alloy Sheet 1.0Mg - 0.8Si - 0.8Cu - 0.5Mn (6013-T4) Solution Heat Treated and Naturally Aged, UNS A96013                                                                              |
| 4348                                                                       | Core, Honeycomb, Aluminum Alloy, Corrosion Inhibited for Sandwich Construction 5052, 350 (177), UNS A95052                                                                                     |
| 4349                                                                       | Core, Honeycomb, Aluminum Alloy, Corrosion Inhibited for Sandwich Construction, 5056, 350 (177), UNS A95056                                                                                    |

| <b>ASTM SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS</b> |                                                                           |
|-------------------------------------------------------------|---------------------------------------------------------------------------|
| <b>ASTM</b>                                                 | <b>Title</b>                                                              |
| <b>Bars, Rods, Wire, and Shapes</b>                         |                                                                           |
| B 211                                                       | Bar, Rod, and Wire, Aluminum and Aluminum-Alloy                           |
| B 221                                                       | Extruded Bars, Rods, Wire, Shapes, and Tubes, Aluminum and Aluminum-Alloy |
| B 236                                                       | Aluminum Bars for Electrical Purposes (Bus Bars)                          |

| <b>ASTM SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                         |
|-------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| <b>ASTM</b>                                                             | <b>Title</b>                                                                                            |
| <b>Bars, Rods, Wire, and Shapes (Continued)</b>                         |                                                                                                         |
| B 308                                                                   | Standard Structural Shapes, Rolled or Extruded, Aluminum-Alloy 6061-T6                                  |
| B 316                                                                   | Rivet and Cold Heading Wire and Rods, Aluminum and Aluminum-Alloy                                       |
| B 317                                                                   | Aluminum-Alloy Extruded Bar, Rod, Pipe, and Structural Shapes for Electrical Purposes                   |
| <b>Castings</b>                                                         |                                                                                                         |
| B 26                                                                    | Sand Castings, Aluminum-Alloy                                                                           |
| B 85                                                                    | Die Castings, Aluminum-Alloy                                                                            |
| B 108                                                                   | Permanent Mold Castings, Aluminum-Alloy                                                                 |
| B 618                                                                   | Aluminum-Alloy Investment Castings                                                                      |
| B 686                                                                   | Aluminum-Alloy Castings, High-Strength                                                                  |
| <b>Products for Electrical Purposes</b>                                 |                                                                                                         |
| B 230                                                                   | Wire for Electrical Purposes, Aluminum 1350-H19                                                         |
| B 236                                                                   | Bars for Electrical Purposes (Bus Bars), Aluminum                                                       |
| B 314                                                                   | Wire for Communication Cable, Aluminum 1350                                                             |
| B 317                                                                   | Extruded Bar, Rod, Pipe, and Structural Shapes for Electrical Purposes (Bus Conductors), Aluminum-Alloy |
| B 324                                                                   | Wire for Electrical Purposes, Rectangular and Square Aluminum                                           |
| B 373                                                                   | Foil for Capacitors, Aluminum                                                                           |
| B 396                                                                   | Wire for Electrical Purposes, 5005-H19 Aluminum-Alloy                                                   |
| B 398                                                                   | Wire for Electrical Purposes, 6201-T81 Aluminum-Alloy                                                   |
| <b>Heat Treatment</b>                                                   |                                                                                                         |
| B 597                                                                   | Heat Treatment of Aluminum Alloys                                                                       |
| B 807                                                                   | Extrusion Press Solution Heat Treatment for Aluminum Alloys                                             |
| <b>Fasteners</b>                                                        |                                                                                                         |
| F 467                                                                   | Nonferrous Nuts for General Use                                                                         |
| F 468                                                                   | Nonferrous Bolts, Hex Cap Screws, and Studs for General Use                                             |
| <b>Forgings</b>                                                         |                                                                                                         |
| B 247                                                                   | Die Forgings, Hand Forgings, and Rolled Ring Forgings, Aluminum and Aluminum-Alloy                      |

| <b>ASTM SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                    |
|-------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| <b>ASTM</b>                                                             | <b>Title</b>                                                                                                                       |
| <b>Ingots</b>                                                           |                                                                                                                                    |
| B 179                                                                   | Sand Castings, Permanent Mold Castings, and Die Castings, Aluminum Alloys in Ingot Form for                                        |
| <b>Pipe and Tubes</b>                                                   |                                                                                                                                    |
| B 210                                                                   | Drawn Seamless Tubes, Aluminum and Aluminum-Alloy                                                                                  |
| B 221                                                                   | Extruded Bars, Rod, Wire, Shape, and Tube, Aluminum-Alloy                                                                          |
| B 234                                                                   | Drawn Seamless Tubes for Condensers and Heat Exchangers, Aluminum and Aluminum-Alloy                                               |
| B 241                                                                   | Seamless Pipe and Seamless Extruded Tube, Aluminum and Aluminum-Alloy                                                              |
| B 313                                                                   | Round Welded Tubes, Aluminum and Aluminum-Alloy                                                                                    |
| B 345                                                                   | Seamless Extruded Tube and Seamless Pipe for Gas and Oil Transmission and Distribution Piping Systems, Aluminum and Aluminum-Alloy |
| B 404                                                                   | Seamless Condenser and Heat-Exchanger Tubes with Integral Fins, Aluminum and Aluminum-Alloy                                        |
| B 429                                                                   | Extruded Structural Pipe and Tube, Aluminum-Alloy                                                                                  |
| B 483                                                                   | Drawn Tubes for General Purpose Applications, Aluminum and Aluminum-Alloy                                                          |
| B 491                                                                   | Extruded Round Tubes for General Purpose Applications, Aluminum and Aluminum-Alloy                                                 |
| B 547                                                                   | Formed and Arc-Welded Round Tube, Aluminum and Aluminum-Alloy                                                                      |
| B 745                                                                   | Corrugated Aluminum Pipe for Sewers and Drains                                                                                     |
| B 789                                                                   | Installing Corrugated Aluminum Structural Plate Pipe for Culverts and Sewers                                                       |
| B 790                                                                   | Structural Design of Corrugated Aluminum, Pipe, Pipe Arches and Arches for Culverts, Storm Sewers and Other Buried Conduits        |
| <b>Sheet, Plate and Foil</b>                                            |                                                                                                                                    |
| B 209                                                                   | Sheet and Plate, Aluminum and Aluminum-Alloy                                                                                       |
| B 373                                                                   | Foil for Capacitors, Aluminum                                                                                                      |
| B 479                                                                   | Foil for Flexible Barrier Applications, Annealed Aluminum and Aluminum Alloy                                                       |
| B 632                                                                   | Tread Plate, Aluminum-Alloy Rolled                                                                                                 |
| B 736                                                                   | Cable Shielding Stock, Aluminum, Aluminum Alloy, and Aluminum-Clad, Steel                                                          |
| B 744                                                                   | Sheet for Corrugated Aluminum Pipe, Aluminum Alloy for                                                                             |
| B 746                                                                   | Structural Plate for Field Bolted Pipe, Pipe Arches and Arches, Corrugated Aluminum Alloy                                          |
| <b>Welding Fittings</b>                                                 |                                                                                                                                    |
| B 361                                                                   | Welding Fittings, Factory-Made Wrought, Aluminum and Aluminum-Alloy                                                                |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - ALUMINUM AND ALUMINUM ALLOYS |        |                                          |                                                                                                                                                     |                                                         |                                                                                                                                                                                                    |                                  |                              |
|-------------------------------------------------------------------------|--------|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|------------------------------|
| AA                                                                      | UNS    | AMS                                      | MIL                                                                                                                                                 | FED                                                     | ASTM                                                                                                                                                                                               | ASME                             | AWS                          |
| 1060                                                                    | A91060 | 4000                                     | ---                                                                                                                                                 | ---                                                     | B 209 (1060), B 210 (1060), B 211 (1060), B 221 (1060), B 234 (1060), B 241 (1060), B 345 (1060), B 361 (1060), B 404 (1060), B 483 (1060), B 548 (1060)                                           | ---                              | ---                          |
| 1100                                                                    | A91100 | 4001, 4003, 4062, 4102, 4180, 7220       | MIL-W-85, MIL-R-5674, MIL-W-6712, MIL-A-12545, MIL-E-15597 (MIL-1100), MIL-S-24149/5, MIL-C-26094, MIL-A-52174, MIL-A-52177, MIL-I-23413 (MIL-1100) | QQ-A-225/1, QQ-A-250/1, QQ-A-430, QQ-A-1876, WW-T-700/1 | B 209 (1100), B 210 (1100), B 211 (1100), B 221 (1100), B 241 (1100), B 247 (1100), B 313 (1100), B 316 (1100), B 361 (1100), B 479 (1100), B 483 (1100), B 491 (1100), B 547 (1100), B 548 (1100) | SFA5.3 (E1100), SFA5.10 (ER1100) | A5.3 (E1100), A5.10 (ER1100) |
| 1145                                                                    | A91145 | 4011                                     | ---                                                                                                                                                 | QQ-A-1876                                               | B 373 (1145), B 479 (1145)                                                                                                                                                                         | ---                              | ---                          |
| 1235                                                                    | A91235 | ---                                      | ---                                                                                                                                                 | QQ-A-1876                                               | B 373 (1235), B 479 (1235), B 491 (1235)                                                                                                                                                           | ---                              | ---                          |
| 1350                                                                    | A91350 | ---                                      | ---                                                                                                                                                 | ---                                                     | B 230, B 231, B 232 (1350), B 233, B 236, B 314 (1350), B 324, B 400 (1350), B 401, B 524, B 549, B 609, B 778 (1350), B 779 (1350)                                                                | ---                              | ---                          |
| 2011                                                                    | A92011 | ---                                      | ---                                                                                                                                                 | QQ-A-225/3                                              | B 210 (2011), B 211 (2011)                                                                                                                                                                         | ---                              | ---                          |
| 2014                                                                    | A92014 | 4028, 4029, 4121, 4133, 4134, 4153, 4314 | MIL-F-5509, MIL-A-12545, MIL-T-15089, MIL-F-18280, MIL-A-22771                                                                                      | QQ-A-200/2, QQ-A-225/4, QQ-A-367                        | B 209 (2014), B 210 (2014), B 211 (2014), B 221 (2014), B 241 (2014), B 247 (2014)                                                                                                                 | ---                              | ---                          |
| 2017                                                                    | A92017 | 4118                                     | MIL-R-5674                                                                                                                                          | QQ-A-225/5, QQ-A-430                                    | B 211 (2017), B 316 (2017)                                                                                                                                                                         | ---                              | ---                          |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - ALUMINUM AND ALUMINUM ALLOYS (Continued) |        |                                                                                                      |                                                                                                  |                                                                      |                                                                                                                                                                                                                      |                  |                |
|-------------------------------------------------------------------------------------|--------|------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------------|
| AA                                                                                  | UNS    | AMS                                                                                                  | MIL                                                                                              | FED                                                                  | ASTM                                                                                                                                                                                                                 | ASME             | AWS            |
| 2018                                                                                | A92018 | 4140                                                                                                 | ---                                                                                              | QQ-A-367                                                             | B 247 (2018)                                                                                                                                                                                                         | ---              | ---            |
| 2024                                                                                | A92024 | 4007, 4035,<br>4037, 4086,<br>4087, 4088,<br>4112, 4120,<br>4152, 4164,<br>4165, 4192,<br>4193, 7223 | MIL-F-5509, MIL-R-5674,<br>MIL-B-6812, MIL-T-15089,<br>MIL-F-18280, MIL-T-50777,<br>MIL-A-81596, | QQ-A-200/3,<br>QQ-A-225/6,<br>QQ-A-250/4,<br>QQ-A-430,<br>WW-T-700/3 | B 209 (2024), B 210 (2024),<br>B 211 (2024), B 221 (2024),<br>B 241 (2024), B 316 (2024),<br>F 467, F 468                                                                                                            | ---              | ---            |
| 2025                                                                                | A92025 | 4130                                                                                                 | ---                                                                                              | QQ-A-367                                                             | B 247                                                                                                                                                                                                                | ---              | ---            |
| 2117                                                                                | A92117 | 7222                                                                                                 | MIL-R-5674, MIL-R-8814                                                                           | QQ-A-430                                                             | B 316 (2117)                                                                                                                                                                                                         | ---              | ---            |
| 2124                                                                                | A92124 | 4101, 4221                                                                                           | ---                                                                                              | QQ-A-250/9,<br>QQ-A-250/29                                           | B 209 (2124)                                                                                                                                                                                                         | ---              | ---            |
| 2218                                                                                | A92218 | ---                                                                                                  | ---                                                                                              | QQ-A-367                                                             | B 247 (2218)                                                                                                                                                                                                         | ---              | ---            |
| 2219                                                                                | A92219 | 4031, 4066,<br>4068, 4143,<br>4144, 4162,<br>4163, 4313                                              | MIL-A-22771, MIL-A-46118,<br>MIL-A-46808                                                         | QQ-A-250/30,<br>QQ-A-367,<br>QQ-A-430                                | B 209 (2219), B 211 (2219),<br>B 221 (2219), B 241 (2219),<br>B 247 (2219), B 316 (2219)                                                                                                                             | ---              | ---            |
| 2319                                                                                | A92319 | 4191                                                                                                 | ---                                                                                              | ---                                                                  | ---                                                                                                                                                                                                                  | SFA5.10 (ER2319) | A5.10 (ER2319) |
| 2618                                                                                | A92618 | 4132                                                                                                 | MIL-A-22771 (2618)                                                                               | QQ-A-367                                                             | B 247 (2618)                                                                                                                                                                                                         | ---              | ---            |
| 3003                                                                                | A93003 | 4006, 4008,<br>4010, 4065,<br>4067                                                                   | MIL-S-12875,<br>MIL-E-15597 (MIL-3003),<br>MIL-P-25995,<br>MIL-A-52174, MIL-A-81596              | QQ-A-200/1,<br>QQ-A-225/E,<br>QQ-A-250/2,<br>QQ-A-430,<br>WW-T-700/2 | B 209 (3003), B 210 (3003),<br>B 211 (3003), B 221 (3003),<br>B 234 (3003), B 241 (3003),<br>B 247 (3003), B 313 (3003),<br>B 316 (3003), B 345 (3003),<br>B 404 (3003), B 483 (3003),<br>B 491 (3003), B 547 (3003) | SFA5.3 (E3003)   | A5.3 (E3003)   |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - ALUMINUM AND ALUMINUM ALLOYS (Continued) |        |      |                                                                  |                    |                                                                                                          |                                       |                                   |
|-------------------------------------------------------------------------------------|--------|------|------------------------------------------------------------------|--------------------|----------------------------------------------------------------------------------------------------------|---------------------------------------|-----------------------------------|
| AA                                                                                  | UNS    | AMS  | MIL                                                              | FED                | ASTM                                                                                                     | ASME                                  | AWS                               |
| 3004                                                                                | A93004 | ---  | ---                                                              | ---                | B 209 (3004), B 221 (3004)<br>B 313 (3004), B 547 (3004),<br>B 548 (3004)                                |                                       | ---                               |
| 3005                                                                                | A93005 | ---  | ---                                                              | ---                | B 209 (3005)                                                                                             |                                       | ---                               |
| 3105                                                                                | A93105 | ---  | ---                                                              | ---                | B 209 (3105)                                                                                             |                                       | ---                               |
| 4032                                                                                | A94032 | 4145 | ---                                                              | QQ-A-367           | B 247 (4032)                                                                                             |                                       | ---                               |
| 4043                                                                                | A94043 | 4190 | MIL-W-6712,<br>MIL-E-15597 (MIL-4043),<br>MIL-I-23413 (MIL-4043) | ---                | ---                                                                                                      | SFA5.3 (E4043),<br>SFA5.10 (ER4043)   | A5.3 (E4043),<br>A5.10 (ER4043)   |
| 4045                                                                                | A94045 | ---  | MIL-B-7883 (BAISi-5)                                             | ---                | ---                                                                                                      | SFA5.8 (BAISi-5)                      | A5.8 (BAISi-5)                    |
| 4047                                                                                | A94047 | 4185 | MIL-B-7883 (BAISi-4),<br>MIL-B-20148                             | ---                | ---                                                                                                      | SFA5.8 (BAISi-4),<br>SFA5.10 (ER4047) | A5.8 (BAISi-4),<br>A5.10 (ER4047) |
| 4145                                                                                | A94145 | 4184 | MIL-B-7883 (BAISi-3)                                             | ---                | ---                                                                                                      | SFA5.8 (BAISi-3),<br>SFA5.10 (ER4145) | A5.8 (BAISi-3),<br>A5.10 (ER4145) |
| 4343                                                                                | A94343 | ---  | MIL-B-7883 (BAISi-2),<br>MIL-B-20148                             | ---                | ---                                                                                                      | SFA5.8 (BAISi-2)                      | A5.8 (BAISi-2)                    |
| 5005                                                                                | A95005 | ---  | MIL-C-26094                                                      | QQ-A-430<br>(5005) | B 209 (5005), B 210 (5005)<br>B 316 (5005), B 396 (5005),<br>B 397 (5005), B 483 (5005),<br>B 531 (5005) | ---                                   | ---                               |
| 5050                                                                                | A95050 | ---  | ---                                                              | ---                | B 209 (5050), B 210 (5050),<br>B 313 (5050), B 483 (5050),<br>B 547 (5050), B 548 (5050)                 | ---                                   | ---                               |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - ALUMINUM AND ALUMINUM ALLOYS (Continued) |        |                                                                  |                                                                 |                                              |                                                                                                                                                                        |                  |                |
|-------------------------------------------------------------------------------------|--------|------------------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------------|
| AA                                                                                  | UNS    | AMS                                                              | MIL                                                             | FED                                          | ASTM                                                                                                                                                                   | ASME             | AWS            |
| 5052                                                                                | A95052 | 4004, 4015, 4016, 4017, 4069, 4070, 4071, 4114, 4175, 4178, 4348 | MIL-S-12875, MIL-G-18014, MIL-G-18015, MIL-C-26094, MIL-A-81596 | QQ-A-225/7, QQ-A-250/8, QQ-A-430, WW-T-700/4 | B 209 (5052), B 210 (5052), B 211 (5052), B 221 (5052), B 234 (5052), B 241 (5052), B 313 (5052), B 316 (5052), B 404 (5052), B 483 (5052), B 547 (5052), B 548 (5052) | ---              | ---            |
| 5056                                                                                | A95056 | 4005, 4176, 4177, 4182, 4349                                     | MIL-R-5674, MIL-R-8814, MIL-A-81596                             | QQ-A-430                                     | B 211 (5056), B 316 (5056)                                                                                                                                             | ---              | ---            |
| 5083                                                                                | A95083 | 4056, 4057, 4058, 4059                                           | MIL-A-45225, MIL-A-46027, MIL-A-46083, MIL-G-S-24149/2          | QQ-A-200/4, QQ-A-250/6, QQ-A-367             | B 209 (5083), B 210 (5083), B 221 (5083), B 241 (5083), B 247 (5083), B 345 (5083), B 361 (5083), B 547 (5083), B 548 (5083)                                           | ---              | ---            |
| 5086                                                                                | A95086 | ---                                                              | MIL-G-18014, MIL-S-24149/2, MIL-C-26094                         | QQ-A-200/5, QQ-A-250/7, WW-T-700/5           | B 209 (5086), B 210 (5086), B 221 (5086), B 241 (5086), B 313 (5086), B 345 (5086), B 361 (5086), B 547 (5086), B 548 (5086)                                           | ---              | ---            |
| 5154                                                                                | A95154 | ---                                                              | MIL-C-26094                                                     | ---                                          | B 209 (5154), B 210 (5154), B 211 (5154), B 221 (5154), B 313 (5154), B 361 (5154), B 547 (5154), B 548 (5154)                                                         | ---              | ---            |
| 5183                                                                                | A95183 | ---                                                              | ---                                                             | ---                                          | ---                                                                                                                                                                    | SFA5.10 (ER5183) | A5.10 (ER5183) |
| 5252                                                                                | A95252 | ---                                                              | ---                                                             | ---                                          | B 209 (5252)                                                                                                                                                           | ---              | ---            |
| 5254                                                                                | A95254 | ---                                                              | ---                                                             | ---                                          | B 209 (5254), B 241 (5254), B548 (5254)                                                                                                                                | ---              | ---            |
| 5356                                                                                | A95356 | ---                                                              | MIL-S-24149/2                                                   | ---                                          | ---                                                                                                                                                                    | SFA5.10 (ER5356) | A5.10 (ER5356) |



| AMERICAN CROSS REFERENCED SPECIFICATIONS - ALUMINUM AND ALUMINUM ALLOYS (Continued) |        |     |                                                                         |                            |                                                                                                           |                  |                |
|-------------------------------------------------------------------------------------|--------|-----|-------------------------------------------------------------------------|----------------------------|-----------------------------------------------------------------------------------------------------------|------------------|----------------|
| AA                                                                                  | UNS    | AMS | MIL                                                                     | FED                        | ASTM                                                                                                      | ASME             | AWS            |
| 5454                                                                                | A95454 | --- | ---                                                                     | QQ-A-200/6,<br>QQ-A-250/10 | B 209 (5454), B 221 (5454),<br>B 234 (5454), B 241 (5454),<br>B 404 (5454), B 547 (5454),<br>B 548 (5454) | ---              | ---            |
| 5456                                                                                | A95456 | --- | MIL-G-18014, MIL-S-24149/2,<br>MIL-A-45225, MIL-A-46027,<br>MIL-A-46083 | QQ-A-200/7,<br>QQ-A-250/9  | B 209 (5456), B 210 (5456),<br>B 221 (5456), B 241 (5456),<br>B 548 (5456)                                | ---              | ---            |
| 5457                                                                                | A95457 | --- | ---                                                                     | ---                        | B 209 (5457)                                                                                              | ---              | ---            |
| 5554                                                                                | A95554 | --- | MIL-G-18014                                                             | ---                        | ---                                                                                                       | SFA5.10 (ER5554) | A5.10 (ER5554) |
| 5556                                                                                | A95556 | --- | ---                                                                     | ---                        | ---                                                                                                       | SFA5.10 (ER5556) | A5.10 (ER5556) |
| 5652                                                                                | A95652 | --- | ---                                                                     | ---                        | B 209 (5652), B 241 (5652),<br>B 548 (5652)                                                               | ---              | ---            |
| 5654                                                                                | A95654 | --- | ---                                                                     | ---                        | ---                                                                                                       | SFA5.10 (ER5654) | A5.10 (ER5654) |
| 5657                                                                                | A95657 | --- | ---                                                                     | ---                        | B 209 (5657)                                                                                              | ---              | ---            |
| 6005,<br>6005A                                                                      | A96005 | --- | ---                                                                     | ---                        | B 221 (6005, 6005A)                                                                                       | ---              | ---            |
| 6053                                                                                | A96053 | --- | ---                                                                     | QQ-A-430                   | B 316 (6053)                                                                                              | ---              | ---            |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - ALUMINUM AND ALUMINUM ALLOYS (Continued) |        |                                                                                                                                                                                       |                                                                                                                                                         |                                                                                                    |                                                                                                                                                                                                                                                                                    |      |     |
|-------------------------------------------------------------------------------------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|
| AA                                                                                  | UNS    | AMS                                                                                                                                                                                   | MIL                                                                                                                                                     | FED                                                                                                | ASTM                                                                                                                                                                                                                                                                               | ASME | AWS |
| 6061                                                                                | A96061 | 4009, 4025,<br>4026, 4027,<br>4079, 4080,<br>4081, 4082,<br>4083, 4113,<br>4115, 5116,<br>4117, 4127,<br>4128, 4146,<br>4150, 4160,<br>4161, 4172,<br>4173, 4248,<br>4312 MAM<br>4248 | MIL-W-85, MIL-F-3922,<br>MIL-T-7081, MIL-A-12545,<br>MIL-G-18014, MIL-G-18015,<br>MIL-F-18280, MIL-A-22771,<br>MIL-W-23351, MIL-P-25995,<br>MIL-F-39000 | QQ-A-200/8,<br>QQ-A-200/16,<br>QQ-A-225/8,<br>QQ-A-250/11,<br>QQ-A-367,<br>QQ-A-430,<br>WW-T-700/6 | B 209 (6061), B 210 (6061),<br>B 211 (6061), B 221 (6061),<br>B 234 (6061), B 241 (6061),<br>B 247 (6061), B 308 (6061),<br>B 313 (6061), B 316 (6061),<br>B 345 (6061), B 361 (6061),<br>B 404 (6061), B 429 (6061),<br>B 483 (6061), B 547 (6061),<br>B 548, B 632, F 467, F 468 | ---  | --- |
| 6063                                                                                | A96063 | 4156                                                                                                                                                                                  | MIL-W-85, MIL-G-18014,<br>MIL-G-18015, MIL-P-25995                                                                                                      | QQ-A-200/9                                                                                         | B 210 (6063), B 221 (6063),<br>B 241 (6063), B 345 (6063),<br>B 361 (6063), B 429 (6063),<br>B 483 (6063), B 491 (6063)                                                                                                                                                            | ---  | --- |
| 6066                                                                                | A96066 | ---                                                                                                                                                                                   | ---                                                                                                                                                     | QQ-A-200/10,<br>QQ-A-367                                                                           | B 221 (6066), B 247 (6066)                                                                                                                                                                                                                                                         | ---  | --- |
| 6070                                                                                | A96070 | ---                                                                                                                                                                                   | MIL-A-12545, MIL-A-46104                                                                                                                                | ---                                                                                                | B 221 (6070), B 345 (6070)                                                                                                                                                                                                                                                         | ---  | --- |
| 6101                                                                                | A96101 | ---                                                                                                                                                                                   | ---                                                                                                                                                     | ---                                                                                                | B 317 (6101)                                                                                                                                                                                                                                                                       | ---  | --- |
| 6105                                                                                | A96105 | ---                                                                                                                                                                                   | ---                                                                                                                                                     | ---                                                                                                | B 221 (6105)                                                                                                                                                                                                                                                                       | ---  | --- |
| 6151                                                                                | A96151 | 4125                                                                                                                                                                                  | MIL-C-10387, MIL-A-22771                                                                                                                                | QQ-A-367                                                                                           | B247                                                                                                                                                                                                                                                                               | ---  | --- |
| 6162                                                                                | A96162 | ---                                                                                                                                                                                   | ---                                                                                                                                                     | QQ-A-200/17                                                                                        |                                                                                                                                                                                                                                                                                    | ---  | --- |
| 6201                                                                                | A96201 | ---                                                                                                                                                                                   | ---                                                                                                                                                     | ---                                                                                                | B 398 (6201), B 399 (6201),<br>B 524 (6201), B 711 (6201)                                                                                                                                                                                                                          | ---  | --- |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - ALUMINUM AND ALUMINUM ALLOYS (Continued) |        |                                                         |     |             |                                                                    |      |     |
|-------------------------------------------------------------------------------------|--------|---------------------------------------------------------|-----|-------------|--------------------------------------------------------------------|------|-----|
| AA                                                                                  | UNS    | AMS                                                     | MIL | FED         | ASTM                                                               | ASME | AWS |
| 6262                                                                                | A96262 | ---                                                     | --- | QQ-A-225/10 | B210 (6262), B 211 (6262),<br>B 221 (6262), B 467,<br>B 483 (6262) | ---  | --- |
| 6351                                                                                | A96351 | ---                                                     | --- | ---         | B 221 (6351), B 241 (6351),<br>B 345 (6351)                        | ---  | --- |
| 6463                                                                                | A96463 | ---                                                     | --- | ---         | B 221 (6463)                                                       | ---  | --- |
| 7005                                                                                | A97005 | ---                                                     | --- | ---         | B 221 (7005)                                                       | ---  | --- |
| 7049                                                                                | A97049 | 4111, 4157,<br>4159, 4200,<br>4247, 4321<br>MAM 4247    | --- | QQ-A-367    | B 247 (7049)                                                       | ---  | --- |
| 7050                                                                                | A97050 | 4050, 4107,<br>4108, 4201,<br>4340, 4341,<br>4342, 4343 | --- | QQ-A-430    | B 247 (7050), B 316 (7050)                                         | ---  | --- |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - ALUMINUM AND ALUMINUM ALLOYS (Continued) |        |                                                                                                                                                               |                                                   |                                                                                                |                                                                                                               |      |     |
|-------------------------------------------------------------------------------------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|------|-----|
| AA                                                                                  | UNS    | AMS                                                                                                                                                           | MIL                                               | FED                                                                                            | ASTM                                                                                                          | ASME | AWS |
| 7075                                                                                | A97075 | 4044, 4045, 4078, 4122, 4123, 4124, 4126, 4131, 4141, 4147, 4154, 4166, 4167, 4168, 4169, 4174, 4186, 4187, 4310, 4311, 4049, 4139, 4323 MAM 4131, 4141, 4323 | MIL-F-5509, MIL-A-12545, MIL-F-18280, MIL-A-22771 | QQ-A-200/11, QQ-A-200/15, QQ-A-225/9, QQ-A-250/13, QQ-A-250/24, QQ-A-367, QQ-A-430, WW-T-700/7 | B 209 (7075), B 210 (7075) B 211 (7075), B 221 (7075), B 241 (7075), B 247 (7075), B 316 (7075), B 468 (7075) | ---  | --- |
| 7175                                                                                | A97175 | 4148, 4149, 4179, 4344                                                                                                                                        | ---                                               | ---                                                                                            | B 247 (7175)                                                                                                  | ---  | --- |
| 7178                                                                                | A97178 |                                                                                                                                                               | ---                                               | QQ-A-200/13, QQ-A-200/14, QQ-A-250/14, QQ-A-250/21, QQ-A-250/28, QQ-A-430                      | B 209 (7178), B 221 (7178), B 241 (7178), B 316 (7178)                                                        | ---  | --- |
| 7475                                                                                | A97475 | 4084, 4085, 4089, 4090, 4202                                                                                                                                  | ---                                               | ---                                                                                            | ---                                                                                                           | ---  | --- |

a. This cross-reference table lists the basic specification or standard number, and since these standards are constantly being revised, it should be kept in mind that they are presented herein as a guide and may not reflect the latest revision.

| <b>AWS WELDING FILLER METAL SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS</b> |                                                                       |
|---------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| <b>AWS</b>                                                                      | <b>Title</b>                                                          |
| A5.3                                                                            | Aluminum and Aluminum Alloy Electrodes for Shielded Metal Arc Welding |
| A5.10                                                                           | Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods          |

| <b>BRITISH BSI GENERAL SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS</b> |                                                                                                                                     |
|----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                                  | <b>Title</b>                                                                                                                        |
| 1470                                                                       | Specification for wrought aluminium and aluminium alloys for general engineering purposes: plate, sheet and strip                   |
| 1471                                                                       | Specification for wrought aluminium and aluminium alloys for general engineering purposes - drawn tube                              |
| 1472                                                                       | Specification for wrought aluminium and aluminium alloys for general engineering purposes - forging stock and forgings              |
| 1473                                                                       | Specification for wrought aluminium and aluminium alloys for general engineering purposes - rivet, bolt and screw stock             |
| 1474                                                                       | Specification for wrought aluminium and aluminium alloys for general engineering purposes - bars, extruded round tubes and sections |
| 1475                                                                       | Specification for wrought aluminium and aluminium alloys for general engineering purposes - wire                                    |
| 1490                                                                       | Specification for aluminium and aluminium alloy ingots and castings for general engineering purposes                                |
| 2627                                                                       | Specification for wrought aluminium for electrical purposes - wire                                                                  |
| 2901                                                                       | Filler rods and wires for gas-shielded arc welding                                                                                  |
| 2901 Part 4                                                                | Specification for aluminium and aluminium alloys and magnesium alloys                                                               |
| 3019 Part 1                                                                | Specification for TIG welding of aluminium, magnesium and their alloys                                                              |
| 3571 Part 1                                                                | Specification for MIG welding of aluminium and aluminium alloys                                                                     |
| 5812 Part 1                                                                | Specification for aluminium alloy for solid bearings                                                                                |

| <b>BRITISH BSI AEROSPACE SERIES SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS</b> |                                                                                                                                                                                                                                                  |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                                           | <b>Title</b>                                                                                                                                                                                                                                     |
| 6L 16                                                                               | Specification for sheet and strip of 99% aluminium (temper designation H14 or H24)                                                                                                                                                               |
| 6L 17                                                                               | Specification for sheet and strip of 99% aluminium (temper designation-O)                                                                                                                                                                        |
| 5L 34                                                                               | Specification for forging stock, bars, extruded sections and forgings of 99% aluminium                                                                                                                                                           |
| 4L 35                                                                               | Specification for ingots and castings of 'Y' aluminium alloy (heat treated) (suitable for pistons) (Cu 4, Mg 1.5, Ni 2.1)                                                                                                                        |
| 5L 36                                                                               | Specification for wire for solid, cold-forged rivets of 99.5% aluminium (not exceeding 10 mm diameter)                                                                                                                                           |
| 7L 37                                                                               | Specification for wire for solid cold-forged rivets of aluminium-copper-magnesium-silicon-manganese alloy (for use in the solution treated and naturally aged condition) (not exceeding 10 mm diameter) (Cu 4.4, Mg 0.5, Si 0.7, Mn 0.8) (2014A) |
| 5L 44                                                                               | Specification for forging stock, bars, extruded sections and forgings of aluminium - 2 ¼% magnesium alloy                                                                                                                                        |
| 3L 51                                                                               | Specification for ingots and castings of aluminium-silicon-copper-iron-nickel-magnesium alloy (precipitation treated) (Si 2.5, Cu 1.2, Fe 1, Ni 1, Mg 0.1)                                                                                       |
| 3L 52                                                                               | Specification for ingots and castings of aluminium-copper-silicon-nickel-magnesium-iron alloy (solution treated and precipitation treated) (suitable for pistons) (Cu 2.2, Si 1.3, Ni 1.3, Mg 1.1, Fe 1.1)                                       |
| 4L 53                                                                               | Specification for ingots and castings of aluminium-magnesium alloy (solution treated) Mg 10.2)                                                                                                                                                   |
| 4L 54                                                                               | Specification for tube of 99% aluminium (cold drawn: seamless: tested hydraulically) (not exceeding 12 mm wall thickness)                                                                                                                        |
| 4L 56                                                                               | Specification for tube of aluminium - 2 ¼% magnesium alloy (temper designation-O) (seamless: tested hydraulically) (not exceeding 12 mm wall thickness)                                                                                          |
| 3L 58                                                                               | Specification for wire for solid, cold-forged rivets of aluminium - 5% magnesium alloy (not exceeding 10 mm diameter)                                                                                                                            |
| 4L 59                                                                               | Specification for sheet and strip of aluminium-manganese alloy (temper designation H16 or H26)                                                                                                                                                   |
| 4L 60                                                                               | Specification for sheet and strip of aluminium-manganese alloy (temper designation H12 or H22)                                                                                                                                                   |
| 4L 61                                                                               | Specification for sheet and strip of aluminium-manganese alloy (temper designation-O)                                                                                                                                                            |
| 3L 63                                                                               | Specification for tube of aluminium-copper-magnesium-silicon-manganese alloy (solution treated and precipitation treated) (Cu 4.4, Mg 0.5, Si 0.7, Mn 0.8)                                                                                       |
| 2L 77                                                                               | Specification for forging stock and forgings of aluminium-copper-magnesium-silicon-manganese alloy (solution treated and precipitation treated) (Cu 4.4, Mg 0.5, Si 0.7, Mn 0.8)                                                                 |
| 3L 78                                                                               | Specification for ingots and castings of aluminium-silicon-copper-magnesium alloy (solution treated and precipitation treated) (Si 5, Cu 1.2, Mg 0.5)                                                                                            |
| 3L 80                                                                               | Specification for sheet and strip of aluminium - 2 ¼% magnesium alloy (temper designation-O)                                                                                                                                                     |
| 3L 81                                                                               | Specification for sheet and strip of aluminium - 2 ¼% magnesium alloy (temper designation H16 or H26)                                                                                                                                            |

| <b>BRITISH BSI AEROSPACE SERIES SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                                                                                              |
|-------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                                                       | <b>Title</b>                                                                                                                                                                                                                                                                                                                 |
| 2L 83                                                                                           | Specification for forging stock, bars, extruded sections and forgings of aluminium-copper-nickel-magnesium-iron-silicon alloy (solution treated and precipitation treated) (Cu 2, Ni 1, Mg 1, Si 0.9, Fe 0.9)                                                                                                                |
| 2L 84                                                                                           | Specification for bars and extruded sections of aluminium-copper-silicon-magnesium alloy (solution treated and aged at room temperature) (not exceeding 200 mm diameter or minor sectional dimension) (Cu 1.5, Si 1, Mg 0.8)                                                                                                 |
| 2L 85                                                                                           | Specification for forging stock, bars, extruded sections and forgings of aluminium-copper-silicon-magnesium alloy (solution treated and precipitation treated) (Cu 1.5, Si 1, Mg 0.8)                                                                                                                                        |
| 3L 86                                                                                           | Specification for wire for solid, cold-forged rivets of aluminium-copper-magnesium alloy (not exceeding 10 mm diameter) (Cu 2.5, Mg 0.3)                                                                                                                                                                                     |
| 2L 87                                                                                           | Specification for hexagonal bars for nuts, couplings and hollow machined parts of aluminium-copper-magnesium-silicon-manganese alloy (solution treated and precipitation treated) (free from peripheral and asymmetric coarse grain) (not less than 14 mm nor more than 36 mm across flats) (Cu 4.4, Mg 0.5, Si 0.7, Mn 0.8) |
| 2L 88                                                                                           | Specification for aluminium-alloy-coated sheet and strip of aluminium-zinc-magnesium-copper-chromium alloy (solution treated and precipitation treated) (Zn 5.8, Mg 2.5, Cu 1.6, Cr 0.15)                                                                                                                                    |
| 2L 91                                                                                           | Specification for ingots and castings of aluminium-copper alloy (165 MN/m <sup>2</sup> 0.2 per cent proof stress) (Cu 4.5)                                                                                                                                                                                                   |
| 2L 92                                                                                           | Specification for ingots and castings of aluminium-copper alloy (200 MN/m <sup>2</sup> 0.2 per cent proof stress) (Cu 4.5)                                                                                                                                                                                                   |
| 2L 93                                                                                           | Specification for plate of aluminium-copper-magnesium-silicon-manganese alloy (solution treated, controlled stretched and precipitation treated) (Cu 4.4, Mg 0.5, Si 0.7, Mn 0.8)                                                                                                                                            |
| 2L 95                                                                                           | Specification for plate of aluminium-zinc-magnesium-copper-chromium alloy (solution treated, controlled stretched and precipitation treated) (Zn 5.8, Mg 2.5, Cu 1.6, Cr 0.15)                                                                                                                                               |
| 2L 97                                                                                           | Specification for plate of aluminium-copper-magnesium-manganese alloy (solution treated, controlled stretched and aged at room temperature) (Cu 4.4, Mg 1.5, Mn 0.6)                                                                                                                                                         |
| 2L 98                                                                                           | Specification for plate of aluminium-copper-magnesium-manganese alloy (solution treated and aged at room temperature: not controlled stretched) (Cu 4.4, Mg 1.5, Mn 0.6)                                                                                                                                                     |
| 2L 99                                                                                           | Specification for ingots and castings of aluminium-silicon-magnesium alloy (solution treated and precipitation treated) (Si 7, Mg 0.3)                                                                                                                                                                                       |
| 3L 100                                                                                          | Procedure for inspection and testing of wrought aluminium and aluminium alloys                                                                                                                                                                                                                                               |
| 4L 101                                                                                          | Procedure for inspection, testing and acceptance of aluminium-base and magnesium-base ingots and castings                                                                                                                                                                                                                    |
| L 102                                                                                           | Specification for bars and extruded sections of aluminium-copper-magnesium-silicon-manganese alloy (solution treated and aged at room temperature) (not exceeding 200 mm diameter or minor sectional dimension) (Cu 4.4, Mg 0.5, Si 0.7, Mn 0.8)                                                                             |

| <b>BRITISH BSI AEROSPACE SERIES SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                                              |
|-------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                                                       | <b>Title</b>                                                                                                                                                                                                                 |
| L 103                                                                                           | Specification for forging stock and forgings of aluminium-copper-magnesium-silicon-manganese alloy (solution treated and aged at room temperature) (Cu 4.4, Mg 0.5, Si 0.7, Mn 0.8)                                          |
| L 105                                                                                           | Specification for tube of aluminium-copper-magnesium-silicon-manganese alloy (solution treated and aged at room temperature) (not exceeding 10 mm wall thickness) (Cu 4.4, Mg 0.5, Si 0.7, Mn 0.8)                           |
| L 109                                                                                           | Specification for aluminium-coated sheet and strip of aluminium-copper-magnesium-manganese alloy (solution treated and aged at room temperature) (Cu 4.4, Mg 1.5, Mn 0.6)                                                    |
| L 110                                                                                           | Specification for aluminium-coated sheet and strip of aluminium-copper-magnesium-manganese alloy (supplied for solution treatment by the user) (Cu 4.4, Mg 1.5, Mn 0.6)                                                      |
| L 111                                                                                           | Specification for bars and extruded sections of aluminium-magnesium-silicon-manganese alloy (solution treated and precipitation treated) (suitable for welding) (Mg 0.8, Si 1, Mn 0.7)                                       |
| L 112                                                                                           | Specification for forging stock and forgings of aluminium-magnesium-silicon-manganese alloy (solution treated and precipitation treated) (suitable for welding) (Mg 0.8, Si 1, Mn 0.7)                                       |
| L 113                                                                                           | Specification for sheet and strip of aluminium-magnesium-silicon-manganese alloy (solution treated and precipitation treated) (suitable for welding) (Mg 0.8, Si 1, Mn 0.7)                                                  |
| L 114                                                                                           | Specification for tube of aluminium-magnesium-silicon-manganese alloy (solution treated and precipitation treated) (not exceeding 10 mm wall thickness) (suitable for welding) (Mg 0.8, Si 1, Mn 0.7)                        |
| L 115                                                                                           | Specification for plate of aluminium-magnesium-silicon-manganese alloy (solution treated, controlled stretched and precipitation treated) (not exceeding 25 mm wall thickness) (suitable for welding) (Mg 0.8, Si 1, Mn 0.7) |
| 2L 116                                                                                          | Specification for tube of 99% aluminium (cold drawn: seamless, not tested hydraulically) (not exceeding 12 mm wall thickness)                                                                                                |
| L 117                                                                                           | Specification for tube of aluminium-magnesium-silicon-copper-chromium alloy (solution treated and artificially aged: not tested hydraulically) (not exceeding 10 mm wall thickness) (Mg 1.0, Si 0.6, Cu 0.28, Cr 0.2)        |
| L 118                                                                                           | Specification for tube of aluminium-magnesium-silicon-copper-chromium alloy (solution treated and artificially aged: tested hydraulically) (not exceeding 10 mm wall thickness) (Mg 1.0, Si 0.6, Cu 0.28, Cr 0.2)            |
| L 119                                                                                           | Specification for ingots and castings of aluminium-copper-nickel-manganese-titanium-zirconium-cobalt-antimony alloy (solution treated and artificially aged) (Cu 5.0, Ni 1.5, Mn 0.25, Ti 0.2, Zr 0.2, Co 0.2, Sb 0.2)       |
| 3L 122                                                                                          | Specification for ingots and castings of magnesium - 8% aluminium-zinc-manganese alloy (solution treated) (Al 8, Zn 0.5, Mn 0.3)                                                                                             |
| L 154                                                                                           | Specification for ingots and castings of aluminium-copper-silicon alloy (solution treated and aged at room temperature) (Cu 4, Si 1)                                                                                         |



| <b>BRITISH BSI AEROSPACE SERIES SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                                                           |
|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                                                       | <b>Title</b>                                                                                                                                                                                                                              |
| L 155                                                                                           | Specification for ingots and castings of aluminium-copper-silicon alloy (solution treated and artificially aged) (Cu 4, Si 1)                                                                                                             |
| L 156                                                                                           | Specification for sheet and strip of aluminium-copper-magnesium-silicon-manganese alloy (solution treated and aged at room temperature) (Cu 4.4, Mg 0.5, Si 0.8, Mn 0.8)                                                                  |
| L 157                                                                                           | Specification for sheet and strip of aluminium-copper-magnesium-silicon-manganese alloy (solution treated and artificially aged) (Cu 4.4, Mg 0.5, Si 0.8, Mn 0.8)                                                                         |
| L 158                                                                                           | Specification for close toleranced sheet and strip of aluminium-copper-magnesium-silicon-manganese alloy (solution treated and aged at room temperature) (Cu 4.4, Mg 0.5, Si 0.8, Mn 0.8)                                                 |
| L 159                                                                                           | Specification for close toleranced sheet and strip of aluminium-copper-magnesium-silicon-manganese alloy (solution treated and artificially aged) (Cu 4.4, Mg 0.5, Si 0.8, Mn 0.8)                                                        |
| L 160                                                                                           | Specification for bars and extruded sections of aluminium-zinc-magnesium-copper-chromium alloy (solution treated and artificially aged to an overaged condition) (Zn 5.6, Mg 2.5, Cu 1.6, Cr 0.22)                                        |
| L 161                                                                                           | Specification for hand and die forgings of aluminium-zinc-magnesium-copper-chromium alloy (solution treated and artificially aged to an overaged condition) (Zn 5.6, Mg 2.5, Cu 1.6, Cr 0.22)                                             |
| L 162                                                                                           | Specification for cold compressed hand forgings of aluminium-zinc-magnesium-copper-chromium alloy (solution treated and artificially aged to an overaged condition) (Zn 5.6, Mg 2.5, Cu 1.6, Cr 0.22)                                     |
| L 163                                                                                           | Specification for sheet and strip of aluminium-coated aluminium-copper-magnesium-silicon-manganese alloy (solution treated, cold worked for flattening and aged at room temperature) (Cu 4.4, Mg 0.5, Si 0.8, Mn 0.8)                     |
| L 164                                                                                           | Specification for sheet and strip of aluminium-coated aluminium-copper-magnesium-silicon-manganese alloy (solution treated and aged at room temperature) (Cu 4.4, Mg 0.5, Si 0.8, Mn 0.8)                                                 |
| L 165                                                                                           | Specification for sheet and strip of aluminium-coated aluminium-copper-magnesium-silicon-manganese alloy (solution treated and artificially aged) (Cu 4.4, Mg 0.5, Si 0.8, Mn 0.8)                                                        |
| L 166                                                                                           | Specification for close toleranced sheet and strip of aluminium-coated aluminium-copper-magnesium-silicon-manganese alloy (solution treated and aged at room temperature) (Cu 4.4, Mg 0.5, Si 0.8, Mn 0.8)                                |
| L 167                                                                                           | Specification for close toleranced sheet and strip of aluminium-coated aluminium copper-magnesium-silicon-manganese alloy (solution treated and artificially aged) (Cu 4.4, Mg 0.5, Si 0.8, Mn 0.8)                                       |
| L 168                                                                                           | Specification for bars and extruded sections of aluminium-copper-magnesium-silicon-manganese alloy (solution treated and artificially aged) (not exceeding 200 mm diameter or minor sectional dimension) (Cu 4.4, Mg 0.5, Si 0.7, Mn 0.8) |

| <b>BRITISH BSI AEROSPACE SERIES SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                           |
|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                                                       | <b>Title</b>                                                                                                                                                                                                                                              |
| L 169                                                                                           | Specification for ingots and castings of aluminium-silicon-magnesium alloy (solution treated and artificially aged) (Si 7, Mg 0.6)                                                                                                                        |
| L 170                                                                                           | Specification for extruded bars and sections of aluminium-zinc-copper-chromium alloy (solution treated, controlled stretched and artificially aged) (not exceeding 150 mm diameter or minor sectional dimension) (Zn 5.6, Mg 2.5, Cu 1.6, Cr 0.23) (7075) |
| L 171                                                                                           | Specification for forging of aluminium-zinc-magnesium-manganese-copper alloy (supplied as-forged or annealed for subsequent heat treatment) (not exceeding 150 mm diameter or minor sectional dimension) (Zn 5.7, Mg 2.7, Mn 0.5, Cu 0.5) (7014)          |
| L 172                                                                                           | Specification for extruded, rolled or cast forging stock of aluminium-zinc-magnesium-manganese-copper alloy (for manufacture of forgings to BS L 171) (Zn 5.7, Mg 2.7, Mn 0.5, Cu 0.5) (7014)                                                             |
| L 173                                                                                           | Specification for castings of aluminium-silicon-magnesium alloy, chill cast (solution treated and precipitation treated to an overaged (T7) condition)                                                                                                    |
| L 174                                                                                           | Specification for castings of aluminium-silicon-magnesium alloy, sand case (solution treated and precipitation treated to an overaged (T7) condition)                                                                                                     |

| <b>GERMAN DIN AEROSPACE SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS</b> |                                                                                                                                                                            |
|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                  | <b>Title</b>                                                                                                                                                               |
| EN 2094                                                                     | Aerospace series; aluminium alloy AL-P-7009T74; die forgings $3 \text{ mm} \leq a \leq 150 \text{ mm}$ ; inactive for new design                                           |
| EN 2100                                                                     | Aerospace series; aluminium alloy AL-P2014A-T4511; extruded bars and sections $a \text{ or } D \leq 200 \text{ mm}$                                                        |
| EN 2101                                                                     | Aerospace series; chromic acid anodizing of aluminium and wrought aluminium alloys                                                                                         |
| EN 2126                                                                     | Aerospace series; aluminium alloy AL-P7075-T651; plate $6 \text{ mm} < a \leq 80 \text{ mm}$ ; inactive for new design                                                     |
| EN 2127                                                                     | Aerospace series; aluminium alloy AL-P7075-T73511; extruded bars and sections $a \text{ or } D \leq 100 \text{ mm}$                                                        |
| EN 2128                                                                     | Aerospace series; aluminium Alloy AL-P7075-T3511; drawn bars $6 \text{ mm} < a \text{ or } D \leq 75 \text{ mm}$                                                           |
| EN 2289                                                                     | Aerospace series; rod bodies, flight controls, in aluminium alloys, technical specification                                                                                |
| EN 2318                                                                     | Aerospace series; aluminium alloy AL-P2024-T3511; extruded bars and sections $1.2 \text{ mm} \leq a \text{ or } D \leq 150 \text{ mm}$                                     |
| EN 2326                                                                     | Aerospace series; aluminium alloy AL-P6082-T6; extruded bars and sections $a \text{ or } D \leq 200 \text{ mm}$                                                            |
| EN 2381                                                                     | Aerospace series; aluminium alloy AL-P7009-T7452; hand forgings $40 \text{ mm} \leq a \leq 150 \text{ mm}$                                                                 |
| EN 2384                                                                     | Aerospace series; aluminium alloy AL-P2014A-T6511; extruded bars and sections $a \text{ or } D \leq 150 \text{ mm}$                                                        |
| EN 2385                                                                     | Aerospace series; aluminium alloy AL-P7009-T74511; extruded bars and sections $a \text{ or } D \leq 125 \text{ mm}$ ; inactive for new design                              |
| EN 2500 Part 2                                                              | Aerospace series; instructions for the drafting and use of metallic material standards; part 2: specific requirements for aluminium, aluminium alloys and magnesium alloys |
| EN 2599                                                                     | Aerospace series; strip in aluminium and aluminium alloys $0.3 \leq a \leq 3.2 \text{ mm}$ ; dimensions                                                                    |

| <b>GERMAN DIN AEROSPACE SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                                                                                                             |
|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                              | <b>Title</b>                                                                                                                                                                                                |
| EN 2615                                                                                 | Aerospace series; wire to close tolerance in aluminium and aluminium alloys $1.6 \leq D \leq 9.6$ mm; dimensions                                                                                            |
| EN 2616                                                                                 | Aerospace series; wire for rivets in aluminium and aluminium alloys, large tolerances $D \leq 10$ mm; dimensions                                                                                            |
| EN 2637                                                                                 | Aerospace series; aluminium alloy 7075-T73; extruded bar and section $1.2 \leq (a \text{ or } D) \leq 100$ mm with coarse peripheral grain control                                                          |
| EN 2638                                                                                 | Aerospace series; aluminium alloy 2024-T3; extruded bar and section $1.2 \leq (a \text{ or } D) \leq 150$ mm with coarse peripheral grain control                                                           |
| EN 2639                                                                                 | Aerospace series; aluminium alloy 2014A-T6; extruded bar and section $1.2 \leq (a \text{ or } D) \leq 150$ mm with coarse peripheral grain control                                                          |
| EN 2644                                                                                 | Aerospace series; rod assemblies for flight controls; technical specification                                                                                                                               |
| EN 2691                                                                                 | Aerospace series; aluminium alloy (2017A); solution treated, water quench, cold worked and naturally aged (T3); sheet and strip $0.4 \leq a \leq 6$ mm                                                      |
| EN 2697                                                                                 | Aerospace series; aluminium alloy (2214); solution treated, water quench and artificially aged (T6); extruded bar and section $1.2 \leq (a \text{ or } D) \leq 100$ mm with coarse peripheral grain control |
| EN 2698                                                                                 | Aerospace series; aluminium alloy (7075); solution treated, water quench, controlled stretched and artificially aged (T6510); extruded bar and section $1.2 \leq (a \text{ or } D) \leq 100$ mm             |
| EN 2699                                                                                 | Aerospace series; aluminium alloy (5086); annealed and straightened (H111); drawn bar $6 \leq D \leq 50$ mm                                                                                                 |
| EN 2700                                                                                 | Aerospace series; aluminium alloy (6061); solution treated, water quench and artificially aged (T6); drawn bar $6 \leq D \leq 75$ mm, with coarse peripheral grain control                                  |
| EN 2701                                                                                 | Aerospace series; aluminium alloy (2024); solution treated, water quench, cold worked and naturally aged (T3); drawn tube for structures $0.6 \leq a \leq 12.5$ mm                                          |
| EN 2702                                                                                 | Aerospace series; aluminium alloy 6061-T6; extruded bar and section $1.2 \leq (a \text{ or } D) \leq 150$ mm                                                                                                |
| EN 2715                                                                                 | Aerospace series; macrographic examination of aluminium and aluminium alloy forging stock, forgings and wrought products                                                                                    |
| EN 2716                                                                                 | Aerospace series; test method for susceptibility to intergranular corrosion of wrought products in 2XXX series aluminium alloys                                                                             |
| EN 2717                                                                                 | Aerospace series; test method for susceptibility to intergranular corrosion of wrought products in 5XXX series aluminium alloys with a magnesium content $\geq 3.5\%$                                       |
| EN 2720                                                                                 | Aerospace series; test method for metallic materials; testing of susceptibility to exfoliation corrosion in 2XXX and 7XXX series wrought aluminium alloy products for aerospace constructions               |
| EN 2721                                                                                 | Aerospace series; aluminium alloy Al-C12-T4; sand castings                                                                                                                                                  |
| EN 2722                                                                                 | Aerospace series; aluminium alloy Al-C12-T4; chill castings                                                                                                                                                 |
| EN 2723                                                                                 | Aerospace series; aluminium alloy Al-C12-T6; sand castings                                                                                                                                                  |

| GERMAN DIN AEROSPACE SPECIFICATIONS - ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                                    |
|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DIN                                                                          | Title                                                                                                                                                              |
| EN 2724                                                                      | Aerospace series; aluminium alloy Al-C12-T6; chill castings                                                                                                        |
| EN 2725                                                                      | Aerospace series; aluminium alloy Al-C14-T6; sand castings                                                                                                         |
| EN 2726                                                                      | Aerospace series; aluminium alloy Al-C26-T6; sand castings                                                                                                         |
| EN 2727                                                                      | Aerospace series; aluminium alloy Al-C26-T6; chill castings                                                                                                        |
| EN 2728                                                                      | Aerospace series; aluminium alloy Al-C27-T6; sand castings                                                                                                         |
| EN 2729                                                                      | Aerospace series; aluminium alloy Al-C27-T6; chill castings                                                                                                        |
| EN 2802                                                                      | Aerospace series; aluminium alloy 7475-T761; sheet and strip $0.8 \leq a \leq 6$ mm                                                                                |
| EN 2803                                                                      | Aerospace series; aluminium alloy 7475-T761; clad sheet and strip $0.8 \leq a \leq 6$ mm                                                                           |
| EN 2804                                                                      | Aerospace series; aluminium alloy 7075-T7651; plate $6 < a \leq 25$ mm                                                                                             |
| EN 2805                                                                      | Aerospace series; aluminium alloy 7475-T7651; plate $6 < a \leq 25$ mm                                                                                             |
| EN 2806                                                                      | Aerospace series; aluminium alloy 2024-T42; extruded section $1.2 \leq a \leq 100$ mm with coarse peripheral grain control                                         |
| EN 2807                                                                      | Aerospace series; aluminium alloy 7020-T6; extruded section $1.2 \leq a \leq 100$ mm with coarse peripheral grain control                                          |
| EN 2813                                                                      | Aerospace series; aluminium alloy 6061-T6; tube for hydraulics $0.6 \leq a \leq 12.5$ mm                                                                           |
| EN 3350                                                                      | Aerospace series; aluminium, aluminium alloys; temper designations                                                                                                 |
| EN 6025                                                                      | Aerospace series; plates; close-tolerance flatness; aluminium alloys                                                                                               |
| WL 3.1124 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 2.6Cu-0.4Mg; rivet wire and rivets                                                                                 |
| WL 3.1124 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 2.6Cu-0.4Mg; rivet wire and rivets; design and production data, conversion                                         |
| WL 3.1254 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 4.5Cu-0.9Si-0.8Mn-0.5Mg; die forgings                                                                              |
| WL 3.1254 Part 2                                                             | Aerospace; wrought aluminium alloy with approx. 4.5Cu-0.9Si-0.8Mn-0.5Mg; hand forgings                                                                             |
| WL 3.1254 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 4.5Cu-0.9Si-0.8Mn-0.5Mg; die forgings and hand forgings; design and production data, conversion                    |
| WL 3.1324 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 4.0Cu-0.7Mg; rivet wire and rivets                                                                                 |
| WL 3.1324 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 4.0Cu-0.7Mg; rivet wire and rivets; design and production data, conversion                                         |
| WL 3.1354 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 4.4Cu-1.5Mg-0.6Mn; sheet and plate                                                                                 |
| WL 3.1354 Part 4                                                             | Aerospace; wrought aluminium alloy with approx. 4.4Cu-1.5Mg-0.6Mn; structural tubes                                                                                |
| WL 3.1354 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 4.4Cu-1.5Mg-0.6Mn; sheet, plate, bars, extruded sections, structural tubes; design and production data, conversion |

| GERMAN DIN AEROSPACE SPECIFICATIONS - ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                                             |
|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DIN                                                                          | Title                                                                                                                                                                       |
| WL 3.1364 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 4.4Cu-1.5Mg-0.6Mn; clad sheet, strip and plate                                                                              |
| WL 3.1364 Part 2                                                             | Aerospace; wrought aluminium alloy with approx. 4.4Cu-1.5Mg-0.6Mn; clad sheet and strip sections                                                                            |
| WL 3.1364 Part 3                                                             | Aerospace; wrought aluminium alloy with approx. 4.4Cu-1.5Mg-0.6Mn; clad wedges                                                                                              |
| WL 3.1364 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 4.4Cu-1.5Mg-0.6Mn; clad sheet, strip and plate, sheet and strip sections and wedges; design and production data, conversion |
| WL 3.1734                                                                    | Aluminium cast alloy with about 4Cu-1.5Mg-2Ni; sand casting                                                                                                                 |
| WL 3.1734 Supp. 1                                                            | Aluminium cast alloy with about 4Cu-1.5Mg-2Ni; sand casting                                                                                                                 |
| WL 3.1754 Part 1                                                             | Aerospace; cast aluminium alloy with approx. 5Cu-1.5Ni-0.25Mn-0.25Sb-0.25Co-0.2Ti-0.2Zr; sand casting and investment casting                                                |
| WL 3.1754 Part 100                                                           | Aerospace; cast aluminium alloy with approx. 5Cu-1.5Ni-0.25Mn-0.25Sb-0.25Co-0.2Ti-0.2Zr; sand casting and investment casting; design and production data, conversion        |
| WL 3.1854                                                                    | Aluminium cast alloy with about 4.5Cu-0.2Mg-0.2Ti; sand casting and chill casting                                                                                           |
| WL 3.1854 Supp. 1                                                            | Aluminium cast alloy with about 4.5Cu-0.2Mg-0.2Ti; sand casting and chill casting                                                                                           |
| WL 3.1924 Supp. 1                                                            | Aluminium wrought alloy with about 2.3Cu-1.5Mg-1.1Ni-1.1Fe-0.2Si; plates, rods, drop forgings and smith hammer forgings                                                     |
| WL 3.1924 Part 1                                                             | Aluminium wrought alloy, Al-Cu2MgNi; plates                                                                                                                                 |
| WL 3.1924 Part 2                                                             | Aluminium wrought alloy; Al-Cu2MgNi; rods                                                                                                                                   |
| WL 3.1924 Part 4                                                             | Aluminium wrought alloy; Al-Cu2MgNi; drop forgings                                                                                                                          |
| WL 3.1924 Part 5                                                             | Aluminium wrought alloy; Al-Cu2MgNi; smith hammer forgings                                                                                                                  |
| WL 3.2134 Supp. 1                                                            | Aluminium cast alloy with about 5Si-1.3Cu-0.5Mg; sand casting and chill casting                                                                                             |
| WL 3.2134 Part 1                                                             | Aluminium cast alloy with about 5Si-1.3Cu-0.5Mg; sand casting                                                                                                               |
| WL 3.2134 Part 2                                                             | Aluminium cast alloy with about 5Si-1.3Cu-0.5Mg; chill casting                                                                                                              |
| WL 3.2364 Part 1                                                             | Cast aluminium alloy (Alcoa 356)                                                                                                                                            |
| WL 3.2364 Part 2                                                             | Cast aluminium alloy (Alcoa 356)                                                                                                                                            |
| WL 3.2374 Part 1                                                             | Aerospace; cast aluminium alloy with approx. 7Si-0.3Mg; sand casting                                                                                                        |
| WL 3.2374 Part 2                                                             | Aerospace; cast aluminium alloy with approx. 7Si-0.3Mg; investment casting                                                                                                  |
| WL 3.2374 Part 3                                                             | Aerospace; cast aluminium alloy with approx. 7Si-0.3Mg; permanent mould casting                                                                                             |
| WL 3.2374 Part 100                                                           | Aerospace; cast aluminium alloy with approx. 7Si-0.3Mg; sand casting, investment casting and permanent mould casting; design and production data, conversion                |

| GERMAN DIN AEROSPACE SPECIFICATIONS - ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                                                                                              |
|------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DIN                                                                          | Title                                                                                                                                                                                                                        |
| WL 3.2384 Part 1                                                             | Aerospace; cast aluminium alloy with approx. 7Si-0.6Mg; sand casting                                                                                                                                                         |
| WL 3.2384 Part 2                                                             | Aerospace; cast aluminium alloy with approx. 7Si-0.6Mg; special sand casting                                                                                                                                                 |
| WL 3.2384 Part 3                                                             | Aerospace; cast aluminium alloy with approx. 7Si-0.6Mg; investment casting                                                                                                                                                   |
| WL 3.2384 Part 4                                                             | Aerospace; cast aluminium alloy with approx. 7Si-0.6Mg; special investment casting                                                                                                                                           |
| WL 3.2384 Part 5                                                             | Aerospace; wrought aluminium alloy with approx. 7Si-0.6Mg; filler metal for welding                                                                                                                                          |
| WL 3.2384 Part 100                                                           | Aerospace; cast aluminium alloy with approx. 7Si-0.6Mg; sand casting, special sand casting and investment casting; design and production data, conversion                                                                    |
| WL 3.3214 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 1.0Mg-0.6Si-0.3Cu-0.20Cr; sheet and plate                                                                                                                                    |
| WL 3.3214 Part 2                                                             | Aerospace; wrought aluminium alloy with approx. 1.0Mg-0.6Si-0.3Cu-0.20Cr; bars                                                                                                                                               |
| WL 3.3214 Part 3                                                             | Aerospace; wrought aluminium alloy with approx. 1.0Mg-0.6Si-0.3Cu-0.20Cr; sections                                                                                                                                           |
| WL 3.3214 Part 4                                                             | Aerospace; wrought aluminium alloy with approx. 1.0Mg-0.6Si-0.3Cu-0.20Cr; die forgings and hand forgings                                                                                                                     |
| WL 3.3214 Part 5                                                             | Aerospace; wrought aluminium alloy with approx. 1.0Mg-0.6Si-0.3Cu-0.20Cr; internal pressure tubes                                                                                                                            |
| WL 3.3214 Part 6                                                             | Aerospace; wrought aluminium alloy with approx. 1.0Mg-0.6Si-0.3Cu-0.20Cr; structural tubes                                                                                                                                   |
| WL 3.3214 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 1.0Mg-0.6Si-0.3Cu-0.20Cr; sheet, plate, bars, sections, die forgings and hand forgings, internal pressure tubes and structural tubes; design and production data, conversion |
| WL 3.3354                                                                    | Aluminium wrought alloy with about 5Mg; rivet wires and rivets                                                                                                                                                               |
| WL 3.3354 Supp. 1                                                            | Aluminium wrought alloy with about 5Mg; rivet wires and rivets                                                                                                                                                               |
| WL 3.3354 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 5Mg; rivet wire and rivets                                                                                                                                                   |
| WL 3.3354 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 5Mg; rivet wire and rivets; design and production data, conversion                                                                                                           |
| WL 3.3524 Supp. 1                                                            | Aluminium wrought alloy with about 2.5Mg-0.25Cr; sheets, strips and conduit pipes                                                                                                                                            |
| WL 3.3524 Part 1                                                             | Aluminium wrought alloy with about 2.5Mg-0.25Cr; sheets and strips                                                                                                                                                           |
| WL 3.3524 Part 2                                                             | Aerospace; wrought aluminium alloy with approx. 2.5Mg-0.25Cr; internal pressure tubes and tubes for fluids, seamless                                                                                                         |
| WL 3.3524 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 2.5Mg-0.25Cr; sheet, strip, internal pressure tubes and tubes for fluids, seamless; design and production data, conversion                                                   |
| WL 3.4144 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 6.2Zn-2.3Cu-2.2Mg-0.12Zr; stretched plate                                                                                                                                    |
| WL 3.4144 Part 2                                                             | Aerospace; wrought aluminium alloy with approx. 6.2Zn-2.3Cu-2.2Mg-0.12Zr; die forgings                                                                                                                                       |
| WL 3.4144 Part 3                                                             | Aerospace; wrought aluminium alloy with approx. 6.2Zn-2.3Cu-2.2Mg-0.12Zr; hand forgings                                                                                                                                      |

| GERMAN DIN AEROSPACE SPECIFICATIONS - ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                                                         |
|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DIN                                                                          | Title                                                                                                                                                                                   |
| WL 3.4144 Part 4                                                             | Aerospace; wrought aluminium alloy with approx. 6.2Zn-2.3Cu-2.2Mg-0.12Zr; rivet wire and rivets                                                                                         |
| WL 3.4144 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 6.2Zn-2.3Cu-2.2Mg-0.12Zr; stretched plate, die and hand forgings; design and production data, conversion                                |
| WL 3.4144 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 6.2Zn-2.3Cu-2.2Mg-0.12Zr; stretched plate, die and hand forgings; rivet wire and rivets; design and production data, conversion         |
| WL 3.4334 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 5.6Zn-2.5Mg-1.6Cu-0.23Cr; die forgings                                                                                                  |
| WL 3.4334 Part 2                                                             | Aerospace; wrought aluminium alloy with approx. 5.6Zn-2.5Mg-1.6Cu-0.23Cr; hand forgings                                                                                                 |
| WL 3.4334 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 5.6Zn-2.5Mg-1.6Cu-0.23Cr; die forgings and hand forgings; design and production data, conversion                                        |
| WL 3.4354 Supp. 1                                                            | Aluminium wrought alloy with about 6.0Zn-2.5Mg-0.95Cu-0.32Ag-0.18Cr; rods, pressed sections, drop forgings and smith hammer forgings                                                    |
| WL 3.4354 Part 1                                                             | Aluminium wrought alloy with about 6.0Zn-2.5Mg-0.95Cu-0.32Ag-0.18Cr; rods                                                                                                               |
| WL 3.4354 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 6.0Zn-2.5Mg-0.95Cu-0.32Ag-0.18Cr; bars                                                                                                  |
| WL 3.4354 Part 4                                                             | Aluminium wrought alloy with about 6.0Zn-2.5Mg-0.95Cu-0.32Ag-0.18Cr; smith hammer forgings                                                                                              |
| WL 3.4354 Part 4                                                             | Aerospace; wrought aluminium alloy with approx. 6.0Zn-2.5Mg-0.95Cu-0.32Ag-0.18Cr; hand forgings                                                                                         |
| WL 3.4354 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 6.0Zn-2.5Mg-0.95Cu-0.32Ag-0.18Cr; bars, extruded sections, die forgings and hand forgings; design and production data, conversion       |
| WL 3.4364 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 5.6Zn-2.5Mg-1.6Cu-0.23Cr; sheet and plate                                                                                               |
| WL 3.4364 Part 4                                                             | Aluminium wrought alloy; Al-Zn6MgCu; drop forgings                                                                                                                                      |
| WL 3.4364 Part 4                                                             | Aerospace; wrought aluminium alloy with approx. 5.6Zn-2.5Mg-1.6Cu-0.23Cr; die forgings                                                                                                  |
| WL 3.4364 Part 5                                                             | Aluminium wrought alloy; Al-Zn6MgCu; smith hammer forgings                                                                                                                              |
| WL 3.4364 Part 5                                                             | Aerospace; wrought aluminium alloy with approx. 5.6Zn-2.5Mg-1.6Cu-0.23Cr; hand forgings                                                                                                 |
| WL 3.4364 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 5.6Zn-2.5Mg-1.6Cu-0.23Cr; sheet, plate, bars, extruded sections, die forgings and hand forgings; design and production data, conversion |
| WL 3.4374 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 5.6Zn-2.5Mg-1.6Cu-0.23Cr; clad sheet                                                                                                    |
| WL 3.4374 Part 2                                                             | Aluminium wrought alloy with about 6Zn-2.5Mg-1.5Cu; key sheets, clad                                                                                                                    |

| GERMAN DIN AEROSPACE SPECIFICATIONS - ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                          |
|------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| DIN                                                                          | Title                                                                                                                                                    |
| WL 3.4374 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 5.6Zn-2.5Mg-1.6Cu-0.23Cr; sheet and tapered sheet, clad; design and production data, conversion          |
| WL 3.4377 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 5.7Zn-2.2Mg-1.6Cu-0.22Cr; sheet and strip, clad                                                          |
| WL 3.4377 Part 2                                                             | Aerospace; wrought aluminium alloy with approx. 5.7Zn-2.2Mg-1.6Cu-0.22Cr; sheet and strip sections, clad                                                 |
| WL 3.4377 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 5.7Zn-2.2Mg-1.6Cu-0.22Cr; clad sheet and strip; design and production data, conversion                   |
| WL 3.4384 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 5.7Zn-2.2Mg-1.6Cu-0.22Cr; stretched plate                                                                |
| WL 3.4384 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 5.7Zn-2.2Mg-1.6Cu-0.22Cr; stretched plate. design and production data, conversion                        |
| WL 3.4394 Part 1                                                             | Aerospace; wrought aluminium alloy with approx. 6.2Zn-2.4Mg-1.8Cu-0.13Zr; stretched plate                                                                |
| WL 3.4394 Part 2                                                             | Aerospace; wrought aluminium alloy with approx. 6.2Zn-2.4Mg-1.8Cu-0.13Zr; die forgings                                                                   |
| WL 3.4394 Part 3                                                             | Aerospace; wrought aluminium alloy with approx. 6.2Zn-2.4Mg-1.8Cu-0.13Zr; hand forgings                                                                  |
| WL 3.4394 Part 100                                                           | Aerospace; wrought aluminium alloy with approx. 6.2Zn-2.4Mg-1.8Cu-0.13Zr; stretched plate, die and hand forgings; design and production data, conversion |

| JAPANESE JIS SPECIFICATIONS - ALUMINUM & ALUMINUM ALLOYS |                                                                                       |
|----------------------------------------------------------|---------------------------------------------------------------------------------------|
| JIS                                                      | Title                                                                                 |
| C 3107                                                   | Half-hard-drawn aluminium wires for electric purposes                                 |
| C 3108                                                   | Hard drawn aluminium wires for electric purposes                                      |
| C 3109                                                   | Hard drawn aluminium stranded conductors                                              |
| C 3110                                                   | Aluminium conductors steel reinforced                                                 |
| H 0001                                                   | Temper designation for aluminium and aluminium alloys                                 |
| H 0201                                                   | Glossary of terms used in the surface treatment of aluminium                          |
| H 0521                                                   | Testing method for atmospheric corrosion of aluminium and aluminium alloys            |
| H 0522                                                   | Methods of radiographic test and classification of radiographs for aluminium castings |
| H 4000                                                   | Aluminium and aluminium alloy sheets and plates, strip and coiled sheets              |
| H 4040                                                   | Aluminium and aluminium alloy rods, bars, and wires                                   |



| <b>JAPANESE JIS SPECIFICATIONS - ALUMINUM &amp; ALUMINUM ALLOYS (Continued)</b> |                                                                                                                     |
|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| <b>JIS</b>                                                                      | <b>Title</b>                                                                                                        |
| H 4080                                                                          | Aluminium and aluminium alloy seamless pipes and tubes                                                              |
| H 4090                                                                          | Aluminium and aluminium alloy welded pipes and tubes                                                                |
| H 4100                                                                          | Aluminium and aluminium alloy extruded shapes                                                                       |
| H 4140                                                                          | Aluminium and aluminium alloy forgings                                                                              |
| H 4160                                                                          | Aluminium and aluminium alloy foils                                                                                 |
| H 4170                                                                          | High purity aluminium foils                                                                                         |
| H 4180                                                                          | Aluminium and aluminium alloy bus conductors                                                                        |
| H 5202                                                                          | Aluminium alloy castings                                                                                            |
| H 5302                                                                          | Aluminium alloys die castings                                                                                       |
| H 8301                                                                          | Aluminium spraying on iron and steel                                                                                |
| H 8642                                                                          | Aluminium coatings (hot-dipped) on iron or steel                                                                    |
| H 8672                                                                          | Methods of test for aluminium coating (hot-dipped) on iron or steel                                                 |
| H 8680                                                                          | Test methods for thickness of anodic oxidation coatings on aluminium and aluminium alloys                           |
| H 8681                                                                          | Test methods for corrosion resistance of anodic oxidation coatings on aluminium and aluminium alloys                |
| H 8682                                                                          | Test methods for abrasion resistance of anodic oxidation coatings on aluminium and aluminium alloys                 |
| H 8683                                                                          | Test methods for sealing quality of anodic oxidation coatings on aluminium and aluminium alloys                     |
| H 8684                                                                          | Test method for resistance to cracking by deforming of anodic oxidation coatings on aluminium and aluminium alloys  |
| H 8685                                                                          | Accelerated test methods for light fastness of coloured anodic oxidation coatings on aluminium and aluminium alloys |
| H 8686                                                                          | Test methods for image clarity of anodic oxidation coatings on aluminium and aluminium alloys                       |
| H 8771                                                                          | Test methods for stress corrosion cracking on aluminium alloys                                                      |
| H 9126                                                                          | Recommended practice for aluminium coating (hot-dipped)                                                             |
| H 9151                                                                          | Recommended practice for aluminium alloy castings                                                                   |
| H 9301                                                                          | Recommended practice for aluminium spraying on iron and steel                                                       |
| H 9500                                                                          | Recommended practice for anodizing on aluminium and aluminium alloys                                                |
| H 9502                                                                          | Recommended practice for combined coatings of anodic oxide and organic coatings on aluminium and aluminium alloys   |
| W 1103                                                                          | Heat treatment of aluminium alloys for aircraft                                                                     |
| W 1111                                                                          | Anodic coatings on aluminium and aluminium alloys for aircraft                                                      |

| <b>CHEMICAL COMPOSITIONS OF WROUGHT ALUMINUM &amp; ALUMINUM ALLOYS</b> |                                                                                                                                                                                                                   |
|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                             | <b>Chemical Composition</b>                                                                                                                                                                                       |
| A82004                                                                 | Core Alloy A92004 Cladding Alloy A91070                                                                                                                                                                           |
| A82014                                                                 | Core Alloy A92014 Cladding Alloy A96003                                                                                                                                                                           |
| A82024                                                                 | Core Alloy A92024 Cladding Alloy A91230                                                                                                                                                                           |
| A82219                                                                 | Core Alloy A92219 Cladding Alloy A97072                                                                                                                                                                           |
| A83003                                                                 | Core Alloy A93003 Cladding Alloy A94343                                                                                                                                                                           |
| A86061                                                                 | Core Alloy A96061 Cladding Alloy A97072                                                                                                                                                                           |
| A87050                                                                 | Core Alloy A97050 Cladding Alloy A97072                                                                                                                                                                           |
| A87075                                                                 | Core Alloy A97075 Cladding Alloy A97072 or A97011                                                                                                                                                                 |
| A87178                                                                 | Core Alloy A97178 Cladding Alloy A97072                                                                                                                                                                           |
| A87475                                                                 | Core Alloy A97475 Cladding Alloy A97072                                                                                                                                                                           |
| A91035                                                                 | Al 99.35 min Cu 0.10 max Fe 0.6 max Mg 0.05 max Mn 0.05 max Si 0.35 max Ti 0.03 max V 0.05 max Zn 0.10 max Other each 0.03 max                                                                                    |
| A91045                                                                 | Al 99.45 min Cu 0.10 max Fe 0.45 max Mg 0.05 max Mn 0.05 max Si 0.30 max Ti 0.03 max V 0.05 max Zn 0.05 max Other each 0.03 max                                                                                   |
| A91050                                                                 | Al 99.50 min Cu 0.05 max Fe 0.40 max Mg 0.05 max Mn 0.05 max Si 0.25 max Ti 0.03 max V 0.05 max Zn 0.05 max Other each 0.03 max                                                                                   |
| A91060                                                                 | Al 99.60 min Cu 0.05 max Fe 0.35 max Mg 0.03 max Mn 0.03 max Si 0.25 max Ti 0.03 max V 0.05 max Zn 0.05 max Other each 0.03 max<br>(Be 0.0008 max for welding electrode and filler metal only)                    |
| A91080                                                                 | Al 99.80 min Cu 0.03 max Fe 0.15 max Ga 0.03 max Mg 0.02 max Mn 0.02 max Si 0.15 max Ti 0.03 max V 0.03 max Zn 0.03 max<br>Other each 0.02 max                                                                    |
| A91100                                                                 | Al 99.00 min Cu 0.05-0.20 Mn 0.05 max Zn 0.10 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only),<br>total 0.15 max, Si+Fe 0.95 max                                               |
| A91145                                                                 | Al 99.45 min Cu 0.05 max Mg 0.05 max Mn 0.05 max Ti 0.03 max Zn 0.05 max Other each 0.03 max, Si+Fe 0.55 max                                                                                                      |
| A91188                                                                 | Al 99.88 min Cu 0.005 max Fe 0.06 max Ga 0.03 max Mg 0.01 max Mn 0.01 max Si 0.06 max Ti 0.01 max V 0.03 max Zn 0.03 max<br>Other each 0.01 max                                                                   |
| A91200                                                                 | Al 99.00 min Cu 0.05 max Mn 0.05 max Zn 0.10 max Other each 0.05 max, total 0.15 max, Si+Fe 1.0 max                                                                                                               |
| A91230                                                                 | Al 99.30 min Cu 0.10 max Mn 0.05 max Zn 0.10 max Other each 0.05 max, plus Si+Fe 0.7 max                                                                                                                          |
| A91235                                                                 | Al 99.35 min Cu 0.05 max Mg 0.05 max Mn 0.05 max Ti 0.03 max Zn 0.010 max Other each 0.03 max, Si+Fe 0.65 max                                                                                                     |
| A91350                                                                 | Al 99.50 min B 0.05 max Cr 0.01 max Cu 0.05 max Fe 0.40 max Mn 0.01 max Si 0.10 max Zn 0.05 max Other Gallium 0.03 max;<br>Vanadium + Titanium 0.02 max; other unspecified elements each 0.03 max, total 0.10 max |

| CHEMICAL COMPOSITIONS OF WROUGHT ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                                                                                                   |
|-------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                                     | Chemical Composition                                                                                                                                                                                                              |
| A91435                                                                  | Al 99.35 min Cu 0.02 max Fe 0.30-0.50 Mg 0.05 max Mn 0.05 max Si 0.15 max Ti 0.03 max Zn 0.10 max Other each 0.03 max                                                                                                             |
| A92004                                                                  | Al rem Cu 5.5-6.5 Fe 0.20 max, Mg 0.50 max Mn 0.10 max Si 0.20 max Ti 0.05 max Zn 0.10 max Zr 0.30-0.50 Other each 0.05 max, total 0.15 max                                                                                       |
| A92011                                                                  | Al rem Bi 0.20-0.6 Cu 5.0-6.0 Fe 0.7 max Pb 0.20-0.6 Si 0.40 max Zn 0.30 max Other each 0.05 max, total 0.15 max                                                                                                                  |
| A92014                                                                  | Al rem Cr 0.10 max Cu 3.9-5.0 Fe 0.7 max Mg 0.20-0.8 Mn 0.40-1.2 Si 0.50-1.2 Ti 0.15 max Zn 0.25 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler metal only), total 0.15 max, Ti+Zn 0.20 max              |
| A92017                                                                  | Al rem Cr 0.10 max Cu 3.5-4.5 Fe 0.7 max Mg 0.40-0.8 Mn 0.40-1.0 Si 0.8 max Zn 0.25 max Other each 0.05 max, total 0.15 max, Ti+Zn 0.20 max                                                                                       |
| A92018                                                                  | Al rem Cr 0.10 max Cu 3.5-4.5 Fe 1.0 max Mg 0.45-0.9 Mn 0.20 max Ni 1.7-2.3 Si 0.9 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                                            |
| A92024                                                                  | Al rem Cr 0.10 max Cu 3.8-4.9 Fe 0.50 max Mg 1.2-1.8 Mn 0.30-0.9 Si 0.50 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                                                      |
| A92025                                                                  | Al rem Cr 0.10 Cu 3.9-5.0 Fe 1.0 max Mg 0.05 max Mn 0.40-1.2 Si 0.50-1.2 Ti 0.15 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                                              |
| A92090                                                                  | Al rem Cr 0.05 max Cu 2.4-3.0 Fe 0.12 max Li 1.9-2.6 Mg 0.25 max Mn 0.05 max Si 0.10 max Ti 0.15 max Zn 0.10 max Zr 0.08-0.15 Other each 0.05 max, total 0.15 max                                                                 |
| A92117                                                                  | Al rem Cr 0.10 max Cu 2.2-3.0 Fe 0.7 max Mg 0.20-0.50 Mn 0.20 max Si 0.8 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                                                      |
| A92124                                                                  | Al rem Cr 0.10 max Cu 3.8-4.9 Fe 0.30 max Mg 1.2-1.8 Mn 0.30-0.90 Si 0.20 max Ti 0.15 max Zn 0.25 max Other each 0.05 max, total 0.15 max plus Ti+Zn 0.20 max                                                                     |
| A92218                                                                  | Al rem Cr 0.10 max Cu 3.5-4.5 Fe 1.0 max Mg 1.2-1.8 Mn 0.20 max Ni 1.7-2.3 Si 0.9 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                                             |
| A92219                                                                  | Al rem Cu 5.8-6.8 Fe 0.30 max Mg 0.02 max Mn 0.20-0.40 Si 0.20 max Ti 0.02-0.10 V 0.05-0.15 Zn 0.10 max Zr 0.10-0.25 Other each 0.05 max, total 0.15 max                                                                          |
| A92319                                                                  | Al rem Be 0.0008 max Cu 5.8-6.8 Fe 0.30 max Mg 0.02 max Mn 0.20-0.40 Si 0.20 max Ti 0.10-0.20 V 0.05-0.15 Zn 0.10 max Zr 0.10-0.25 Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max |
| A92618                                                                  | Al rem Cu 1.9-2.7 Fe 0.9-1.3 Mg 1.3-1.8 Ni 0.9-1.2 Si 0.25 max Ti 0.04-0.10 Other each 0.05 max, total 0.15 max                                                                                                                   |
| A93003                                                                  | Al rem Cu 0.05-0.20 Fe 0.7 max Mn 1.0-1.5 Si 0.6 max Zn 0.10 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max                                                                   |
| A93004                                                                  | Al rem Cu 0.25 max Fe 0.7 max Mg 0.8-1.3 Mn 1.0-1.5 Si 0.30 max Zn 0.25 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max                                                        |
| A93005                                                                  | Al rem Cr 0.10 max Cu 0.30 max Fe 0.7 max Mg 0.20-0.6 Mn 1.0-1.5 Si 0.6 max Ti 0.10 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                                           |
| A93102                                                                  | Al rem Cu 0.10 max Fe 0.7 max Mn 0.05-0.40 Si 0.40 max Ti 0.10 max Zn 0.30 max Other each 0.05 max, total 0.15 max                                                                                                                |

| CHEMICAL COMPOSITIONS OF WROUGHT ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                                                               |
|-------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                                     | Chemical Composition                                                                                                                                                                          |
| A93105                                                                  | Al rem Cr 0.20 max Cu 0.30 max Fe 0.7 max Mg 0.20-0.8 Mn 0.30-0.8 Si 0.6 max Ti 0.10 max Zn 0.40 max Other each 0.05 max, total 0.15 max                                                      |
| A93303                                                                  | Al rem Cu 0.05-0.20 Fe 0.7 max Mn 1.0-1.5 Si 0.6 max Zn 0.30 max Other each 0.05 max, total 0.15 max                                                                                          |
| A94004                                                                  | Al rem Cu 0.25 max Fe 0.8 max Mg 1.0-2.0 Mn 0.10 max Si 9.0-10.5 Zn 0.20 max Other each 0.05 max, total 0.15 max                                                                              |
| A94008                                                                  | Al rem Be 0.0008 max Cu 0.05 max Fe 0.09 max Mg 0.30-0.45 Mn 0.05 max Si 6.5-7.5 Ti 0.04-0.15 Zn 0.05 max Other each 0.05 max, total 0.15 max                                                 |
| A94011                                                                  | Al rem Cu 0.20 max Fe 0.20 max Mg 0.45-0.7 Mn 0.10 max Si 6.5-7.5 Ti 0.20 max Zn 0.10 max Other each 0.05 max, total 0.15 max;<br>Be 0.0008 for welding electrode and filler wire             |
| A94032                                                                  | Al rem Cr 0.10 max Cu 0.50-1.3 Fe 1.0 max Mg 0.8-1.3 Ni 0.50-1.3 Si 11.0-13.5 Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                 |
| A94043                                                                  | Al rem Cu 0.30 max Fe 0.8 max Mg 0.05 max Mn 0.05 max Si 4.5-6.0 Ti 0.20 max Zn 0.10 max Other each 0.05 max<br>(Be 0.0008 max for welding electrode and filler wire only), total 0.15 max    |
| A94045                                                                  | Al rem Cu 0.30 max Fe 0.8 max Mg 0.05 max Mn 0.05 max Si 9.0-11.0 Ti 0.20 max Zn 0.10 max Other each 0.05 max, total 0.15 max                                                                 |
| A94047                                                                  | Al rem Cu 0.30 max Fe 0.8 max Mg 0.10 max Mn 0.15 max Si 11.0-13.0 Zn 0.20 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max                 |
| A94104                                                                  | Al rem Bi 0.02-0.20 Cu 0.25 max Fe 0.8 max Mg 1.0-2.0 Mn 0.10 max Si 9.5-10.5 Zn 0.20 max Other each 0.05 max, total 0.15 max                                                                 |
| A94145                                                                  | Al rem Cr 0.15 max Cu 3.3-4.7 Fe 0.8 max Mg 0.15 max Mn 0.15 max Si 9.3-10.7 Zn 0.20 max Other each 0.05 max<br>(Be 0.0008 max for welding electrode and filler wire only), total 0.15 max    |
| A94147                                                                  | Al rem Be 0.0008 max Cu 0.25 max Fe 0.8 max Mg 0.10-0.50 Mn 0.10 max Si 11.0-13.0 Zn 0.20 max Other 0.05 max each, 0.15 max total                                                             |
| A94343                                                                  | Al rem Cu 0.25 max Fe 0.8 max Mn 0.10 max Si 6.8-8.2 Zn 0.20 max Other each 0.05 max, total 0.15 max                                                                                          |
| A94643                                                                  | Al rem Be 0.0008 max Cu 0.10 max Fe 0.8 max Mg 0.10-0.30 Mn 0.05 max Si 3.6-4.6 Ti 0.15 max Zn 0.10 max Other each 0.05 max, total 0.15 max                                                   |
| A95005                                                                  | Al rem Cr 0.10 max Cu 0.20 max Fe 0.7 max Mg 0.50-1.1 Mn 0.20 max Si 0.40 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                 |
| A95010                                                                  | Al rem Cr 0.15 max Cu 0.25 max Fe 0.7 max Mg 0.20-0.6 Mn 0.10-0.30 Si 0.40 max Ti 0.10 max Zn 0.30 max Other each 0.05 max, total 0.15 max                                                    |
| A95050                                                                  | Al rem Cr 0.10 max Cu 0.20 max Fe 0.7 max Mg 1.1-1.8 Mn 0.10 max Si 0.40 max Zn 0.25 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max       |
| A95052                                                                  | Al rem Cr 0.15-0.35 Cu 0.10 max Mg 2.2-2.8 Mn 0.10 max Zn 0.10 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max, plus Si+Fe 0.45 max        |
| A95056                                                                  | Al rem Cr 0.05-0.20 Cu 0.10 max Fe 0.40 max Mg 4.5-5.6 Mn 0.05-0.20 Si 0.30 max Zn 0.10 max Other each 0.05 max<br>(Be 0.0008 max for welding electrode and filler wire only), total 0.15 max |

| CHEMICAL COMPOSITIONS OF WROUGHT ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                                                                                                  |
|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                                     | Chemical Composition                                                                                                                                                                                                             |
| A95083                                                                  | Al rem Cr 0.05-0.25 Cu 0.10 max Fe 0.40 max Mg 4.0-4.9 Mn 0.40-1.0 Si 0.40 max Ti 0.15 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                                       |
| A95086                                                                  | Al rem Cr 0.05-0.25 Cu 0.10 max Fe 0.50 max Mg 3.5-4.5 Mn 0.20-0.7 Si 0.40 max Ti 0.15 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                                       |
| A95154                                                                  | Al rem Cr 0.15-0.35 Cu 0.10 max Fe 0.40 max Mg 3.1-3.9 Mn 0.10 max Si 0.25 max Ti 0.20 max Zn 0.20 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max                            |
| A95183                                                                  | Al rem Be 0.0008 max Cr 0.05-0.25 Cu 0.10 max Fe 0.40 max Mg 4.3-5.2 Mn 0.50-1.0 Si 0.40 max Ti 0.15 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                         |
| A95252                                                                  | Al rem Cu 0.10 max Fe 0.10 max Mg 2.2-2.8 Mn 0.10 max Si 0.08 max Other each 0.03 max, total 0.10 max                                                                                                                            |
| A95254                                                                  | Al rem Cr 0.15-0.35 Cu 0.05 max Fe 0.40 max Mg 3.1-3.9 Mn 0.01 max Si 0.25 max Ti 0.05 max Zn 0.20 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max                            |
| A95356                                                                  | Al rem Cr 0.05-0.20 Cu 0.10 max Fe 0.40 max Mg 4.5-5.5 Mn 0.05-0.20 Si 0.25 max Ti 0.06-0.20 Si 0.25 max Ti 0.06-0.20 Zn 0.10 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max |
| A95454                                                                  | Al rem Cr 0.05-0.20 Cu 0.10 max Mg 2.4-3.0 Mn 0.50-1.0 Ti 0.20 max Zn 0.25 max Other each 0.05 max, total 0.15 max, Si+Fe 0.40 max                                                                                               |
| A95457                                                                  | Al rem Cu 0.20 max Fe 0.10 max Mg 0.8-1.2 Mn 0.15-0.45 Si 0.08 max Zn 0.03 max Other each 0.03 max, total 0.10 max                                                                                                               |
| A95554                                                                  | Al rem Be 0.0008 max Cr 0.05-0.20 Cu 0.10 max Fe 0.40 max Mg 2.4-3.0 Mn 0.50-1.0 Si 0.25 max Ti 0.05-0.20 Zn 0.25 max Other each 0.05 max, total 0.15 max, Si+Fe 0.40 max                                                        |
| A95556                                                                  | Al rem Be 0.0008 max Cr 0.05-0.20 Cu 0.10 max Fe 0.40 max Mg 4.7-5.5 Mn 0.50-1.0 Si 0.25 max Ti 0.05-0.20 Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                        |
| A95652                                                                  | Al rem Cr 0.15-0.35 Cu 0.04 max Mg 2.2-2.8 Mn 0.01 max Zn 0.10 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max, Si+Fe 0.40 max                                                |
| A95654                                                                  | Al rem Be 0.0008 max Cr 0.15-0.35 Cu 0.05 max Mg 3.1-3.9 Mn 0.01 max Ti 0.05-0.15 Zn 0.20 max Other each 0.05 max, total 0.15 max, Si+Fe 0.45 max                                                                                |
| A95657                                                                  | Al rem Cu 0.10 max Fe 0.10 max Ga 0.03 max Mg 0.6-1.0 Mn 0.03 max Si 0.08 max Zn 0.03 max Other 0.02 max, total 0.05 max                                                                                                         |
| A96003                                                                  | Al rem Cr 0.35 max Cu 0.10 max Fe 0.06 max Mg 0.8-1.5 Mn 0.8 max Si 0.35-1.0 Ti 0.10 max Zn 0.20 max                                                                                                                             |
| A96005                                                                  | Al rem Cr 0.10 max Cu 0.10 max Fe 0.35 max Mg 0.40-0.6 Mn 0.10 max Si 0.6-0.9 Ti 0.10 max Zn 0.10 max Other each 0.05 max, total 0.15 max                                                                                        |
| A96013                                                                  | Al rem Cr 0.10 max Cu 0.6-1.1 Fe 0.50 max Mg 0.8-1.2 Mn 0.20-0.8 Si 0.6-1.0 Ti 0.10 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                                          |
| A96053                                                                  | Al rem Cr 0.15-0.35 Cu 0.10 max Fe 0.35 max Mg 1.1-1.4 Si 45.0-65.0 of Mg Zn 0.10 max Other each 0.05 max, total 0.15 max                                                                                                        |
| A96060                                                                  | Al rem Cr 0.05 max Cu 0.10 max Fe 0.10-0.30 Mg 0.35-0.6 Mn 0.10 max Si 0.30-0.6 Ti 0.10 max Zn 0.15 max Other each 0.05 max, total 0.15 max                                                                                      |

| CHEMICAL COMPOSITIONS OF WROUGHT ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                                       |
|-------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                                     | Chemical Composition                                                                                                                                                  |
| A96061                                                                  | Al rem Cr 0.04-0.35 Cu 0.15-0.40 Fe 0.7 max Mg 0.8-1.2 Mn 0.15 max Si 0.40-0.8 Ti-0.15 max Zn 0.25 max Other each 0.05 max, total 0.15 max                            |
| A96063                                                                  | Al rem Cr 0.10 max Cu 0.10 max Fe 0.35 max Mg 0.45-0.9 Mn 0.10 max Si 0.20-0.6 Ti 0.10 max Zn 0.10 max Other each 0.05 max, total 0.15 max                            |
| A96066                                                                  | Al rem Cr 0.40 max Cu 0.7-1.2 Mg 0.8-1.4 Mn 0.6-1.1 Pb 0.50 max Si 0.9-1.8 Ti 0.20 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                |
| A96070                                                                  | Al rem Cr 0.10 max Cu 0.15-0.40 Fe 0.50 max Mg 0.50-1.2 Mn 0.40-1.0 Si 1.0-1.7 Ti 0.15 max Zn 0.25 max Other each 0.05 max, total 0.15 max                            |
| A96101                                                                  | Al rem B 0.06 max Cr 0.03 max Cu 0.10 max Fe 0.50 max Mg 0.35-0.8 Mn 0.03 max Si 0.30-0.7 Zn 0.10 max Other each 0.03 max, total 0.10 max                             |
| A96105                                                                  | Al rem Cr 0.10 max Cu 0.10 max Fe 0.35 max Mg 0.45-0.8 Mn 0.10 max Si 0.6-1.0 Ti 0.10 max Zn 0.10 max Other each 0.05 max, total 0.15 max                             |
| A96110                                                                  | Al rem Cr 0.04-0.25 Cu 0.20-0.7 Fe 0.8 max Mg 0.50-1.1 Mn 0.20-0.7 Si 0.7-1.5 Ti 0.15 max Zn 0.30 max Other each 0.05 max, total 0.15 max                             |
| A96151                                                                  | Al rem Cr 0.15-0.35 Cu 0.35 max Fe 1.0 max Mg 0.45-0.8 Mn 0.20 max Si 0.6-1.2 Ti 0.15 max Zn 0.25 max Other each 0.05 max, total 0.15 max                             |
| A96201                                                                  | Al rem B 0.06 max Cr 0.03 max Cu 0.10 max Fe 0.50 max Mg 0.6-0.9 Mn 0.03 max Si 0.50-0.9 Zn 0.10 max Other each 0.03 max, total 0.10 max                              |
| A96253                                                                  | Al rem Cr 0.15-0.35 Cu 0.10 max Fe 0.50 max Mg 1.0-1.5 Si 45.0-65.0 of Mg Zn 1.6-2.4 Other each 0.05 max, total 0.15 max                                              |
| A96262                                                                  | Al rem Bi 0.40-0.7 Cr 0.04-0.14 Cu 0.15-0.40 Fe 0.7 max Mg 0.8-1.2 Mn 0.15 max Pb 0.40-0.7 Si 0.40-0.8 Ti 0.15 max Zn 0.25 max<br>Other each 0.05 max, total 0.15 max |
| A96351                                                                  | Al rem Cu 0.10 max Fe 0.50 max Mg 0.40-0.8 Mn 0.40-0.8 Si 0.7-1.3 Ti - 0.20 max Zn 0.20 max Other each 0.05 max, total 0.15 max                                       |
| A96463                                                                  | Al rem Cu 0.20 max Fe 0.15 max Mg 0.45-0.9 Mn 0.05 max Si 0.20-0.6 Other each 0.05 max, total 0.15 max                                                                |
| A97001                                                                  | Al rem Cr 0.18-0.35 Cu 1.6-2.6 Fe 0.40 max Mg 2.6-3.4 Mn 0.20 max Si 0.35 max Ti 0.20 max Zn 6.8-8.0 Other each 0.05 max, total 0.15 max                              |
| A97005                                                                  | Al rem Cr 0.06-0.20 Cu 0.10 max Fe 0.40 max Mg 1.0-1.8 Mn 0.20-0.7 Si 0.35 max Ti 0.01-0.06 Zn 4.0-5.0 Zr 0.08-0.20 Other each 0.05 max,<br>total 0.15 max            |
| A97008                                                                  | Al rem Cr 0.12-0.25 Cu 0.05 max Fe 0.10 max Mg 0.7-1.4 Mn 0.05 max Si 0.10 max Ti 0.05 max Zn 4.5-5.5 Other each 0.05 max, total 0.10 max                             |
| A97010                                                                  | Al rem Cr 0.05 max Cu 1.5-2.0 Fe 0.15 max Mg 2.1-2.6 Mn 0.10 max Si 0.12 max Ti 0.6 max Zn 5.7-6.7 Zr 0.10-0.16 Other each 0.05 max,<br>total 0.15 max                |
| A97039                                                                  | Al rem Cr 0.15-0.25 Cu 0.10 max Fe 0.40 max Mg 2.3-3.3 Mn 0.10-0.40 Si 0.30 max Ti 0.10 max Zn 3.5-4.5 Other each 0.05 max, total 0.15 max                            |
| A97049                                                                  | Al rem Cr 0.10-0.22 Cu 1.2-1.9 Fe 0.35 max Mg 2.0-2.9 Mn 0.20 max Si 0.25 max Ti 0.10 max Zn 7.2-8.2 Other each 0.05 max, total 0.15 max                              |
| A97050                                                                  | Al rem Cr 0.04 max Cu 2.0-2.6 Fe 0.15 max Mg 1.9-2.6 Mn 0.10 max Si 0.12 max Ti 0.06 max Zn 5.7-6.7 Zr 0.08-0.15 Other each 0.05 max,<br>total 0.15 max               |
| A97072                                                                  | Al rem Cu 0.10 max Mg 0.10 max Mn 0.10 max Zn 0.8-1.3 Other each 0.05 max, total 0.15 max Si+Fe 0.7 max                                                               |
| A97075                                                                  | Al rem Cr 0.18-0.28 Cu 1.2-2.0 Fe 0.50 max Mg 2.1-2.9 Mn 0.30 max Si 0.40 max Ti 0.20 max Zn 5.1-6.1 Other each 0.05 max, total 0.15 max                              |
| A97076                                                                  | Al rem Cu 0.30-1.0 Fe 0.6 max Mg 1.2-2.0 Mn 0.30-0.8 Si 0.40 max Ti 0.20 max Zn 7.0-8.0 Other each 0.05 max, total 0.15 max                                           |

| CHEMICAL COMPOSITIONS OF WROUGHT ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                      |
|-------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                                     | Chemical Composition                                                                                                                                 |
| A97116                                                                  | Al rem Cu 0.50-1.1 Fe 0.30 max Ga 0.03 max Mg 0.8-1.4 Mn 0.05 max Si 0.15 max Ti 0.05 max V 0.05 max Zn 4.2-5.2 Other each 0.05 max, total 0.15 max  |
| A97149                                                                  | Al rem Cr 0.10-0.22 Cu 1.2-1.9 Fe 0.20 max Mg 2.0-2.9 Mn 0.20 max Si 0.15 max Ti 0.10 max Zn 7.2-8.2 Other each 0.05 max, total 0.15 max             |
| A97150                                                                  | Al rem Cr 0.04 max Cu 1.9-2.5 Fe 0.15 max Mg 2.0-2.7 Mn 0.10 max Si 0.12 max Ti 0.06 max Zn 5.9-6.9 Zr 0.08-0.15 Other each 0.05 max, total 0.15 max |
| A97175                                                                  | Al rem Cr 0.18-0.28 Cu 1.2-2.0 Fe 0.20 max Mg 2.1-2.9 Mn 0.10 max Si 0.15 max Ti 0.10 max Zn 5.1-6.1 Other each 0.05 max, total 0.15 max             |
| A97178                                                                  | Al rem Cr 0.18-0.35 Cu 1.6-2.4 Fe 0.50 max Mg 2.4-3.1 Mn 0.30 max Si 0.40 max Ti 0.20 max Zn 6.3-7.3 Other each 0.05 max, total 0.15 max             |
| A97277                                                                  | Al rem Cr 0.18-0.35 Cu 0.8-1.7 Fe 0.7 max Mg 1.7-2.3 Si 0.50 max Ti 0.10 max Zn 3.7-4.3 Other each 0.05 max, total 0.15 max                          |
| A97475                                                                  | Al rem Cr 0.18-0.25 Cu 1.2-1.9 Fe 0.12 max Mg 1.9-2.6 Mn 0.06 max Si 0.10 max Ti 0.06 max Zn 5.2-6.2 Other each 0.05 max, total 0.15 max             |
| A98017                                                                  | Al rem B 0.04 max Cu 0.10-0.20 Fe 0.55-0.8 Li 0.003 max Mg 0.01-0.05 Si 0.10 max Zn 0.05 max Other each 0.03 max, total 0.10 max                     |
| A98030                                                                  | Al rem B 0.001-0.04 Cu 0.15-0.30 Fe 0.30-0.8 Mg 0.05 max Si 0.10 max Zn 0.05 max Other each 0.03 max, total 0.10 max                                 |
| A98076                                                                  | Al rem B 0.04 max Cu 0.04 max Fe 0.6-0.9 Mg 0.08-0.22 Si 0.10 max Zn 0.05 max Other each 0.03 max, total 0.10 max                                    |
| A98079                                                                  | Al rem Cu 0.05 max Fe 0.7-1.3 Si 0.05-0.30 Zn 0.10 max Other each 0.05 max, total 0.15 max                                                           |
| A98111                                                                  | Al rem Cr 0.05 Cu 0.10 Fe 0.40-1.0 Mg 0.05 Mn 0.10 Si 0.30-1.1 Ti 0.08 Zn 0.10 Other each 0.05, total 0.15                                           |
| A98130                                                                  | Al rem Cu 0.05-0.15 Fe 0.40-1.0 Si 0.15 max Zn 0.10 max Other each 0.03 max, total 0.10 max                                                          |
| A98176                                                                  | Al rem Fe 0.40-1.0 Ga 0.03 max Si 0.03-0.15 Zn 0.10 max Other each 0.05 max, total 0.15 max                                                          |
| A98177                                                                  | Al rem B 0.04 Cu 0.04 Fe 0.25-0.45 Mg 0.04-0.12 Si 0.10 Zn 0.05 Other each 0.03, total 0.10                                                          |
| A98280                                                                  | Al rem Cu 0.7-1.3 Fe 0.7 max Ni 0.20-0.7 Si 1.0-2.0 Sn 5.5-7.0 Ti 0.10 max Other each 0.05 max, total 0.15 max                                       |

rem - remainder; nom - nominal

| CHEMICAL COMPOSITIONS OF CAST ALUMINUM & ALUMINUM ALLOYS |                                                                                                                                                         |
|----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                      | Title                                                                                                                                                   |
| A02010                                                   | Ag 0.40-1.2 Al rem Cu 4.0-5.2 Fe 0.15 max Mg 0.15-0.55 Mn 0.20-0.50 Si 0.10 max Ti 0.15-0.35 Other each 0.05 max, total 0.10 max                        |
| A02040                                                   | Al rem Cu 4.2-5.0 Fe 0.35 max Mg 0.15-0.35 Mn 0.10 max Ni 0.05 max Si 0.20 max Sn 0.05 max Ti 0.15-0.30 Zn 0.10 max Other each 0.05 max, total 0.15 max |
| A02080                                                   | Al rem Cu 3.5-4.5 Fe 1.2 max Mg 0.10 max Mn 0.50 max Ni 0.35 max Si 2.5-3.5 Ti 0.25 max Zn 1.0 max Other total 0.50 max                                 |

| CHEMICAL COMPOSITIONS OF CAST ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                                                                          |
|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                                  | Title                                                                                                                                                                                                    |
| A02220                                                               | Al rem Cu 9.2-10.7 Fe 1.5 max Mg 0.15-0.35 Mn 0.50 max Ni 0.50 max Si 2.0 max Ti 0.25 max Zn 0.8 max Other total 0.35 max                                                                                |
| A02420                                                               | Al rem Cr 0.25 max Cu 3.5-4.5 Fe 1.0 max Mg 1.2-1.8 Mn 0.35 max Ni 1.7-2.3 Si 0.7 max Ti 0.25 max Zn 0.35 max Other each 0.05 max, total 0.15 max                                                        |
| A02950                                                               | Al rem Cu 4.0-5.0 Fe 1.0 max Mg 0.03 max Mn 0.35 max Si 0.7-1.5 Ti 0.25 max Zn 0.35 max Other each 0.05 max, total 0.15 max                                                                              |
| A03190                                                               | Al rem Cu 3.0-4.0 Fe 1.0 max Mg 0.10 max Mn 0.50 max Ni 0.35 max Si 5.5-6.5 Ti 0.25 max Zn 1.0 max Other total 0.50 max                                                                                  |
| A03280                                                               | Al rem Cr 0.35 max Cu 1.0-2.0 Fe 1.0 max Mg 0.20-0.6 Mn 0.20-0.6 Ni 0.25 max Si 7.5-8.5 Ti 0.25 max Zn 1.5 max Other total 0.50 max                                                                      |
| A03320                                                               | Al rem Cu 2.0-4.0 Fe 1.2 max Mg 0.50-1.5 Mn 0.50 max Ni 0.50 max Si 8.5-10.5 Ti 0.25 max Zn 1.0 max Other total 0.50 max                                                                                 |
| A03330                                                               | Al rem Cu 3.0-4.0 Fe 1.0 max Mg 0.05-0.50 Mn 0.50 max Ni 0.50 max Si 8.0-10.0 Ti 0.25 max Zn 1.0 max Other total 0.50 max                                                                                |
| A03360                                                               | Al rem Cu 0.5-1.5 Fe 1.2 max Mg 0.7-1.3 Mn 0.35 max Ni 2.0-3.0 Si 11.0-13.0 Ti 0.25 max Zn 0.35 max Other each 0.05 max                                                                                  |
| A03540                                                               | Al rem Cu 1.6-2.0 Fe 0.20 max Mg 0.40-0.6 Mn 0.10 max Si 8.6-9.4 Ti 0.20 max Zn 0.10 max Other each 0.05 max, total 0.15 max                                                                             |
| A03550                                                               | Al rem Cr 0.25 max Cu 1.0-1.5 Fe 0.6 max Mg 0.40-0.6 Mn 0.50 max Si 4.5-5.5 Ti 0.25 max Zn 0.35 max Other each 0.05 max, total 0.15 max.<br>Note: If Fe exceeds 0.45, Mn shall not be less than 0.5 x Fe |
| A03560                                                               | Al rem Cu 0.25 max Fe 0.6 max Mg 0.20-0.45 Mn 0.35 max Si 6.5-7.5 Ti 0.25 max Zn 0.35 max Other each 0.05 max, total 0.15 max                                                                            |
| A03570                                                               | Al rem Cu 0.05 max Fe 0.15 max Mg 0.45-0.6 Mn 0.03 max Si 6.5-7.5 Ti 0.20 max Zn 0.05 max Other each 0.05 max, total 0.15 max                                                                            |
| A03590                                                               | Al rem Cu 0.20 max Fe 0.20 max Mg 0.50-0.7 Mn 0.10 max Si 8.5-9.5 Ti 0.20 max Zn 0.10 max Other each 0.05 max, total 0.15 max                                                                            |
| A03600                                                               | Al rem Cu 0.6 max Fe 2.0 max Mg 0.40-0.6 Mn 0.35 max Ni 0.50 max Si 9.0-10.0 Sn 0.15 max Zn 0.50 max Other total 0.25 max                                                                                |
| A04130                                                               | Al rem Cu 0.6 max Fe 2.0 max Mg 0.10 max Mn 0.35 max Ni 0.50 max Si 11.0-13.0 Sn 0.15 max Zn 0.50 max Other total 0.25 max                                                                               |
| A04430                                                               | Al rem Cr 0.25 max Cu 0.6 max Fe 0.8 max Mg 0.05 max Mn 0.50 max Si 4.5-6.0 Ti 0.25 max Zn 0.50 max Other total 0.35 max                                                                                 |
| A05120                                                               | Al rem Cr 0.25 max Cu 0.35 max Fe 0.6 max Mg 3.5-4.5 Mn 0.8 max Si 1.4-2.2 Ti 0.25 max Zn 0.35 max Other each 0.05 max, total 0.15 max                                                                   |
| A05130                                                               | Al rem Cu 0.10 max Fe 0.40 max Mg 3.5-4.5 Mn 0.30 max Si 0.30 max Ti 0.20 max Zn 1.4-2.2 Other each 0.05 max, total 0.15 max                                                                             |
| A05140                                                               | Al rem Cu 0.15 max Fe 0.50 max Mg 3.5-4.5 Mn 0.35 max Si 0.35 max Ti 0.25 max Zn 0.15 max Other each 0.05 max, total 0.15 max                                                                            |
| A05180                                                               | Al rem Cu 0.25 max Fe 1.8 max Mg 7.5-8.5 Mn 0.35 max Ni 0.15 max Si 0.35 max Sn 0.15 max Zn 0.15 max Other total 0.25 max                                                                                |
| A05200                                                               | Al rem Cu 0.25 max Fe 0.30 max Mg 9.5-10.6 Mn 0.15 max Si 0.25 max Ti 0.25 max Zn 0.15 max Other each 0.05 max, total 0.15 max                                                                           |
| A05350                                                               | Al rem B 0.005 max Be 0.003-0.007 Cu 0.05 max Fe 0.15 max Mg 6.2-7.5 Mn 0.10-0.25 Si 0.15 max Ti 0.10-0.25 Other each 0.05 max, total 0.15 max                                                           |
| A07050                                                               | Al rem Cr 0.20-0.40 Cu 0.20 max Fe 0.8 max Mg 1.4-1.8 Mn 0.40-0.6 Si 0.20 max Ti 0.25 max Zn 2.7-3.3 Other each 0.05 max, total 0.15 max                                                                 |
| A07051                                                               | Al rem Cr 0.20-0.40 Cu 0.20 max Fe 0.6 max Mg 1.5-1.8 Mn 0.40-0.6 Si 0.20 max Ti 0.25 max Zn 2.7-3.3 Other each 0.05 max, total 0.15 max                                                                 |



| CHEMICAL COMPOSITIONS OF CAST ALUMINUM & ALUMINUM ALLOYS (Continued) |                                                                                                                                                      |
|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                                  | Title                                                                                                                                                |
| A07070                                                               | Al rem Cr 0.20-0.40 Cu 0.20 max Fe 0.8 max Mg 1.8-2.4 Mn 0.40-0.6 Si 0.20 max Ti 0.25 max Zn 4.0-4.5 Other 0.05 max, total 0.15 max                  |
| A07100                                                               | Al rem Cu 0.35-0.65 Fe 0.50 max Mg 0.6-0.8 Mn 0.05 max Si 0.15 max Ti 0.25 max Zn 6.0-7.0 Other each 0.05 max, total 0.15 max                        |
| A07110                                                               | Al rem Cu 0.35-0.65 Fe 0.7-1.4 Mg 0.25-0.45 Mn 0.5 max Si 0.30 max Ti 0.20 max Zn 6.0-7.0 Other each 0.05 max, total 0.15 max                        |
| A07120                                                               | Al rem Cr 0.40-0.6 Cu 0.25 max Fe 0.50 max Mg 0.50-0.65 Mn 0.10 max Si 0.30 max Ti 0.15-0.25 Zn 5.0-6.5 Other each 0.05 max, total 0.20 max          |
| A07130                                                               | Al rem Cr 0.35 max Cu 0.40-1.0 Fe 1.1 max Mg 0.20-0.50 Mn 0.6 max Ni 0.15 max Si 0.25 max Ti 0.25 max Zn 7.0-8.0 Other each 0.10 max, total 0.25 max |
| A07710                                                               | Al rem Cr 0.06-0.20 Cu 0.10 max Fe 0.15 max Mg 0.8-1.0 Mn 0.10 max Si 0.15 max Ti 0.10-0.20 Zn 6.5-7.5 Other each 0.05 max, total 0.15 max           |
| A08500                                                               | Al rem Cu 0.7-1.3 Fe 0.7 max Mg 0.10 max Mn 0.10 max Ni 0.7-1.3 Si 0.7 max Sn 5.5-7.0 Ti 0.20 max Other total 0.30 max                               |
| A08510                                                               | Al rem Cu 0.7-1.3 Fe 0.7 max Mg 0.10 max Mn 0.10 max Ni 0.30-0.7 Si 2.0-3.0 Sn 5.5-7.0 Ti 0.20 max Other total 0.30 max                              |
| A08520                                                               | Al rem Cu 1.7-2.3 Fe 0.7 max Mg 0.6-0.9 Mn 0.10 max Ni 0.9-1.5 Si 0.40 max Sn 5.5-7.0 Ti 0.20 max Other total 0.30 max                               |
| A12010                                                               | Ag 0.40-1.0 Al rem Cu 4.0-5.0 Fe 0.10 max Mg 0.15-0.35 Mn 0.20-0.40 Si 0.05 max Ti 0.15-0.35 Other each 0.03 max, total 0.10 max                     |
| A12420                                                               | Al rem Cr 0.15-0.25 Cu 3.7-4.5 Fe 0.8 max Mg 1.2-1.7 Mn 0.10 max Ni 1.8-2.3 Si 0.6 max Ti 0.07-0.20 Zn 0.10 max Other each 0.05 max, total 0.15 max  |
| A13560                                                               | Al rem Cu 0.20 max Fe 0.20 max Mg 0.20-0.40 Mn 0.10 max Si 6.5-7.5 Ti 0.20 max Zn 0.10 max Other each 0.05 max, total 0.15 max                       |
| A13570                                                               | Al rem Be 0.04-0.07 Cu 0.20 max Fe 0.20 max Mg 0.40-0.7 Mn 0.10 max Si 6.5-7.5 Ti 0.10-0.20 Zn 0.10 max Other each 0.05 max, total 0.15 max          |
| A13600                                                               | Al rem Cu 0.6 max Fe 1.3 max Mg 0.40-0.6 Mn 0.35 max Ni 0.50 max Si 9.0-10.0 Sn 0.15 max Zn 0.50 max Other total 0.25 max                            |
| A13800                                                               | Al rem Cu 3.0-4.0 Fe 1.3 max Mg 0.10 max Mn 0.50 max Ni 0.50 max Si 7.5-9.5 Sn 0.35 max Zn 3.0 max Other total 0.50 max                              |
| A14130                                                               | Al rem Cu 0.6 max Fe 1.3 max Mg 0.10 max Mn 0.35 max Ni 0.50 max Si 11.0-13.0 Sn 0.15 max Zn 0.50 max Other total 0.25 max                           |
| A14440                                                               | Al rem Cu 0.10 max Fe 0.20 max Mg 0.05 max Mn 0.10 max Si 6.5-7.5 Ti 0.20 max Zn 0.10 max Other each 0.05 max, total 0.15 max                        |
| A23900                                                               | Al rem Cu 4.0-5.0 Fe 0.50 max Mg 0.45-0.65 Mn 0.50 max Ni 0.10 max Si 16.0-18.0 Ti 0.20 max Zn 1.5 max Other each 0.10 max, total 0.20 max           |
| A24430                                                               | Al rem Cu 0.15 max Fe 0.8 max Mg 0.05 max Mn 0.35 max Si 4.5-6.0 Ti 0.25 max Zn 0.35 max Other each 0.05 max, total 0.15 max                         |
| A33550                                                               | Al rem Cu 1.0-1.5 Fe 0.20 max Mg 0.40-0.6 Mn 0.10 max Si 4.5-5.5 Ti 0.20 max Zn 0.10 max Other each 0.05 max, total 0.15 max                         |
| A34430                                                               | Al rem Cu 0.6 max Fe 2.0 max Mg 0.10 max Mn 0.35 max Ni 0.50 max Si 4.5-6.0 Sn 0.15 max Zn 0.50 max Other total 0.25 max                             |

rem - remainder; nom - nominal

| CHEMICAL COMPOSITION OF AWS ALUMINUM ELECTRODE & ROD FILLER METAL |        |                                                                                                                                                                                                                                   |
|-------------------------------------------------------------------|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A5.3                                                              | UNS    | Chemical Composition                                                                                                                                                                                                              |
| E1100                                                             | A91100 | Al 99.00 min Cu 0.05-0.20 Mn 0.05 max Zn 0.10 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max, Si+Fe 0.95 max                                                                  |
| E3003                                                             | A93003 | Al rem Cu 0.05-0.20 Fe 0.7 max Mn 1.0-1.5 Si 0.6 max Zn 0.10 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max                                                                   |
| E4043                                                             | A94043 | Al rem Cu 0.30 max Fe 0.8 max Mg 0.05 max Mn 0.05 max Si 4.5-6.0 Ti 0.20 max Zn 0.10 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max                                           |
| A5.10                                                             | UNS    | Chemical Composition                                                                                                                                                                                                              |
| ER1100<br>R1100                                                   | A91100 | Al 99.00 min Cu 0.05-0.20 Mn 0.05 max Zn 0.10 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max, Si+Fe 0.95 max                                                                  |
| ER1188<br>R1188                                                   | A91188 | Al 99.88 min Cu 0.005 max Fe 0.06 max Ga 0.03 max Mg 0.01 max Mn 0.01 max Si 0.06 max Ti 0.01 max V 0.03 max Zn 0.03 max Other each 0.01 max                                                                                      |
| ER2319<br>R2319                                                   | A92319 | Al rem Be 0.0008 max Cu 5.8-6.8 Fe 0.30 max Mg 0.02 max Mn 0.20-0.40 Si 0.20 max Ti 0.10-0.20 V 0.05-0.15 Zn 0.10 max Zr 0.10-0.25 Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max |
| ER4043<br>R4043                                                   | A94043 | Al rem Cu 0.30 max Fe 0.8 max Mg 0.05 max Mn 0.05 max Si 4.5-6.0 Ti 0.20 max Zn 0.10 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max                                           |
| ER4047<br>R4047                                                   | A94047 | Al rem Cu 0.30 max Fe 0.8 max Mg 0.10 max Mn 0.15 max Si 11.0-13.0 Zn 0.20 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max                                                     |
| ER4145<br>R4145                                                   | A94145 | Al rem Cr 0.15 max Cu 3.3-4.7 Fe 0.8 max Mg 0.15 max Mn 0.15 max Si 9.3-10.7 Zn 0.20 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max                                           |
| ER4643<br>R4643                                                   | A94643 | Al rem Be 0.0008 max Cu 0.10 max Fe 0.8 max Mg 0.10-0.30 Mn 0.05 max Si 3.6-4.6 Ti 0.15 max Zn 0.10 max Other each 0.05 max, total 0.15 max                                                                                       |
| ER5183<br>R5183                                                   | A95183 | Al rem Be 0.0008 max Cr 0.05-0.25 Cu 0.10 max Fe 0.40 max Mg 4.3-5.2 Mn 0.50-1.0 Si 0.40 max Ti 0.15 max Zn 0.25 max Other each 0.05 max, total 0.15 max                                                                          |
| ER5356<br>R5356                                                   | A95356 | Al rem Cr 0.05-0.20 Cu 0.10 max Fe 0.40 max Mg 4.5-5.5 Mn 0.05-0.20 Si 0.25 max Ti 0.06-0.20 Si 0.25 max Ti 0.06-0.20 Zn 0.10 max Other each 0.05 max (Be 0.0008 max for welding electrode and filler wire only), total 0.15 max  |
| ER5554<br>R5554                                                   | A95554 | Al rem Be 0.0008 max Cr 0.05-0.20 Cu 0.10 max Fe 0.40 max Mg 2.4-3.0 Mn 0.50-1.0 Si 0.25 max Ti 0.05-0.20 Zn 0.25 max Other each 0.05 max, total 0.15 max, Si+Fe 0.40 max                                                         |

| <b>CHEMICAL COMPOSITION OF AWS ALUMINUM ELECTRODE &amp; ROD FILLER METAL (Continued)</b> |            |                                                                                                                                                              |
|------------------------------------------------------------------------------------------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>A5.10</b>                                                                             | <b>UNS</b> | <b>Chemical Composition</b>                                                                                                                                  |
| ER5556<br>R5556                                                                          | A95556     | Al rem Be 0.0008 max Cr 0.05-0.20 Cu 0.10 max Fe 0.40 max Mg 4.7-5.5 Mn 0.50-1.0 Si 0.25 max Ti 0.05-0.20 Zn 0.25 max<br>Other each 0.05 max, total 0.15 max |
| ER5654<br>R5654                                                                          | A95654     | Al rem Be 0.0008 max Cr 0.15-0.35 Cu 0.05 max Mg 3.1-3.9 Mn 0.01 max Ti 0.05-0.15 Zn 0.20 max Other each 0.05 max,<br>total 0.15 max, Si+Fe 0.45 max         |
| R-206.0                                                                                  | A02060     | Al rem Cu 4.2-5.0 Fe 0.15 max Mg 0.15-0.35 Mn 0.20-0.50 Ni 0.05 max Si 0.10 max Sn 0.05 max Ti 0.15-0.30 Zn 0.10 max<br>Other each 0.05 max, total 0.15 max  |
| R-C355.0                                                                                 | A33550     | Al rem Cu 1.0-1.5 Fe 0.20 max Mg 0.40-0.6 Mn 0.10 max Si 4.5-5.5 Ti 0.20 max Zn 0.10 max Other each 0.05 max, total 0.15 max                                 |
| R-A356.0                                                                                 | A13560     | Al rem Cu 0.20 max Fe 0.20 max Mg 0.20-0.40 Mn 0.10 max Si 6.5-7.5 Ti 0.20 max Zn 0.10 max Other each 0.05 max, total 0.15 max                               |
| R-357                                                                                    | A03570     | Al rem Cu 0.05 max Fe 0.15 max Mg 0.45-0.6 Mn 0.03 max Si 6.5-7.5 Ti 0.20 max Zn 0.05 max Other each 0.05 max, total 0.15 max                                |
| R-A357.0                                                                                 | A13570     | Al rem Be 0.04-0.07 Cu 0.20 max Fe 0.20 max Mg 0.40-0.7 Mn 0.10 max Si 6.5-7.5 Ti 0.10-0.20 Zn 0.10 max Other each 0.05 max,<br>total 0.15 max               |

rem - remainder;

nom - nominal.

Single values are maximum, unless otherwise stated.

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                            | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                       |                             | min                   | max  | min                 | max |             |                       |
| 1060                                                                                  |                             |                       |      |                     |     |             |                       |
| O                                                                                     | 0.006-0.019                 | 8.0                   | 14.0 | 2.5                 | --- | 15          | ---                   |
|                                                                                       | 0.020-0.050                 | 8.0                   | 14.0 | 2.5                 | --- | 22          | ---                   |
|                                                                                       | 0.051-3.000                 | 8.0                   | 14.0 | 2.5                 | --- | 25          | ---                   |
| H12 or H22                                                                            | 0.017-0.050                 | 11.0                  | 16.0 | 9.0                 | --- | 6           | ---                   |
|                                                                                       | 0.051-2.000                 | 11.0                  | 16.0 | 9.0                 | --- | 12          | ---                   |
| H14 or H24                                                                            | 0.009-0.019                 | 12.0                  | 17.0 | 10.0                | --- | 1           | ---                   |
|                                                                                       | 0.020-0.050                 | 12.0                  | 17.0 | 10.0                | --- | 5           | ---                   |
|                                                                                       | 0.051-1.000                 | 12.0                  | 17.0 | 10.0                | --- | 10          | ---                   |
| H16 or H26                                                                            | 0.006-0.019                 | 14.0                  | 19.0 | 11.0                | --- | 1           | ---                   |
|                                                                                       | 0.020-0.050                 | 14.0                  | 19.0 | 11.0                | --- | 4           | ---                   |
|                                                                                       | 0.051-0.162                 | 14.0                  | 19.0 | 11.0                | --- | 5           | ---                   |
| H18 or H28                                                                            | 0.006-0.019                 | 16.0                  | ---  | 12.0                | --- | 1           | ---                   |
|                                                                                       | 0.020-0.050                 | 16.0                  | ---  | 12.0                | --- | 3           | ---                   |
|                                                                                       | 0.051-0.128                 | 16.0                  | ---  | 12.0                | --- | 4           | ---                   |
| H112                                                                                  | 0.250-0.499                 | 11.0                  | ---  | 7.0                 | --- | 10          | ---                   |
|                                                                                       | 0.500-1.000                 | 10.0                  | ---  | 5.0                 | --- | 20          | ---                   |
|                                                                                       | 1.001-3.000                 | 9.0                   | ---  | 4.0                 | --- | 25          | ---                   |
| F                                                                                     | 0.250-3.000                 | ---                   | ---  | ---                 | --- | ---         | ---                   |
| 1100                                                                                  |                             |                       |      |                     |     |             |                       |
| O                                                                                     | 0.006-0.019                 | 11.0                  | 15.5 | 3.5                 | --- | 15          | 0                     |
|                                                                                       | 0.020-0.031                 | 11.0                  | 15.5 | 3.5                 | --- | 20          | 0                     |
|                                                                                       | 0.032-0.050                 | 11.0                  | 15.5 | 3.5                 | --- | 25          | 0                     |
|                                                                                       | 0.051-0.249                 | 11.0                  | 15.5 | 3.5                 | --- | 30          | 0                     |
|                                                                                       | 0.250-3.000                 | 11.0                  | 15.5 | 3.5                 | --- | 28          | 0                     |
| H12 or H22                                                                            | 0.017-0.019                 | 14.0                  | 19.0 | 11.0                | --- | 3           | 0                     |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 1100 (Continued)                                                                                  |                             |                       |      |                     |     |             |                       |
| H12 or H22                                                                                        | 0.020-0.031                 | 14.0                  | 19.0 | 11.0                | --- | 4           | 0                     |
|                                                                                                   | 0.032-0.050                 | 14.0                  | 19.0 | 11.0                | --- | 6           | 0                     |
|                                                                                                   | 0.051-0.113                 | 14.0                  | 19.0 | 11.0                | --- | 8           | 0                     |
|                                                                                                   | 0.114-0.499                 | 14.0                  | 19.0 | 11.0                | --- | 9           | 0                     |
|                                                                                                   | 0.500-2.000                 | 14.0                  | 19.0 | 11.0                | --- | 12          | ---                   |
| H14 or H24                                                                                        | 0.009-0.012                 | 16.0                  | 21.0 | 14.0                | --- | 1           | 0                     |
|                                                                                                   | 0.013-0.019                 | 16.0                  | 21.0 | 14.0                | --- | 2           | 0                     |
|                                                                                                   | 0.020-0.031                 | 16.0                  | 21.0 | 14.0                | --- | 3           | 0                     |
|                                                                                                   | 0.032-0.050                 | 16.0                  | 21.0 | 14.0                | --- | 4           | 0                     |
|                                                                                                   | 0.051-0.113                 | 16.0                  | 21.0 | 14.0                | --- | 5           | 0                     |
|                                                                                                   | 0.114-0.499                 | 16.0                  | 21.0 | 14.0                | --- | 6           | 0                     |
|                                                                                                   | 0.500-1.000                 | 16.0                  | 21.0 | 14.0                | --- | 10          | ---                   |
| H16 or H26                                                                                        | 0.006-0.019                 | 19.0                  | 24.0 | 17.0                | --- | 1           | 4                     |
|                                                                                                   | 0.020-0.031                 | 19.0                  | 24.0 | 17.0                | --- | 2           | 4                     |
|                                                                                                   | 0.032-0.050                 | 19.0                  | 24.0 | 17.0                | --- | 3           | 4                     |
|                                                                                                   | 0.051-0.162                 | 19.0                  | 24.0 | 17.0                | --- | 4           | 4                     |
| H18 or H28                                                                                        | 0.006-0.019                 | 22.0                  | ---  | ---                 | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 22.0                  | ---  | ---                 | --- | 2           | ---                   |
|                                                                                                   | 0.032-0.050                 | 22.0                  | ---  | ---                 | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.128                 | 22.0                  | ---  | ---                 | --- | 4           | ---                   |
| H112                                                                                              | 0.250-0.499                 | 13.0                  | ---  | 7.0                 | --- | 9           | ---                   |
|                                                                                                   | 0.500-2.000                 | 12.0                  | ---  | 5.0                 | --- | 14          | ---                   |
|                                                                                                   | 2001-3.000                  | 11.5                  | ---  | 4.0                 | --- | 20          | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | --- | ---         | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 3003                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.006-0.007                 | 14.0                  | 19.0 | 5.0                 | --- | 14          | 0                     |
|                                                                                                   | 0.008-0.012                 | 14.0                  | 19.0 | 5.0                 | --- | 18          | 0                     |
|                                                                                                   | 0.013-0.031                 | 14.0                  | 19.0 | 5.0                 | --- | 20          | 0                     |
|                                                                                                   | 0.032-0.050                 | 14.0                  | 19.0 | 5.0                 | --- | 23          | 0                     |
|                                                                                                   | 0.051-0.249                 | 14.0                  | 19.0 | 5.0                 | --- | 25          | 0                     |
|                                                                                                   | 0.250-3.000                 | 14.0                  | 19.0 | 5.0                 | --- | 23          | ---                   |
| H12 or H22                                                                                        | 0.017-0.019                 | 17.0                  | 23.0 | 12.0                | --- | 3           | 0                     |
|                                                                                                   | 0.020-0.031                 | 17.0                  | 23.0 | 12.0                | --- | 4           | 0                     |
|                                                                                                   | 0.032-0.050                 | 17.0                  | 23.0 | 12.0                | --- | 5           | 0                     |
|                                                                                                   | 0.051-0.113                 | 17.0                  | 23.0 | 12.0                | --- | 6           | 0                     |
|                                                                                                   | 0.114-0.161                 | 17.0                  | 23.0 | 12.0                | --- | 7           | 0                     |
|                                                                                                   | 0.162-0.249                 | 17.0                  | 23.0 | 12.0                | --- | 8           | 0                     |
|                                                                                                   | 0.250-0.499                 | 17.0                  | 23.0 | 12.0                | --- | 9           | ---                   |
|                                                                                                   | 0.500-2.000                 | 17.0                  | 23.0 | 12.0                | --- | 10          | ---                   |
| H14 or H24                                                                                        | 0.009-0.012                 | 20.0                  | 26.0 | 17.0                | --- | 1           | 0                     |
|                                                                                                   | 0.013-0.019                 | 20.0                  | 26.0 | 17.0                | --- | 2           | 0                     |
|                                                                                                   | 0.020-0.031                 | 20.0                  | 26.0 | 17.0                | --- | 3           | 0                     |
|                                                                                                   | 0.032-0.050                 | 20.0                  | 26.0 | 17.0                | --- | 4           | 0                     |
|                                                                                                   | 0.051-0.113                 | 20.0                  | 26.0 | 17.0                | --- | 5           | 0                     |
|                                                                                                   | 0.114-0.161                 | 20.0                  | 26.0 | 17.0                | --- | 6           | 2                     |
|                                                                                                   | 0.162-0.249                 | 20.0                  | 26.0 | 17.0                | --- | 7           | 2                     |
|                                                                                                   | 0.250-0.499                 | 20.0                  | 26.0 | 17.0                | --- | 8           | ---                   |
|                                                                                                   | 0.500-1.000                 | 20.0                  | 26.0 | 17.0                | --- | 10          | ---                   |
| H16 or H26                                                                                        | 0.006-0.019                 | 24.0                  | 30.0 | 21.0                | --- | 1           | 4                     |
|                                                                                                   | 0.020-0.031                 | 24.0                  | 30.0 | 21.0                | --- | 2           | 4                     |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 3003 (Continued)                                                                                  |                             |                       |      |                     |     |             |                       |
| H16 or H26 (Con't)                                                                                | 0.032-0.050                 | 24.0                  | 30.0 | 21.0                | --- | 3           | 4                     |
|                                                                                                   | 0.051-0.162                 | 24.0                  | 30.0 | 21.0                | --- | 4           | 6                     |
| H18                                                                                               | 0.006-0.019                 | 27.0                  | ---  | 24.0                | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 27.0                  | ---  | 24.0                | --- | 2           | ---                   |
|                                                                                                   | 0.032-0.050                 | 27.0                  | ---  | 24.0                | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.128                 | 27.0                  | ---  | 24.0                | --- | 4           | ---                   |
| H112                                                                                              | 0.250-0.499                 | 17.0                  | ---  | 10.0                | --- | 8           | ---                   |
|                                                                                                   | 0.500-2.000                 | 15.0                  | ---  | 6.0                 | --- | 12          | ---                   |
|                                                                                                   | 2.001-3.000                 | 14.5                  | ---  | 6.0                 | --- | 18          | ---                   |
| F                                                                                                 | 0.250-0.300                 | ---                   | ---  | ---                 | --- | ---         | ---                   |
| Alclad Alloy 3003                                                                                 |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.006-0.007                 | 13.0                  | 18.0 | 4.5                 | --- | 14          | ---                   |
|                                                                                                   | 0.008-0.012                 | 13.0                  | 18.0 | 4.5                 | --- | 18          | ---                   |
|                                                                                                   | 0.013-0.031                 | 13.0                  | 18.0 | 4.5                 | --- | 20          | ---                   |
|                                                                                                   | 0.032-0.050                 | 13.0                  | 18.0 | 4.5                 | --- | 23          | ---                   |
|                                                                                                   | 0.051-0.249                 | 13.0                  | 18.0 | 4.5                 | --- | 25          | ---                   |
|                                                                                                   | 0.250-0.499                 | 13.0                  | 18.0 | 4.5                 | --- | 23          | ---                   |
|                                                                                                   | 0.500-3.000                 | 14.0                  | 19.0 | 5.0                 | --- | 23          | ---                   |
| H12 or H22                                                                                        | 0.017-0.031                 | 16.0                  | 22.0 | 11.0                | --- | 4           | ---                   |
|                                                                                                   | 0.032-0.050                 | 16.0                  | 22.0 | 11.0                | --- | 5           | ---                   |
|                                                                                                   | 0.051-0.113                 | 16.0                  | 22.0 | 11.0                | --- | 6           | ---                   |
|                                                                                                   | 0.114-0.161                 | 16.0                  | 22.0 | 11.0                | --- | 7           | ---                   |
|                                                                                                   | 0.162-0.249                 | 16.0                  | 22.0 | 11.0                | --- | 8           | ---                   |
|                                                                                                   | 0.250-0.499                 | 16.0                  | 22.0 | 11.0                | --- | 9           | ---                   |
|                                                                                                   | 0.500-2.000                 | 17.0                  | 23.0 | 12.0                | --- | 10          | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| Alclad Alloy 3003 (Continued)                                                                     |                             |                       |      |                     |     |             |                       |
| H14 or H24                                                                                        | 0.009-0.012                 | 19.0                  | 25.0 | 16.0                | --- | 1           | ---                   |
|                                                                                                   | 0.013-0.019                 | 19.0                  | 25.0 | 16.0                | --- | 2           | ---                   |
|                                                                                                   | 0.020-0.031                 | 19.0                  | 25.0 | 16.0                | --- | 3           | ---                   |
|                                                                                                   | 0.032-0.050                 | 19.0                  | 25.0 | 16.0                | --- | 4           | ---                   |
|                                                                                                   | 0.051-0.113                 | 19.0                  | 25.0 | 16.0                | --- | 5           | ---                   |
|                                                                                                   | 0.114-0.161                 | 19.0                  | 25.0 | 16.0                | --- | 6           | ---                   |
|                                                                                                   | 0.162-0.249                 | 19.0                  | 25.0 | 16.0                | --- | 7           | ---                   |
|                                                                                                   | 0.250-0.499                 | 19.0                  | 25.0 | 16.0                | --- | 8           | ---                   |
| H16 or H26                                                                                        | 0.500-1.000                 | 20.0                  | 26.0 | 17.0                | --- | 10          | ---                   |
|                                                                                                   | 0.006-0.019                 | 23.0                  | 29.0 | 20.0                | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 23.0                  | 29.0 | 20.0                | --- | 2           | ---                   |
|                                                                                                   | 0.032-0.050                 | 23.0                  | 29.0 | 20.0                | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.162                 | 23.0                  | 29.0 | 20.0                | --- | 4           | ---                   |
| H18                                                                                               | 0.006-0.019                 | 26.0                  | ---  | ---                 | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 26.0                  | ---  | ---                 | --- | 2           | ---                   |
|                                                                                                   | 0.032-0.050                 | 26.0                  | ---  | ---                 | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.128                 | 26.0                  | ---  | ---                 | --- | 4           | ---                   |
| H112                                                                                              | 0.250-0.499                 | 16.0                  | ---  | 9.0                 | --- | 8           | ---                   |
|                                                                                                   | 0.500-2.000                 | 15.0                  | ---  | 6.0                 | --- | 12          | ---                   |
|                                                                                                   | 2.001-3.000                 | 14.5                  | ---  | 6.0                 | --- | 18          | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | --- | ---         | ---                   |
| 3004                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.006-0.007                 | 22.0                  | 29.0 | 8.5                 | --- | ---         | ---                   |
|                                                                                                   | 0.008-0.019                 | 22.0                  | 29.0 | 8.5                 | --- | 10          | 0                     |
|                                                                                                   | 0.020-0.031                 | 22.0                  | 29.0 | 8.5                 | --- | 14          | 0                     |



| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 3004 (Continued)                                                                                  |                             |                       |      |                     |     |             |                       |
| O (continued)                                                                                     | 0.032-0.050                 | 22.0                  | 29.0 | 8.5                 | --- | 16          | 0                     |
|                                                                                                   | 0.051-0.249                 | 22.0                  | 29.0 | 8.5                 | --- | 18          | 0                     |
|                                                                                                   | 0.250-3.000                 | 22.0                  | 29.0 | 8.5                 | --- | 16          | ---                   |
| H32 or H22                                                                                        | 0.017-0.019                 | 28.0                  | 35.0 | 21.0                | --- | 1           | 0                     |
|                                                                                                   | 0.020-0.031                 | 28.0                  | 35.0 | 21.0                | --- | 3           | 1                     |
|                                                                                                   | 0.032-0.050                 | 28.0                  | 35.0 | 21.0                | --- | 4           | 1                     |
|                                                                                                   | 0.051-0.113                 | 28.0                  | 35.0 | 21.0                | --- | 5           | 2                     |
|                                                                                                   | 0.114-2.000                 | 28.0                  | 35.0 | 21.0                | --- | 6           | ---                   |
|                                                                                                   |                             |                       |      |                     |     |             |                       |
| H34 or H24                                                                                        | 0.009-0.019                 | 32.0                  | 38.0 | 25.0                | --- | 1           | 2                     |
|                                                                                                   | 0.020-0.050                 | 32.0                  | 38.0 | 25.0                | --- | 3           | 3                     |
|                                                                                                   | 0.051-0.113                 | 32.0                  | 38.0 | 25.0                | --- | 4           | 4                     |
|                                                                                                   | 0.114-1.000                 | 32.0                  | 38.0 | 25.0                | --- | 5           | ---                   |
| H36 or H26                                                                                        | 0.006-0.007                 | 35.0                  | 41.0 | 28.0                | --- | ---         | ---                   |
|                                                                                                   | 0.008-0.019                 | 35.0                  | 41.0 | 28.0                | --- | 1           | 6                     |
|                                                                                                   | 0.020-0.031                 | 35.0                  | 41.0 | 28.0                | --- | 2           | 6                     |
|                                                                                                   | 0.032-0.050                 | 35.0                  | 41.0 | 28.0                | --- | 3           | 6                     |
|                                                                                                   | 0.051-0.162                 | 35.0                  | 41.0 | 28.0                | --- | 4           | 8                     |
| H38 or H28                                                                                        | 0.006-0.007                 | 38.0                  | ---  | 31.0                | --- | ---         | ---                   |
|                                                                                                   | 0.008-0.019                 | 38.0                  | ---  | 31.0                | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 38.0                  | ---  | 31.0                | --- | 2           | ---                   |
|                                                                                                   | 0.032-0.050                 | 38.0                  | ---  | 31.0                | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.128                 | 38.0                  | ---  | 31.0                | --- | 4           | ---                   |
| H112                                                                                              | 0.250-3.000                 | 23.0                  | ---  | 9.0                 | --- | 7           | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | --- | ---         | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| Alclad Alloy 3004                                                                                 |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.006-0.007                 | 21.0                  | 28.0 | 8.0                 | --- | ---         | ---                   |
|                                                                                                   | 0.008-0.019                 | 21.0                  | 28.0 | 8.0                 | --- | 10          | ---                   |
|                                                                                                   | 0.020-0.031                 | 21.0                  | 28.0 | 8.0                 | --- | 14          | ---                   |
|                                                                                                   | 0.032-0.050                 | 21.0                  | 28.0 | 8.0                 | --- | 16          | ---                   |
|                                                                                                   | 0.051-0.249                 | 21.0                  | 28.0 | 8.0                 | --- | 18          | ---                   |
|                                                                                                   | 0.250-0.499                 | 21.0                  | 28.0 | 8.0                 | --- | 16          | ---                   |
| H32 or H22                                                                                        | 0.500-3.000                 | 22.0                  | 29.0 | 8.5                 | --- | 16          | ---                   |
|                                                                                                   | 0.017-0.019                 | 27.0                  | 34.0 | 20.0                | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 27.0                  | 34.0 | 20.0                | --- | 3           | ---                   |
|                                                                                                   | 0.032-0.050                 | 27.0                  | 34.0 | 20.0                | --- | 4           | ---                   |
|                                                                                                   | 0.114-0.249                 | 27.0                  | 34.0 | 20.0                | --- | 6           | ---                   |
|                                                                                                   | 0.250-0.499                 | 27.0                  | 34.0 | 20.0                | --- | 6           | ---                   |
| H34 or H24                                                                                        | 0.500-2.000                 | 28.0                  | 35.0 | 21.0                | --- | 6           | ---                   |
|                                                                                                   | 0.009-0.019                 | 31.0                  | 37.0 | 24.0                | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.050                 | 31.0                  | 37.0 | 24.0                | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.113                 | 31.0                  | 37.0 | 24.0                | --- | 4           | ---                   |
|                                                                                                   | 0.114-0.249                 | 31.0                  | 37.0 | 24.0                | --- | 5           | ---                   |
|                                                                                                   | 0.250-0.499                 | 31.0                  | 37.0 | 24.0                | --- | 5           | ---                   |
| H36 or H26                                                                                        | 0.500-1.000                 | 32.0                  | 38.0 | 25.0                | --- | 5           | ---                   |
|                                                                                                   | 0.006-0.007                 | 34.0                  | 40.0 | 27.0                | --- | ---         | ---                   |
|                                                                                                   | 0.008-0.019                 | 34.0                  | 40.0 | 27.0                | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 34.0                  | 40.0 | 27.0                | --- | 2           | ---                   |
|                                                                                                   | 0.032-0.050                 | 34.0                  | 40.0 | 27.0                | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.162                 | 34.0                  | 40.0 | 27.0                | --- | 4           | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 3005                                                                                              |                             |                       |      |                     |     |             |                       |
| H38                                                                                               | 0.006-0.007                 | 37.0                  | ---  | ---                 | --- | ---         | ---                   |
|                                                                                                   | 0.008-0.019                 | 37.0                  | ---  | ---                 | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 37.0                  | ---  | ---                 | --- | 2           | ---                   |
|                                                                                                   | 0.032-0.050                 | 37.0                  | ---  | ---                 | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.128                 | 37.0                  | ---  | ---                 | --- | 4           | ---                   |
| H112                                                                                              | 0.250-0.499                 | 22.0                  | ---  | 8.5                 | --- | 7           | ---                   |
|                                                                                                   | 0.500-3.000                 | 23.0                  | ---  | 9.0                 | --- | 7           | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | --- | ---         | ---                   |
| O                                                                                                 | 0.006-0.007                 | 17.0                  | 24.0 | 6.5                 | --- | 10          | ---                   |
|                                                                                                   | 0.008-0.012                 | 17.0                  | 24.0 | 6.5                 | --- | 12          | ---                   |
|                                                                                                   | 0.013-0.019                 | 17.0                  | 24.0 | 6.5                 | --- | 14          | ---                   |
|                                                                                                   | 0.020-0.031                 | 17.0                  | 24.0 | 6.5                 | --- | 16          | ---                   |
|                                                                                                   | 0.032-0.050                 | 17.0                  | 24.0 | 6.5                 | --- | 18          | ---                   |
|                                                                                                   | 0.051-0.249                 | 17.0                  | 24.0 | 6.5                 | --- | 20          | ---                   |
| H12                                                                                               | 0.017-0.019                 | 20.0                  | 27.0 | 17.0                | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.050                 | 20.0                  | 27.0 | 17.0                | --- | 2           | ---                   |
|                                                                                                   | 0.051-0.113                 | 20.0                  | 27.0 | 17.0                | --- | 3           | ---                   |
|                                                                                                   | 0.114-0.161                 | 20.0                  | 27.0 | 17.0                | --- | 4           | ---                   |
|                                                                                                   | 0.162-0.249                 | 20.0                  | 27.0 | 17.0                | --- | 5           | ---                   |
| H14                                                                                               | 0.009-0.031                 | 24.0                  | 31.0 | 21.0                | --- | 1           | ---                   |
|                                                                                                   | 0.032-0.050                 | 24.0                  | 31.0 | 21.0                | --- | 2           | ---                   |
|                                                                                                   | 0.051-0.113                 | 24.0                  | 31.0 | 21.0                | --- | 3           | ---                   |
|                                                                                                   | 0.114-0.249                 | 24.0                  | 31.0 | 21.0                | --- | 4           | ---                   |
| H16                                                                                               | 0.006-0.031                 | 28.0                  | 35.0 | 25.0                | --- | 1           | ---                   |
|                                                                                                   | 0.032-0.113                 | 28.0                  | 35.0 | 25.0                | --- | 2           | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 3005 (Continued)                                                                                  |                             |                       |      |                     |     |             |                       |
| H16 (continued)                                                                                   | 0.114-0.162                 | 28.0                  | 35.0 | 25.0                | --- | 3           | ---                   |
| H18                                                                                               | 0.006-0.031                 | 32.0                  | ---  | 29.0                | --- | 1           | ---                   |
|                                                                                                   | 0.032-0.128                 | 32.0                  | ---  | 29.0                | --- | 2           | ---                   |
| H19                                                                                               | 0.006-0.012                 | 34.0                  | ---  | ---                 | --- | ---         | ---                   |
|                                                                                                   | 0.013-0.063                 | 34.0                  | ---  | ---                 | --- | 1           | ---                   |
| H25                                                                                               | 0.016-0.019                 | 26.0                  | 34.0 | 22.0                | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 26.0                  | 34.0 | 22.0                | --- | 2           | ---                   |
|                                                                                                   | 0.032-0.050                 | 26.0                  | 34.0 | 22.0                | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.080                 | 26.0                  | 34.0 | 22.0                | --- | 4           | ---                   |
| H27                                                                                               | 0.016-0.019                 | 29.5                  | 37.5 | 25.5                | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 29.5                  | 37.5 | 25.5                | --- | 2           | ---                   |
|                                                                                                   | 0.032-0.050                 | 29.5                  | 37.5 | 25.5                | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.080                 | 29.5                  | 37.5 | 25.5                | --- | 4           | ---                   |
| H28                                                                                               | 0.016-0.019                 | 31.0                  | ---  | 27.0                | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 31.0                  | ---  | 27.0                | --- | 2           | ---                   |
|                                                                                                   | 0.032-0.050                 | 31.0                  | ---  | 27.0                | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.080                 | 31.0                  | ---  | 27.0                | --- | 4           | ---                   |
| H29                                                                                               | 0.025-0.031                 | 33.0                  | ---  | 28.0                | --- | 1           | ---                   |
|                                                                                                   | 0.032-0.050                 | 33.0                  | ---  | 28.0                | --- | 2           | ---                   |
|                                                                                                   | 0.051-0.071                 | 33.0                  | ---  | 28.0                | --- | 3           | ---                   |
| 3105                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.013-0.019                 | 14.0                  | 21.0 | 5.0                 | --- | 16          | ---                   |
|                                                                                                   | 0.020-0.031                 | 14.0                  | 21.0 | 5.0                 | --- | 18          | ---                   |
|                                                                                                   | 0.032-0.080                 | 14.0                  | 21.0 | 5.0                 | --- | 20          | ---                   |
| H12                                                                                               | 0.017-0.019                 | 19.0                  | 26.0 | 15.0                | --- | 1           | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 3105 (Continued)                                                                                  |                             |                       |      |                     |     |             |                       |
| H12 (continued)                                                                                   | 0.020-0.031                 | 19.0                  | 26.0 | 15.0                | --- | 1           | ---                   |
|                                                                                                   | 0.032-0.050                 | 19.0                  | 26.0 | 15.0                | --- | 2           | ---                   |
|                                                                                                   | 0.051-0.080                 | 19.0                  | 26.0 | 15.0                | --- | 3           | ---                   |
| H14                                                                                               | 0.013-0.019                 | 22.0                  | 29.0 | 18.0                | --- | 1           | ---                   |
|                                                                                                   | 0.020-0.031                 | 22.0                  | 29.0 | 18.0                | --- | 1           | ---                   |
|                                                                                                   | 0.032-0.050                 | 22.0                  | 29.0 | 18.0                | --- | 2           | ---                   |
|                                                                                                   | 0.051-0.080                 | 22.0                  | 29.0 | 18.0                | --- | 2           | ---                   |
| H16                                                                                               | 0.013-0.031                 | 25.0                  | 32.0 | 21.0                | --- | 1           | ---                   |
|                                                                                                   | 0.032-0.050                 | 25.0                  | 32.0 | 21.0                | --- | 2           | ---                   |
|                                                                                                   | 0.051-0.080                 | 25.0                  | 32.0 | 21.0                | --- | 2           | ---                   |
| H18                                                                                               | 0.013-0.031                 | 28.0                  | ---  | 24.0                | --- | 1           | ---                   |
|                                                                                                   | 0.032-0.050                 | 28.0                  | ---  | 24.0                | --- | 1           | ---                   |
|                                                                                                   | 0.051-0.080                 | 28.0                  | ---  | 24.0                | --- | 2           | ---                   |
| H25                                                                                               | 0.013-0.019                 | 23.0                  | ---  | 19.0                | --- | 2           | ---                   |
|                                                                                                   | 0.020-0.031                 | 23.0                  | ---  | 19.0                | --- | 3           | ---                   |
|                                                                                                   | 0.032-0.050                 | 23.0                  | ---  | 19.0                | --- | 4           | ---                   |
|                                                                                                   | 0.051-0.080                 | 23.0                  | ---  | 19.0                | --- | 6           | ---                   |
| 5005                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.006-0.007                 | 15.0                  | 21.0 | 5.0                 | --- | 12          | ---                   |
|                                                                                                   | 0.008-0.012                 | 15.0                  | 21.0 | 5.0                 | --- | 14          | ---                   |
|                                                                                                   | 0.013-0.019                 | 15.0                  | 21.0 | 5.0                 | --- | 16          | ---                   |
|                                                                                                   | 0.020-0.031                 | 15.0                  | 21.0 | 5.0                 | --- | 18          | ---                   |
|                                                                                                   | 0.032-0.050                 | 15.0                  | 21.0 | 5.0                 | --- | 20          | ---                   |
|                                                                                                   | 0.051-0.113                 | 15.0                  | 21.0 | 5.0                 | --- | 21          | ---                   |
|                                                                                                   | 0.114-0.249                 | 15.0                  | 21.0 | 5.0                 | --- | 22          | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max  |             |                       |
| 5005 (Continued)                                                                                  |                             |                       |      |                     |      |             |                       |
| O (continued)                                                                                     | 0.250-3.000                 | 15.0                  | 21.0 | 5.0                 | ---  | 22          | ---                   |
| H12                                                                                               | 0.017-0.019                 | 18.0                  | 24.0 | 14.0                | ---  | 2           | ---                   |
|                                                                                                   | 0.020-0.031                 | 18.0                  | 24.0 | 14.0                | ---  | 3           | ---                   |
|                                                                                                   | 0.032-0.050                 | 18.0                  | 24.0 | 14.0                | ---  | 4           | ---                   |
|                                                                                                   | 0.051-0.113                 | 18.0                  | 24.0 | 14.0                | ---  | 6           | ---                   |
|                                                                                                   | 0.114-0.161                 | 18.0                  | 24.0 | 14.0                | ---  | 7           | ---                   |
|                                                                                                   | 0.162-0.249                 | 18.0                  | 24.0 | 14.0                | ---  | 8           | ---                   |
|                                                                                                   | 0.250-0.499                 | 18.0                  | 24.0 | 14.0                | ---  | 9           | ---                   |
|                                                                                                   | 0.500-2.000                 | 18.0                  | 24.0 | 14.0                | ---  | 10          | ---                   |
| H14                                                                                               | 0.009-0.031                 | 21.0                  | 27.0 | 17.0                | ---  | 1           | ---                   |
|                                                                                                   | 0.032-0.050                 | 21.0                  | 27.0 | 17.0                | ---  | 2           | ---                   |
|                                                                                                   | 0.051-0.113                 | 21.0                  | 27.0 | 17.0                | ---  | 3           | ---                   |
|                                                                                                   | 0.114-0.161                 | 21.0                  | 27.0 | 17.0                | ---  | 5           | ---                   |
|                                                                                                   | 0.162-0.249                 | 21.0                  | 27.0 | 17.0                | ---  | 6           | ---                   |
|                                                                                                   | 0.250-0.499                 | 21.0                  | 27.0 | 17.0                | ---  | 8           | ---                   |
|                                                                                                   | 0.500-1.000                 | 21.0                  | 27.0 | 17.0                | ---  | 10          | ---                   |
|                                                                                                   | H16                         | 0.006-0.031           | 24.0 | 30.0                | 20.0 | ---         | 1                     |
| 0.032-0.050                                                                                       |                             | 24.0                  | 30.0 | 20.0                | ---  | 2           | ---                   |
| 0.051-0.162                                                                                       |                             | 24.0                  | 30.0 | 20.0                | ---  | 3           | ---                   |
| H18                                                                                               | 0.006-0.031                 | 27.0                  | ---  | ---                 | ---  | 1           | ---                   |
|                                                                                                   | 0.051-0.128                 | 27.0                  | ---  | ---                 | ---  | 3           | ---                   |
| H32 or H22                                                                                        | 0.017-0.019                 | 17.0                  | 23.0 | 12.0                | ---  | 3           | ---                   |
|                                                                                                   | 0.020-0.031                 | 17.0                  | 23.0 | 12.0                | ---  | 4           | ---                   |
|                                                                                                   | 0.032-0.050                 | 17.0                  | 23.0 | 12.0                | ---  | 5           | ---                   |
|                                                                                                   | 0.051-0.113                 | 17.0                  | 23.0 | 12.0                | ---  | 7           | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 5005 (Continued)                                                                                  |                             |                       |      |                     |     |             |                       |
| H32 or H22 (con't)                                                                                | 0.114-0.161                 | 17.0                  | 23.0 | 12.0                | --- | 8           | ---                   |
|                                                                                                   | 0.162-0.249                 | 17.0                  | 23.0 | 12.0                | --- | 9           | ---                   |
|                                                                                                   | 0.250-2.000                 | 17.0                  | 23.0 | 12.0                | --- | 10          | ---                   |
| H34 or H24                                                                                        | 0.009-0.012                 | 20.0                  | 26.0 | 15.0                | --- | 2           | ---                   |
|                                                                                                   | 0.013-0.031                 | 20.0                  | 26.0 | 15.0                | --- | 3           | ---                   |
|                                                                                                   | 0.032-0.050                 | 20.0                  | 26.0 | 15.0                | --- | 4           | ---                   |
|                                                                                                   | 0.051-0.113                 | 20.0                  | 26.0 | 15.0                | --- | 5           | ---                   |
|                                                                                                   | 0.114-0.161                 | 20.0                  | 26.0 | 15.0                | --- | 6           | ---                   |
|                                                                                                   | 0.162-0.249                 | 20.0                  | 26.0 | 15.0                | --- | 7           | ---                   |
|                                                                                                   | 0.250-0.499                 | 20.0                  | 26.0 | 15.0                | --- | 8           | ---                   |
|                                                                                                   | 0.500-1.000                 | 20.0                  | 26.0 | 15.0                | --- | 10          | ---                   |
| H36 or H26                                                                                        | 0.006-0.007                 | 23.0                  | 29.0 | 18.0                | --- | 1           | ---                   |
|                                                                                                   | 0.008-0.019                 | 23.0                  | 29.0 | 18.0                | --- | 2           | ---                   |
|                                                                                                   | 0.020-0.031                 | 23.0                  | 29.0 | 18.0                | --- | 3           | ---                   |
|                                                                                                   | 0.032-0.162                 | 23.0                  | 29.0 | 18.0                | --- | 4           | ---                   |
| H38                                                                                               | 0.006-0.012                 | 26.0                  | ---  | ---                 | --- | 1           | ---                   |
|                                                                                                   | 0.013-0.019                 | 26.0                  | ---  | ---                 | --- | 2           | ---                   |
|                                                                                                   | 0.020-0.031                 | 26.0                  | ---  | ---                 | --- | 3           | ---                   |
|                                                                                                   | 0.032-0.128                 | 26.0                  | ---  | ---                 | --- | 4           | ---                   |
| H112                                                                                              | 0.250-0.499                 | 17.0                  | ---  | ---                 | --- | 8           | ---                   |
|                                                                                                   | 0.500-2.000                 | 15.0                  | ---  | ---                 | --- | 12          | ---                   |
|                                                                                                   | 2.001-3.000                 | 14.5                  | ---  | ---                 | --- | 18          | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | --- | ---         | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 5010                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.010-0.070                 | 15.0                  | 21.0 | 5.0                 | --- | 3           | ---                   |
| H22                                                                                               | 0.010-0.070                 | 17.0                  | 23.0 | 14.0                | --- | 2           | ---                   |
| H24                                                                                               | 0.010-0.070                 | 20.0                  | 26.0 | 17.0                | --- | 1           | ---                   |
| H26                                                                                               | 0.010-0.070                 | 23.0                  | 29.0 | 21.0                | --- | 1           | ---                   |
| H28                                                                                               | 0.010-0.070                 | 26.0                  | ---  | ---                 | --- | ---         | ---                   |
| 5050                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.006-0.007                 | 18.0                  | 24.0 | 6.0                 | --- | ---         | 0                     |
|                                                                                                   | 0.008-0.019                 | 18.0                  | 24.0 | 6.0                 | --- | 16          | 0                     |
|                                                                                                   | 0.020-0.031                 | 18.0                  | 24.0 | 6.0                 | --- | 18          | 0                     |
|                                                                                                   | 0.032-0.050                 | 18.0                  | 24.0 | 6.0                 | --- | 20          | 0                     |
|                                                                                                   | 0.051-0.113                 | 18.0                  | 24.0 | 6.0                 | --- | 20          | 0                     |
|                                                                                                   | 0.114-0.249                 | 18.0                  | 24.0 | 6.0                 | --- | 22          | 0                     |
|                                                                                                   | 0.250-3.000                 | 18.0                  | 24.0 | 6.0                 | --- | 20          | 2                     |
| H32 or H22                                                                                        | 0.017-0.050                 | 22.0                  | 28.0 | 16.0                | --- | 4           | 1                     |
|                                                                                                   | 0.051-0.249                 | 22.0                  | 28.0 | 16.0                | --- | 6           | 2                     |
| H34 or H24                                                                                        | 0.009-0.031                 | 25.0                  | 31.0 | 20.0                | --- | 3           | 1                     |
|                                                                                                   | 0.032-0.050                 | 25.0                  | 31.0 | 20.0                | --- | 4           | 1                     |
|                                                                                                   | 0.051-0.249                 | 25.0                  | 31.0 | 20.0                | --- | 5           | 3                     |
| H36 or H26                                                                                        | 0.006-0.019                 | 27.0                  | 33.0 | 22.0                | --- | 2           | 3                     |
|                                                                                                   | 0.020-0.050                 | 27.0                  | 33.0 | 22.0                | --- | 3           | 3                     |
|                                                                                                   | 0.051-0.162                 | 27.0                  | 33.0 | 22.0                | --- | 4           | 4                     |
| H38                                                                                               | 0.006-0.007                 | 29.0                  | ---  | ---                 | --- | ---         | ---                   |
|                                                                                                   | 0.008-0.031                 | 29.0                  | ---  | ---                 | --- | 2           | ---                   |
|                                                                                                   | 0.032-0.050                 | 29.0                  | ---  | ---                 | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.128                 | 29.0                  | ---  | ---                 | --- | 4           | ---                   |



| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 5050 (Continued)                                                                                  |                             |                       |      |                     |     |             |                       |
| H112                                                                                              | 0.250-3.000                 | 20.0                  | ---  | 8.0                 | --- | 12          | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | --- | ---         | ---                   |
| 5052                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.006-0.007                 | 25.0                  | 31.0 | 9.5                 | --- | ---         | 0                     |
|                                                                                                   | 0.008-0.012                 | 25.0                  | 31.0 | 9.5                 | --- | 14          | 0                     |
|                                                                                                   | 0.013-0.019                 | 25.0                  | 31.0 | 9.5                 | --- | 15          | 0                     |
|                                                                                                   | 0.020-0.031                 | 25.0                  | 31.0 | 9.5                 | --- | 16          | 0                     |
|                                                                                                   | 0.032-0.050                 | 25.0                  | 31.0 | 9.5                 | --- | 18          | 0                     |
|                                                                                                   | 0.051-0.113                 | 25.0                  | 31.0 | 9.5                 | --- | 19          | 0                     |
|                                                                                                   | 0.114-0.249                 | 25.0                  | 31.0 | 9.5                 | --- | 20          | 0                     |
|                                                                                                   | 0.250-3.000                 | 25.0                  | 31.0 | 9.5                 | --- | 18          | ---                   |
| H32 or H22                                                                                        | 0.017-0.019                 | 31.0                  | 38.0 | 23.0                | --- | 4           | 0                     |
|                                                                                                   | 0.020-0.050                 | 31.0                  | 38.0 | 23.0                | --- | 5           | 1                     |
|                                                                                                   | 0.051-0.113                 | 31.0                  | 38.0 | 23.0                | --- | 7           | 2                     |
|                                                                                                   | 0.114-0.249                 | 31.0                  | 38.0 | 23.0                | --- | 9           | 3                     |
|                                                                                                   | 0.250-0.499                 | 31.0                  | 38.0 | 23.0                | --- | 11          | ---                   |
|                                                                                                   | 0.500-2.000                 | 31.0                  | 38.0 | 23.0                | --- | 12          | ---                   |
| H34 or H24                                                                                        | 0.009-0.019                 | 34.0                  | 41.0 | 26.0                | --- | 3           | 1                     |
|                                                                                                   | 0.020-0.050                 | 34.0                  | 41.0 | 26.0                | --- | 4           | 2                     |
|                                                                                                   | 0.051-0.113                 | 34.0                  | 41.0 | 26.0                | --- | 6           | 3                     |
|                                                                                                   | 0.114-0.249                 | 34.0                  | 41.0 | 26.0                | --- | 7           | 4                     |
|                                                                                                   | 0.250-1.000                 | 34.0                  | 41.0 | 26.0                | --- | 10          | ---                   |
| H36 or H26                                                                                        | 0.006-0.007                 | 37.0                  | 44.0 | 29.0                | --- | 2           | ---                   |
|                                                                                                   | 0.008-0.031                 | 37.0                  | 44.0 | 29.0                | --- | 3           | 4                     |
|                                                                                                   | 0.032-0.162                 | 37.0                  | 44.0 | 29.0                | --- | 4           | 5                     |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max  |             |                       |
| 5052 (Continued)                                                                                  |                             |                       |      |                     |      |             |                       |
| H38 or H28                                                                                        | 0.006-0.007                 | 39.0                  | ---  | 32.0                | ---  | 4           | ---                   |
|                                                                                                   | 0.008-0.031                 | 39.0                  | ---  | 32.0                | ---  | 2           | ---                   |
|                                                                                                   | 0.032-0.128                 | 39.0                  | ---  | 32.0                | ---  | 3           | ---                   |
| H112                                                                                              | 0.250-0.499                 | 28.0                  | ---  | 16.0                | ---  | 7           | ---                   |
|                                                                                                   | 0.500-2.000                 | 25.0                  | ---  | 9.5                 | ---  | 12          | ---                   |
|                                                                                                   | 2.001-3.000                 | 25.0                  | ---  | 9.5                 | ---  | 16          | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | ---  | ---         | ---                   |
| 5083                                                                                              |                             |                       |      |                     |      |             |                       |
| O                                                                                                 | 0.051-1.500                 | 40.0                  | 51.0 | 18.0                | 29.0 | 16          | ---                   |
|                                                                                                   | 1.501-3.000                 | 39.0                  | 50.0 | 17.0                | 29.0 | 16          | ---                   |
|                                                                                                   | 3.001-4.000                 | 38.0                  | ---  | 16.0                | ---  | 16          | ---                   |
|                                                                                                   | 4.001-5.000                 | 38.0                  | ---  | 16.0                | ---  | 14          | ---                   |
|                                                                                                   | 5.001-7.000                 | 37.0                  | ---  | 15.0                | ---  | 14          | ---                   |
|                                                                                                   | 7.001-8.000                 | 36.0                  | ---  | 14.0                | ---  | 12          | ---                   |
| H321                                                                                              | 0.188-1.500                 | 44.0                  | 56.0 | 31.0                | 43.0 | 12          | ---                   |
|                                                                                                   | 1.501-3.000                 | 41.0                  | 56.0 | 29.0                | 43.0 | 12          | ---                   |
| H112                                                                                              | 0.250-1.500                 | 40.0                  | ---  | 18.0                | ---  | 12          | ---                   |
|                                                                                                   | 1.501-3.000                 | 39.0                  | ---  | 17.0                | ---  | 12          | ---                   |
| H116                                                                                              | 0.063-0.499                 | 44.0                  | ---  | 31.0                | ---  | 10          | ---                   |
|                                                                                                   | 0.500-1.250                 | 44.0                  | ---  | 31.0                | ---  | 12          | ---                   |
|                                                                                                   | 1.251-1.500                 | 44.0                  | ---  | 31.0                | ---  | 12          | ---                   |
|                                                                                                   | 1.501-3.000                 | 41.0                  | ---  | 29.0                | ---  | 12          | ---                   |
| F                                                                                                 | 0.250-8.000                 | ---                   | ---  | ---                 | ---  | ---         | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 5086                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.020-0.050                 | 35.0                  | 44.0 | 14.0                | --- | 15          | ---                   |
|                                                                                                   | 0.051-0.249                 | 35.0                  | 44.0 | 14.0                | --- | 18          | ---                   |
|                                                                                                   | 0.250-2.000                 | 35.0                  | 44.0 | 14.0                | --- | 16          | ---                   |
| H32 or H22                                                                                        | 0.020-0.050                 | 40.0                  | 47.0 | 28.0                | --- | 6           | ---                   |
|                                                                                                   | 0.051-0.249                 | 40.0                  | 47.0 | 28.0                | --- | 8           | ---                   |
|                                                                                                   | 0.250-2.000                 | 40.0                  | 47.0 | 28.0                | --- | 12          | ---                   |
| H34 or H24                                                                                        | 0.009-0.019                 | 44.0                  | 51.0 | 34.0                | --- | 4           | ---                   |
|                                                                                                   | 0.020-0.050                 | 44.0                  | 51.0 | 34.0                | --- | 5           | ---                   |
|                                                                                                   | 0.051-0.249                 | 44.0                  | 51.0 | 34.0                | --- | 6           | ---                   |
|                                                                                                   | 0.250-1.000                 | 44.0                  | 51.0 | 34.0                | --- | 10          | ---                   |
| H36 or H26                                                                                        | 0.006-0.019                 | 47.0                  | 54.0 | 38.0                | --- | 3           | ---                   |
|                                                                                                   | 0.020-0.050                 | 47.0                  | 54.0 | 38.0                | --- | 4           | ---                   |
|                                                                                                   | 0.051-0.162                 | 47.0                  | 54.0 | 38.0                | --- | 6           | ---                   |
| H38 or H28                                                                                        | 0.006-0.020                 | 50.0                  | ---  | 41.0                | --- | 3           | ---                   |
| H112                                                                                              | 0.188-0.499                 | 36.0                  | ---  | 18.0                | --- | 8           | ---                   |
|                                                                                                   | 0.500-1.000                 | 35.0                  | ---  | 16.0                | --- | 10          | ---                   |
|                                                                                                   | 1.001-2.000                 | 35.0                  | ---  | 14.0                | --- | 14          | ---                   |
|                                                                                                   | 2.001-3.000                 | 34.0                  | ---  | 14.0                | --- | 14          | ---                   |
| H116                                                                                              | 0.063-0.249                 | 40.0                  | ---  | 28.0                | --- | 8           | ---                   |
|                                                                                                   | 0.250-0.499                 | 40.0                  | ---  | 28.0                | --- | 10          | ---                   |
|                                                                                                   | 0.500-1.250                 | 40.0                  | ---  | 28.0                | --- | 10          | ---                   |
|                                                                                                   | 1.251-2.000                 | 40.0                  | ---  | 28.0                | --- | 10          | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | --- | ---         | ---                   |
| 5154                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.020-0.031                 | 30.0                  | 41.0 | 11.0                | --- | 12          | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 5154 (Continued)                                                                                  |                             |                       |      |                     |     |             |                       |
| O (continued)                                                                                     | 0.032-0.050                 | 30.0                  | 41.0 | 11.0                | --- | 14          | ---                   |
|                                                                                                   | 0.051-0.113                 | 30.0                  | 41.0 | 11.0                | --- | 16          | ---                   |
|                                                                                                   | 0.114-3.000                 | 30.0                  | 41.0 | 11.0                | --- | 18          | ---                   |
| H32 or H22                                                                                        | 0.020-0.050                 | 36.0                  | 43.0 | 26.0                | --- | 5           | ---                   |
|                                                                                                   | 0.051-0.249                 | 36.0                  | 43.0 | 26.0                | --- | 8           | ---                   |
|                                                                                                   | 0.250-2.000                 | 36.0                  | 43.0 | 26.0                | --- | 12          | ---                   |
| H34 or H24                                                                                        | 0.009-0.050                 | 39.0                  | 46.0 | 29.0                | --- | 4           | ---                   |
|                                                                                                   | 0.051-0.161                 | 39.0                  | 46.0 | 29.0                | --- | 6           | ---                   |
|                                                                                                   | 0.162-0.249                 | 39.0                  | 46.0 | 29.0                | --- | 7           | ---                   |
|                                                                                                   | 0.250-1.000                 | 39.0                  | 46.0 | 29.0                | --- | 10          | ---                   |
| H36 or H26                                                                                        | 0.006-0.050                 | 42.0                  | 49.0 | 32.0                | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.113                 | 42.0                  | 49.0 | 32.0                | --- | 4           | ---                   |
|                                                                                                   | 0.114-0.162                 | 42.0                  | 49.0 | 32.0                | --- | 5           | ---                   |
| H38 or H28                                                                                        | 0.006-0.050                 | 45.0                  | ---  | 35.0                | --- | 3           | ---                   |
|                                                                                                   | 0.051-0.113                 | 45.0                  | ---  | 35.0                | --- | 4           | ---                   |
|                                                                                                   | 0.114-0.128                 | 45.0                  | ---  | 35.0                | --- | 5           | ---                   |
| H112                                                                                              | 0.250-0.499                 | 32.0                  | ---  | 18.0                | --- | 8           | ---                   |
|                                                                                                   | 0.500-2.000                 | 30.0                  | ---  | 11.0                | --- | 11          | ---                   |
|                                                                                                   | 2.001-3.000                 | 30.0                  | ---  | 11.0                | --- | 15          | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | --- | ---         | ---                   |
| 5252                                                                                              |                             |                       |      |                     |     |             |                       |
| H24                                                                                               | 0.030-0.090                 | 30.0                  | 38.0 | ---                 | --- | 10          | ---                   |
| H25                                                                                               | 0.030-0.090                 | 31.0                  | 39.0 | ---                 | --- | 9           | ---                   |
| H28                                                                                               | 0.030-0.090                 | 38.0                  | ---  | ---                 | --- | 3           | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 5254                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.051-0.113                 | 30.0                  | 41.0 | 11.0                | --- | 16          | ---                   |
|                                                                                                   | 0.114-3.000                 | 30.0                  | 41.0 | 11.0                | --- | 18          | ---                   |
| H32 or H22                                                                                        | 0.051-0.249                 | 36.0                  | 43.0 | 26.0                | --- | 8           | ---                   |
|                                                                                                   | 0.250-2.000                 | 36.0                  | 43.0 | 26.0                | --- | 12          | ---                   |
| H34 or H24                                                                                        | 0.051-0.161                 | 39.0                  | 46.0 | 29.0                | --- | 6           | ---                   |
|                                                                                                   | 0.162-0.249                 | 39.0                  | 46.0 | 29.0                | --- | 7           | ---                   |
|                                                                                                   | 0.250-1.000                 | 39.0                  | 46.0 | 29.0                | --- | 10          | ---                   |
| H36 or H26                                                                                        | 0.051-0.113                 | 42.0                  | 49.0 | 32.0                | --- | 4           | ---                   |
|                                                                                                   | 0.114-0.162                 | 42.0                  | 49.0 | 32.0                | --- | 5           | ---                   |
| H38 or H28                                                                                        | 0.051-0.113                 | 45.0                  | ---  | 35.0                | --- | 4           | ---                   |
|                                                                                                   | 0.114-0.128                 | 45.0                  | ---  | 35.0                | --- | 5           | ---                   |
| H112                                                                                              | 0.250-0.499                 | 32.0                  | ---  | 18.0                | --- | 8           | ---                   |
|                                                                                                   | 0.500-2.000                 | 30.0                  | ---  | 11.0                | --- | 11          | ---                   |
|                                                                                                   | 2.001-3.000                 | 30.0                  | ---  | 11.0                | --- | 15          | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | --- | ---         | ---                   |
| 5454                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.020-0.031                 | 31.0                  | 41.0 | 12.0                | --- | 12          | ---                   |
|                                                                                                   | 0.032-0.050                 | 31.0                  | 41.0 | 12.0                | --- | 14          | ---                   |
|                                                                                                   | 0.051-0.113                 | 31.0                  | 41.0 | 12.0                | --- | 16          | ---                   |
|                                                                                                   | 0.114-3.000                 | 31.0                  | 41.0 | 12.0                | --- | 18          | ---                   |
| H32 or H22                                                                                        | 0.020-0.050                 | 36.0                  | 44.0 | 26.0                | --- | 5           | ---                   |
|                                                                                                   | 0.051-0.249                 | 36.0                  | 44.0 | 26.0                | --- | 8           | ---                   |
|                                                                                                   | 0.250-2.000                 | 36.0                  | 44.0 | 26.0                | --- | 12          | ---                   |
| H34 or H24                                                                                        | 0.020-0.050                 | 39.0                  | 47.0 | 29.0                | --- | 4           | ---                   |
|                                                                                                   | 0.051-0.161                 | 39.0                  | 47.0 | 29.0                | --- | 6           | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max  |             |                       |
| 5454 (Continued)                                                                                  |                             |                       |      |                     |      |             |                       |
| H34 or H24 (con't)                                                                                | 0.162-0.249                 | 39.0                  | 47.0 | 29.0                | ---  | 7           | ---                   |
|                                                                                                   | 0.250-1.000                 | 39.0                  | 47.0 | 29.0                | ---  | 10          | ---                   |
| H112                                                                                              | 0.250-0.499                 | 32.0                  | ---  | 18.0                | ---  | 8           | ---                   |
|                                                                                                   | 0.500-2.000                 | 31.0                  | ---  | 12.0                | ---  | 11          | ---                   |
|                                                                                                   | 2.001-3.000                 | 31.0                  | ---  | 12.0                | ---  | 15          | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | ---  | ---         | ---                   |
| 5456                                                                                              |                             |                       |      |                     |      |             |                       |
| O                                                                                                 | 0.051-1.500                 | 42.0                  | 53.0 | 19.0                | 30.0 | 16          | ---                   |
|                                                                                                   | 1.501-3.000                 | 41.0                  | 52.0 | 18.0                | 30.0 | 16          | ---                   |
|                                                                                                   | 3.001-5.000                 | 40.0                  | ---  | 17.0                | ---  | 14          | ---                   |
|                                                                                                   | 5.001-7.000                 | 39.0                  | ---  | 16.0                | ---  | 14          | ---                   |
|                                                                                                   | 7.001-8.000                 | 38.0                  | ---  | 15.0                | ---  | 12          | ---                   |
| H321                                                                                              | 0.188-0.499                 | 46.0                  | 59.0 | 33.0                | 46.0 | 12          | ---                   |
|                                                                                                   | 0.500-1.500                 | 44.0                  | 56.0 | 31.0                | 44.0 | 12          | ---                   |
|                                                                                                   | 1.501-3.000                 | 41.0                  | 54.0 | 29.0                | 43.0 | 12          | ---                   |
| H112                                                                                              | 0.250-1.500                 | 42.0                  | ---  | 19.0                | ---  | 12          | ---                   |
|                                                                                                   | 1.501-3.000                 | 41.0                  | ---  | 18.0                | ---  | 12          | ---                   |
| H116                                                                                              | 0.063-0.499                 | 46.0                  | ---  | 33.0                | ---  | 10          | ---                   |
|                                                                                                   | 0.500-1.250                 | 46.0                  | ---  | 33.0                | ---  | 12          | ---                   |
|                                                                                                   | 1.251-1.500                 | 44.0                  | ---  | 31.0                | ---  | 12          | ---                   |
|                                                                                                   | 1.501-3.000                 | 41.0                  | ---  | 29.0                | ---  | 12          | ---                   |
|                                                                                                   | 3.001-4.000                 | 40.0                  | ---  | 25.0                | ---  | 12          | ---                   |
| F                                                                                                 | 0.250-8.000                 | ---                   | ---  | ---                 | ---  | ---         | ---                   |
| 5457                                                                                              |                             |                       |      |                     |      |             |                       |
| O                                                                                                 | 0.030-0.090                 | 16.0                  | 22.0 | ---                 | ---  | 20          | ---                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM NONHEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |     |             |                       |
|---------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|-----|-------------|-----------------------|
| ASTM B 209<br>Alloy/Temper                                                                        | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |     | % El<br>min | Bend Dia.<br>Factor N |
|                                                                                                   |                             | min                   | max  | min                 | max |             |                       |
| 5652                                                                                              |                             |                       |      |                     |     |             |                       |
| O                                                                                                 | 0.051-0.113                 | 25.0                  | 31.0 | 9.5                 | --- | 19          | 0                     |
|                                                                                                   | 0.114-0.249                 | 25.0                  | 31.0 | 9.5                 | --- | 20          | 0                     |
|                                                                                                   | 0.250-3.000                 | 25.0                  | 31.0 | 9.5                 | --- | 18          | ---                   |
| H32 or H22                                                                                        | 0.051-0.113                 | 31.0                  | 38.0 | 23.0                | --- | 7           | 2                     |
|                                                                                                   | 0.114-0.249                 | 31.0                  | 38.0 | 23.0                | --- | 9           | 3                     |
|                                                                                                   | 0.250-0.499                 | 31.0                  | 38.0 | 23.0                | --- | 11          | ---                   |
|                                                                                                   | 0.500-2.000                 | 31.0                  | 38.0 | 23.0                | --- | 12          | ---                   |
| H34 or H24                                                                                        | 0.051-0.113                 | 34.0                  | 41.0 | 26.0                | --- | 6           | 3                     |
|                                                                                                   | 0.114-0.249                 | 34.0                  | 41.0 | 26.0                | --- | 7           | 4                     |
|                                                                                                   | 0.250-1.000                 | 34.0                  | 41.0 | 26.0                | --- | 10          | ---                   |
| H112                                                                                              | 0.250-0.499                 | 28.0                  | ---  | 16.0                | --- | 7           | ---                   |
|                                                                                                   | 0.500-2.000                 | 25.0                  | ---  | 9.5                 | --- | 12          | ---                   |
|                                                                                                   | 2.001-3.000                 | 25.0                  | ---  | 9.5                 | --- | 16          | ---                   |
| F                                                                                                 | 0.250-3.000                 | ---                   | ---  | ---                 | --- | ---         | ---                   |
| 5657                                                                                              |                             |                       |      |                     |     |             |                       |
| H241                                                                                              | 0.030-0.090                 | 18.0                  | 26.0 | ---                 | --- | 13          | ---                   |
| H25                                                                                               | 0.030-0.090                 | 20.0                  | 28.0 | ---                 | --- | 8           | ---                   |
| H26                                                                                               | 0.030-0.090                 | 22.0                  | 30.0 | ---                 | --- | 7           | ---                   |
| H28                                                                                               | 0.030-0.090                 | 25.0                  | ---  | ---                 | --- | 5           | ---                   |

See ASTM B 209 for more testing details.

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                         | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                    |                             | min                   | max  | min                 | max  |             |
| 2014                                                                               |                             |                       |      |                     |      |             |
| O                                                                                  | 0.020-0.499                 | ---                   | 32.0 | ---                 | 16.0 | 16          |
|                                                                                    | 0.500-1.000                 | ---                   | 32.0 | ---                 | ---  | 10          |
| T3                                                                                 | 0.020-0.039                 | 59.0                  | ---  | 35.0                | ---  | 14          |
|                                                                                    | 0.040-0.249                 | 59.0                  | ---  | 36.0                | ---  | 14          |
| T4                                                                                 | 0.020-0.249                 | 59.0                  | ---  | 35.0                | ---  | 14          |
| T42                                                                                | 0.020-1.000                 | 58.0                  | ---  | 34.0                | ---  | 14          |
| T451                                                                               | 0.250-1.000                 | 58.0                  | ---  | 36.0                | ---  | 14          |
|                                                                                    | 1.001-2.000                 | 58.0                  | ---  | 36.0                | ---  | 12          |
|                                                                                    | 2.001-3.000                 | 57.0                  | ---  | 36.0                | ---  | 8           |
| T6, T62                                                                            | 0.020-0.039                 | 64.0                  | ---  | 57.0                | ---  | 6           |
|                                                                                    | 0.040-0.249                 | 66.0                  | ---  | 58.0                | ---  | 7           |
| T62, T651                                                                          | 0.250-0.499                 | 67.0                  | ---  | 59.0                | ---  | 7           |
|                                                                                    | 0.500-1.000                 | 67.0                  | ---  | 59.0                | ---  | 6           |
|                                                                                    | 1.001-2.000                 | 67.0                  | ---  | 59.0                | ---  | 4           |
|                                                                                    | 2.001-2.500                 | 65.0                  | ---  | 58.0                | ---  | 2           |
|                                                                                    | 2.501-3.000                 | 63.0                  | ---  | 57.0                | ---  | 2           |
|                                                                                    | 3.001-4.000                 | 59.0                  | ---  | 55.0                | ---  | 1           |
| F                                                                                  | 0.250-1.000                 | ---                   | ---  | ---                 | ---  | ---         |
| Alclad Alloy 2014                                                                  |                             |                       |      |                     |      |             |
| O                                                                                  | 0.020-0.499                 | ---                   | 30.0 | ---                 | 14.0 | 16          |
|                                                                                    | 0.500-1.000                 | ---                   | 32.0 | ---                 | ---  | 10          |
| T3                                                                                 | 0.020-0.024                 | 54.0                  | ---  | 33.0                | ---  | 14          |
|                                                                                    | 0.025-0.039                 | 55.0                  | ---  | 34.0                | ---  | 14          |
|                                                                                    | 0.040-0.249                 | 57.0                  | ---  | 35.0                | ---  | 15          |
| T4                                                                                 | 0.020-0.024                 | 54.0                  | ---  | 31.0                | ---  | 14          |



| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| Alclad Alloy 2014 (Continued)                                                                  |                             |                       |      |                     |      |             |
| T4 (continued)                                                                                 | 0.025-0.039                 | 55.0                  | ---  | 32.0                | ---  | 14          |
|                                                                                                | 0.040-0.249                 | 57.0                  | ---  | 34.0                | ---  | 15          |
| T42                                                                                            | 0.020-0.024                 | 54.0                  | ---  | 31.0                | ---  | 14          |
|                                                                                                | 0.025-0.039                 | 55.0                  | ---  | 32.0                | ---  | 14          |
|                                                                                                | 0.040-0.499                 | 57.0                  | ---  | 34.0                | ---  | 15          |
|                                                                                                | 0.500-1.000                 | 58.0                  | ---  | 34.0                | ---  | 14          |
|                                                                                                |                             |                       |      |                     |      |             |
| T451                                                                                           | 0.250-0.499                 | 57.0                  | ---  | 36.0                | ---  | 15          |
|                                                                                                | 0.500-1.000                 | 58.0                  | ---  | 36.0                | ---  | 14          |
|                                                                                                | 1.001-2.000                 | 58.0                  | ---  | 36.0                | ---  | 12          |
|                                                                                                | 2.001-3.000                 | 57.0                  | ---  | 36.0                | ---  | 8           |
| T6, T62                                                                                        | 0.020-0.024                 | 62.0                  | ---  | 54.0                | ---  | 7           |
|                                                                                                | 0.025-0.039                 | 63.0                  | ---  | 55.0                | ---  | 7           |
|                                                                                                | 0.040-0.249                 | 64.0                  | ---  | 57.0                | ---  | 8           |
| T62, T651                                                                                      | 0.250-0.499                 | 64.0                  | ---  | 57.0                | ---  | 8           |
|                                                                                                | 0.500-1.000                 | 67.0                  | ---  | 59.0                | ---  | 6           |
|                                                                                                | 1.001-2.000                 | 67.0                  | ---  | 59.0                | ---  | 4           |
|                                                                                                | 2.001-2.500                 | 65.0                  | ---  | 58.0                | ---  | 2           |
|                                                                                                | 2.501-3.000                 | 63.0                  | ---  | 57.0                | ---  | 2           |
|                                                                                                | 3.001-4.000                 | 59.0                  | ---  | 55.0                | ---  | 1           |
| F                                                                                              | 0.250-1.000                 | ---                   | ---  | ---                 | ---  | ---         |
| 2024                                                                                           |                             |                       |      |                     |      |             |
| O                                                                                              | 0.010-0.499                 | ---                   | 32.0 | ---                 | 14.0 | 12          |
|                                                                                                | 0.500-1.750                 | ---                   | 32.0 | ---                 | ---  | 12          |
| T3                                                                                             | 0.008-0.009                 | 63.0                  | ---  | 42.0                | ---  | 10          |
|                                                                                                | 0.010-0.020                 | 63.0                  | ---  | 42.0                | ---  | 12          |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| 2024 (Continued)                                                                               |                             |                       |      |                     |      |             |
| T3 (continued)                                                                                 | 0.021-0.128                 | 63.0                  | ---  | 42.0                | ---  | 15          |
|                                                                                                | 0.129-0.249                 | 64.0                  | ---  | 42.0                | ---  | 15          |
| T351                                                                                           | 0.250-0.499                 | 64.0                  | ---  | 42.0                | ---  | 12          |
|                                                                                                | 0.500-1.000                 | 63.0                  | ---  | 42.0                | ---  | 8           |
|                                                                                                | 1.001-1.500                 | 62.0                  | ---  | 42.0                | ---  | 7           |
|                                                                                                | 1.501-2.000                 | 62.0                  | ---  | 42.0                | ---  | 6           |
|                                                                                                | 2.001-3.000                 | 60.0                  | ---  | 42.0                | ---  | 4           |
|                                                                                                | 3.001-4.000                 | 57.0                  | ---  | 41.0                | ---  | 4           |
|                                                                                                | T361                        | 0.020-0.062           | 67.0 | ---                 | 50.0 | ---         |
| 0.063-0.249                                                                                    |                             | 68.0                  | ---  | 51.0                | ---  | 9           |
| 0.250-0.499                                                                                    |                             | 66.0                  | ---  | 49.0                | ---  | 9           |
| 0.500                                                                                          |                             | 66.0                  | ---  | 49.0                | ---  | 10          |
| T4                                                                                             | 0.010-0.020                 | 62.0                  | ---  | 40.0                | ---  | 12          |
|                                                                                                | 0.021-0.249                 | 62.0                  | ---  | 40.0                | ---  | 15          |
| T42                                                                                            | 0.010-0.020                 | 62.0                  | ---  | 38.0                | ---  | 12          |
|                                                                                                | 0.021-0.249                 | 62.0                  | ---  | 38.0                | ---  | 15          |
|                                                                                                | 0.250-0.499                 | 62.0                  | ---  | 38.0                | ---  | 12          |
|                                                                                                | 0.500-1.000                 | 61.0                  | ---  | 38.0                | ---  | 8           |
|                                                                                                | 1.001-1.500                 | 60.0                  | ---  | 38.0                | ---  | 7           |
|                                                                                                | 1.501-2.000                 | 60.0                  | ---  | 38.0                | ---  | 6           |
|                                                                                                | 2.001-3.000                 | 58.0                  | ---  | 38.0                | ---  | 4           |
| T62                                                                                            | 0.010-0.499                 | 64.0                  | ---  | 50.0                | ---  | 5           |
|                                                                                                | 0.500-2.000                 | 63.0                  | ---  | 50.0                | ---  | 5           |
| T72                                                                                            | 0.010-0.249                 | 60.0                  | ---  | 46.0                | ---  | 5           |
| T81                                                                                            | 0.010-0.249                 | 67.0                  | ---  | 58.0                | ---  | 5           |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| 2024 (Continued)                                                                               |                             |                       |      |                     |      |             |
| T851                                                                                           | 0.250-0.499                 | 67.0                  | ---  | 58.0                | ---  | 5           |
|                                                                                                | 0.500-1.000                 | 66.0                  | ---  | 58.0                | ---  | 5           |
|                                                                                                | 1.001-1.499                 | 66.0                  | ---  | 57.0                | ---  | 5           |
| T861                                                                                           | 0.020-0.062                 | 70.0                  | ---  | 62.0                | ---  | 3           |
|                                                                                                | 0.063-0.249                 | 71.0                  | ---  | 66.0                | ---  | 4           |
|                                                                                                | 0.250-0.499                 | 70.0                  | ---  | 64.0                | ---  | 4           |
|                                                                                                | 0.500                       | 70.0                  | ---  | 64.0                | ---  | 4           |
| F                                                                                              | 0.250-3.000                 | ---                   | ---  | ---                 | ---  | ---         |
| Alclad Alloy 2024                                                                              |                             |                       |      |                     |      |             |
| O                                                                                              | 0.008-0.009                 | ---                   | 30.0 | ---                 | 14.0 | 10          |
|                                                                                                | 0.010-0.062                 | ---                   | 30.0 | ---                 | 14.0 | 12          |
|                                                                                                | 0.063-0.499                 | ---                   | 32.0 | ---                 | 14.0 | 12          |
|                                                                                                | 0.500-1.750                 | ---                   | 32.0 | ---                 | ---  | 12          |
| T3                                                                                             | 0.008-0.009                 | 58.0                  | ---  | 39.0                | ---  | 10          |
|                                                                                                | 0.010-0.020                 | 59.0                  | ---  | 39.0                | ---  | 12          |
|                                                                                                | 0.021-0.062                 | 59.0                  | ---  | 39.0                | ---  | 15          |
|                                                                                                | 0.063-0.128                 | 61.0                  | ---  | 40.0                | ---  | 15          |
|                                                                                                | 0.129-0.249                 | 62.0                  | ---  | 40.0                | ---  | 15          |
| T351                                                                                           | 0.250-0.499                 | 62.0                  | ---  | 40.0                | ---  | 12          |
|                                                                                                | 0.500-1.000                 | 63.0                  | ---  | 42.0                | ---  | 8           |
|                                                                                                | 1.001-1.500                 | 62.0                  | ---  | 42.0                | ---  | 7           |
|                                                                                                | 1.501-2.000                 | 62.0                  | ---  | 42.0                | ---  | 6           |
|                                                                                                | 2.001-3.000                 | 60.0                  | ---  | 42.0                | ---  | 4           |
|                                                                                                | 3.001-4.000                 | 57.0                  | ---  | 41.0                | ---  | 4           |
| T361                                                                                           | 0.020-0.062                 | 61.0                  | ---  | 47.0                | ---  | 8           |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |     |                     |     |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|-----|---------------------|-----|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |     | Yield Strength, ksi |     | % El<br>min |
|                                                                                                |                             | min                   | max | min                 | max |             |
| Alclad Alloy 2024 (Continued)                                                                  |                             |                       |     |                     |     |             |
| T361                                                                                           | 0.063-0.187                 | 64.0                  | --- | 48.0                | --- | 9           |
|                                                                                                | 0.188-0.249                 | 64.0                  | --- | 48.0                | --- | 9           |
|                                                                                                | 0.250-0.499                 | 64.0                  | --- | 48.0                | --- | 9           |
|                                                                                                | 0.500                       | 66.0                  | --- | 49.0                | --- | 10          |
| T4                                                                                             | 0.010-0.020                 | 58.0                  | --- | 36.0                | --- | 12          |
|                                                                                                | 0.021-0.062                 | 58.0                  | --- | 36.0                | --- | 12          |
|                                                                                                | 0.063-0.128                 | 61.0                  | --- | 38.0                | --- | 15          |
| T42                                                                                            | 0.008-0.009                 | 55.0                  | --- | 34.0                | --- | 10          |
|                                                                                                | 0.010-0.020                 | 57.0                  | --- | 34.0                | --- | 12          |
|                                                                                                | 0.021-0.062                 | 57.0                  | --- | 34.0                | --- | 15          |
|                                                                                                | 0.063-0.187                 | 60.0                  | --- | 36.0                | --- | 15          |
|                                                                                                | 0.188-0.249                 | 60.0                  | --- | 36.0                | --- | 15          |
|                                                                                                | 0.250-0.499                 | 60.0                  | --- | 36.0                | --- | 12          |
|                                                                                                | 0.500-1.000                 | 61.0                  | --- | 38.0                | --- | 8           |
|                                                                                                | 1.001-1.500                 | 60.0                  | --- | 38.0                | --- | 7           |
|                                                                                                | 1.501-2.000                 | 60.0                  | --- | 38.0                | --- | 6           |
|                                                                                                | 2.001-3.000                 | 58.0                  | --- | 38.0                | --- | 4           |
| T62                                                                                            | 0.010-0.062                 | 60.0                  | --- | 47.0                | --- | 5           |
|                                                                                                | 0.063-0.499                 | 62.0                  | --- | 49.0                | --- | 5           |
| T72                                                                                            | 0.010-0.062                 | 56.0                  | --- | 43.0                | --- | 5           |
|                                                                                                | 0.063-0.249                 | 58.0                  | --- | 45.0                | --- | 5           |
| T81                                                                                            | 0.010-0.062                 | 62.0                  | --- | 54.0                | --- | 5           |
|                                                                                                | 0.063-0.249                 | 65.0                  | --- | 56.0                | --- | 5           |
| T851                                                                                           | 0.250-0.499                 | 65.0                  | --- | 56.0                | --- | 5           |
|                                                                                                | 0.500-1.000                 | 66.0                  | --- | 58.0                | --- | 5           |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| Alclad Alloy 2024 (Continued)                                                                  |                             |                       |      |                     |      |             |
| T861                                                                                           | 0.020-0.062                 | 64.0                  | ---  | 58.0                | ---  | 3           |
|                                                                                                | 0.063-0.187                 | 69.0                  | ---  | 64.0                | ---  | 4           |
|                                                                                                | 0.188-0.249                 | 69.0                  | ---  | 64.0                | ---  | 4           |
|                                                                                                | 0.250-0.499                 | 68.0                  | ---  | 62.0                | ---  | 4           |
|                                                                                                | 0.500                       | 70.0                  | ---  | 64.0                | ---  | 4           |
| F                                                                                              | 0.250-3.000                 | ---                   | ---  | ---                 | ---  | ---         |
| 1 ½ % Alclad Alloy 2024                                                                        |                             |                       |      |                     |      |             |
| O                                                                                              | 0.188-0.499                 | ---                   | 32.0 | ---                 | 14.0 | 12          |
|                                                                                                | 0.050-1.750                 | ---                   | 32.0 | ---                 | ---  | 12          |
| T3                                                                                             | 0.188-0.249                 | 63.0                  | ---  | 41.0                | ---  | 15          |
| T361                                                                                           | 0.188-0.249                 | 65.0                  | ---  | 49.0                | ---  | 9           |
|                                                                                                | 0.250-0.499                 | 65.0                  | ---  | 48.0                | ---  | 9           |
|                                                                                                | 0.500                       | 66.0                  | ---  | 49.0                | ---  | 10          |
| T351                                                                                           | 0.250-0.499                 | 63.0                  | ---  | 41.0                | ---  | 12          |
|                                                                                                | 0.500-1.000                 | 63.0                  | ---  | 42.0                | ---  | 8           |
|                                                                                                | 1.001-1.500                 | 62.0                  | ---  | 42.0                | ---  | 7           |
|                                                                                                | 1.501-2.000                 | 62.0                  | ---  | 42.0                | ---  | 6           |
|                                                                                                | 2.001-3.000                 | 60.0                  | ---  | 42.0                | ---  | 4           |
|                                                                                                | 3.001-4.000                 | 57.0                  | ---  | 41.0                | ---  | 4           |
| T42                                                                                            | 0.188-0.249                 | 61.0                  | ---  | 37.0                | ---  | 15          |
|                                                                                                | 0.250-0.499                 | 61.0                  | ---  | 37.0                | ---  | 12          |
|                                                                                                | 0.500-1.000                 | 61.0                  | ---  | 38.0                | ---  | 8           |
|                                                                                                | 1.001-1.500                 | 60.0                  | ---  | 38.0                | ---  | 7           |
|                                                                                                | 1.501-2.000                 | 60.0                  | ---  | 38.0                | ---  | 6           |
|                                                                                                | 2.001-3.000                 | 58.0                  | ---  | 38.0                | ---  | 4           |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| 1 ½ % Alclad Alloy 2024 (Continued)                                                            |                             |                       |      |                     |      |             |
| T62                                                                                            | 0.188-0.499                 | 62.0                  | ---  | 49.0                | ---  | 5           |
| T72                                                                                            | 0.188-0.249                 | 59.0                  | ---  | 45.0                | ---  | 5           |
| T81                                                                                            | 0.188-0.249                 | 66.0                  | ---  | 57.0                | ---  | 5           |
| T851                                                                                           | 0.250-0.499                 | 66.0                  | ---  | 57.0                | ---  | 5           |
|                                                                                                | 0.500-1.000                 | 66.0                  | ---  | 58.0                | ---  | 5           |
| T861                                                                                           | 0.188-0.249                 | 70.0                  | ---  | 65.0                | ---  | 4           |
|                                                                                                | 0.250-0.499                 | 69.0                  | ---  | 63.0                | ---  | 4           |
|                                                                                                | 0.500                       | 70.0                  | ---  | 64.0                | ---  | 4           |
| F                                                                                              | 0.250-3.000                 | ---                   | ---  | ---                 | ---  | ---         |
| Alclad One-Side Alloy 2024                                                                     |                             |                       |      |                     |      |             |
| O                                                                                              | 0.008-0.009                 | ---                   | 31.0 | ---                 | 14.0 | 10          |
|                                                                                                | 0.010-0.062                 | ---                   | 31.0 | ---                 | 14.0 | 12          |
|                                                                                                | 0.063-0.499                 | ---                   | 32.0 | ---                 | 14.0 | 12          |
| T3                                                                                             | 0.010-0.020                 | 61.0                  | ---  | 40.0                | ---  | 12          |
|                                                                                                | 0.021-0.062                 | 61.0                  | ---  | 40.0                | ---  | 15          |
|                                                                                                | 0.063-0.128                 | 62.0                  | ---  | 41.0                | ---  | 15          |
|                                                                                                | 0.129-0.249                 | 63.0                  | ---  | 41.0                | ---  | 15          |
| T351                                                                                           | 0.250-0.499                 | 63.0                  | ---  | 41.0                | ---  | 12          |
| T361                                                                                           | 0.020-0.062                 | 64.0                  | ---  | 48.0                | ---  | 8           |
|                                                                                                | 0.063-0.249                 | 66.0                  | ---  | 49.0                | ---  | 9           |
|                                                                                                | 0.250-0.499                 | 65.0                  | ---  | 48.0                | ---  | 9           |
| T42                                                                                            | 0.010-0.020                 | 59.0                  | ---  | 35.0                | ---  | 12          |
|                                                                                                | 0.021-0.062                 | 59.0                  | ---  | 36.0                | ---  | 15          |
|                                                                                                | 0.063-0.249                 | 61.0                  | ---  | 37.0                | ---  | 15          |
|                                                                                                | 0.250-0.499                 | 61.0                  | ---  | 37.0                | ---  | 12          |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| Alclad One-Side Alloy 2024 (Continued)                                                         |                             |                       |      |                     |      |             |
| T62                                                                                            | 0.010-0.062                 | 62.0                  | ---  | 48.0                | ---  | 5           |
|                                                                                                | 0.063-0.249                 | 63.0                  | ---  | 49.0                | ---  | 5           |
| T72                                                                                            | 0.010-0.062                 | 58.0                  | ---  | 44.0                | ---  | 5           |
|                                                                                                | 0.063-0.499                 | 59.0                  | ---  | 45.0                | ---  | 5           |
| T81                                                                                            | 0.010-0.062                 | 64.0                  | ---  | 56.0                | ---  | 5           |
|                                                                                                | 0.063-0.249                 | 66.0                  | ---  | 57.0                | ---  | 5           |
| T851                                                                                           | 0.250-0.499                 | 66.0                  | ---  | 57.0                | ---  | 5           |
| T861                                                                                           | 0.020-0.062                 | 67.0                  | ---  | 60.0                | ---  | 3           |
|                                                                                                | 0.063-0.249                 | 70.0                  | ---  | 65.0                | ---  | 4           |
|                                                                                                | 0.250-0.499                 | 69.0                  | ---  | 63.0                | ---  | 4           |
| F                                                                                              | 0.250-0.499                 | ---                   | ---  | ---                 | ---  | ---         |
| 1 ½ % Alclad One-Side Alloy 2024                                                               |                             |                       |      |                     |      |             |
| O                                                                                              | 0.188-0.499                 | ---                   | 32.0 | ---                 | 14.0 | 12          |
| T3                                                                                             | 0.188-0.249                 | 63.0                  | ---  | 41.0                | ---  | 15          |
| T351                                                                                           | 0.250-0.499                 | 63.0                  | ---  | 41.0                | ---  | 12          |
| T361                                                                                           | 0.188-0.249                 | 66.0                  | ---  | 49.0                | ---  | 9           |
|                                                                                                | 0.250-0.499                 | 65.0                  | ---  | 48.0                | ---  | 9           |
| T42                                                                                            | 0.188-0.249                 | 61.0                  | ---  | 37.0                | ---  | 15          |
|                                                                                                | 0.250-0.499                 | 61.0                  | ---  | 37.0                | ---  | 12          |
| T62                                                                                            | 0.188-0.499                 | 63.0                  | ---  | 49.0                | ---  | 5           |
| T72                                                                                            | 0.188-0.249                 | 59.0                  | ---  | 45.0                | ---  | 5           |
| T81                                                                                            | 0.188-0.249                 | 66.0                  | ---  | 57.0                | ---  | 5           |
| T851                                                                                           | 0.250-0.499                 | 66.0                  | ---  | 57.0                | ---  | 5           |
| T861                                                                                           | 0.188-0.249                 | 70.0                  | ---  | 65.0                | ---  | 4           |
|                                                                                                | 0.250-0.499                 | 69.0                  | ---  | 63.0                | ---  | 4           |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| 1 ½ % Alclad One-Side Alloy 2024 (Continued)                                                   |                             |                       |      |                     |      |             |
| F                                                                                              | 0.250-0.499                 | ---                   | ---  | ---                 | ---  | ---         |
| 2124 T851 (see page 103)                                                                       |                             |                       |      |                     |      |             |
| 2219                                                                                           |                             |                       |      |                     |      |             |
| O                                                                                              | 0.020-2.000                 | ---                   | 32.0 | ---                 | 16.0 | 12          |
| T31 flat sheet                                                                                 | 0.020-0.039                 | 46.0                  | ---  | 29.0                | ---  | 8           |
|                                                                                                | 0.040-0.249                 | 46.0                  | ---  | 28.0                | ---  | 10          |
| T351 plate                                                                                     | 0.250-2.000                 | 46.0                  | ---  | 28.0                | ---  | 10          |
|                                                                                                | 2.001-3.000                 | 44.0                  | ---  | 28.0                | ---  | 10          |
|                                                                                                | 3.001-4.000                 | 42.0                  | ---  | 27.0                | ---  | 9           |
|                                                                                                | 4.001-5.000                 | 40.0                  | ---  | 26.0                | ---  | 9           |
|                                                                                                | 5.001-6.000                 | 39.0                  | ---  | 25.0                | ---  | 8           |
| T37                                                                                            | 0.020-0.039                 | 49.0                  | ---  | 38.0                | ---  | 6           |
|                                                                                                | 0.040-2.500                 | 49.0                  | ---  | 37.0                | ---  | 6           |
|                                                                                                | 2.501-3.000                 | 47.0                  | ---  | 36.0                | ---  | 6           |
|                                                                                                | 3.001-4.000                 | 45.0                  | ---  | 35.0                | ---  | 5           |
|                                                                                                | 4.001-5.000                 | 43.0                  | ---  | 34.0                | ---  | 4           |
| T62                                                                                            | 0.020-0.039                 | 54.0                  | ---  | 36.0                | ---  | 6           |
|                                                                                                | 0.040-0.249                 | 54.0                  | ---  | 36.0                | ---  | 7           |
|                                                                                                | 0.250-1.000                 | 54.0                  | ---  | 36.0                | ---  | 8           |
|                                                                                                | 1.001-2.000                 | 54.0                  | ---  | 36.0                | ---  | 7           |
| T81 sheet                                                                                      | 0.020-0.039                 | 62.0                  | ---  | 46.0                | ---  | 6           |
|                                                                                                | 0.040-0.249                 | 62.0                  | ---  | 46.0                | ---  | 7           |
| T851 plate                                                                                     | 0.250-1.000                 | 62.0                  | ---  | 46.0                | ---  | 8           |
|                                                                                                | 1.001-2.000                 | 62.0                  | ---  | 46.0                | ---  | 7           |
|                                                                                                | 2.001-3.000                 | 62.0                  | ---  | 45.0                | ---  | 6           |



| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| 2219 (Continued)                                                                               |                             |                       |      |                     |      |             |
| T851 plate                                                                                     | 3.001-4.000                 | 60.0                  | ---  | 44.0                | ---  | 5           |
|                                                                                                | 4.001-5.000                 | 59.0                  | ---  | 43.0                | ---  | 5           |
|                                                                                                | 5.001-6.000                 | 57.0                  | ---  | 42.0                | ---  | 4           |
| T87                                                                                            | 0.020-0.039                 | 64.0                  | ---  | 52.0                | ---  | 5           |
|                                                                                                | 0.040-0.249                 | 64.0                  | ---  | 52.0                | ---  | 6           |
|                                                                                                | 0.250-1.000                 | 64.0                  | ---  | 51.0                | ---  | 7           |
|                                                                                                | 1.001-2.000                 | 64.0                  | ---  | 51.0                | ---  | 6           |
|                                                                                                | 2.001-3.000                 | 64.0                  | ---  | 51.0                | ---  | 6           |
|                                                                                                | 3.001-4.000                 | 62.0                  | ---  | 50.0                | ---  | 4           |
|                                                                                                | 4.001-5.000                 | 61.0                  | ---  | 49.0                | ---  | 3           |
|                                                                                                | F                           | 0.250-2.000           | ---  | ---                 | ---  | ---         |
| Alclad Alloy 2219                                                                              |                             |                       |      |                     |      |             |
| O                                                                                              | 0.020-2.000                 | ---                   | 32.0 | ---                 | 16.0 | 12          |
| T31 flat sheet                                                                                 | 0.040-0.099                 | 42.0                  | ---  | 25.0                | ---  | 10          |
|                                                                                                | 0.100-0.249                 | 44.0                  | ---  | 26.0                | ---  | 10          |
| T351 plate                                                                                     | 0.250-0.499                 | 44.0                  | ---  | 26.0                | ---  | 10          |
| T37                                                                                            | 0.040-0.099                 | 45.0                  | ---  | 34.0                | ---  | 6           |
|                                                                                                | 0.100-0.499                 | 47.0                  | ---  | 35.0                | ---  | 6           |
| T62                                                                                            | 0.020-0.039                 | 44.0                  | ---  | 29.0                | ---  | 6           |
|                                                                                                | 0.040-0.099                 | 49.0                  | ---  | 32.0                | ---  | 7           |
|                                                                                                | 0.100-0.249                 | 51.0                  | ---  | 34.0                | ---  | 7           |
|                                                                                                | 0.250-0.499                 | 51.0                  | ---  | 34.0                | ---  | 8           |
|                                                                                                | 0.500-1.000                 | 54.0                  | ---  | 36.0                | ---  | 8           |
|                                                                                                | 1.001-2.000                 | 54.0                  | ---  | 36.0                | ---  | 7           |
|                                                                                                | 0.020-0.039                 | 49.0                  | ---  | 37.0                | ---  | 6           |
| T81 flat sheet                                                                                 | 0.020-0.039                 | 49.0                  | ---  | 37.0                | ---  | 6           |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| Alclad Alloy 2219 (Continued)                                                                  |                             |                       |      |                     |      |             |
| T81 flat sheet (con't)                                                                         | 0.040-0.099                 | 55.0                  | ---  | 41.0                | ---  | 7           |
|                                                                                                | 0.100-0.249                 | 58.0                  | ---  | 43.0                | ---  | 7           |
| T851 plate                                                                                     | 0.250-0.499                 | 58.0                  | ---  | 42.0                | ---  | 8           |
| T87                                                                                            | 0.040-0.099                 | 57.0                  | ---  | 46.0                | ---  | 6           |
|                                                                                                | 0.100-0.249                 | 60.0                  | ---  | 48.0                | ---  | 6           |
|                                                                                                | 0.250-0.499                 | 60.0                  | ---  | 48.0                | ---  | 7           |
| F                                                                                              | 0.250-2.000                 | ---                   | ---  | ---                 | ---  | ---         |
| 6061                                                                                           |                             |                       |      |                     |      |             |
| O                                                                                              | 0.006-0.007                 | ---                   | 22.0 | ---                 | 12.0 | 10          |
|                                                                                                | 0.008-0.009                 | ---                   | 22.0 | ---                 | 12.0 | 12          |
|                                                                                                | 0.010-0.020                 | ---                   | 22.0 | ---                 | 12.0 | 14          |
|                                                                                                | 0.021-0.128                 | ---                   | 22.0 | ---                 | 12.0 | 16          |
|                                                                                                | 0.129-0.499                 | ---                   | 22.0 | ---                 | 12.0 | 18          |
|                                                                                                | 0.500-1.000                 | ---                   | 22.0 | ---                 | ---  | 18          |
|                                                                                                | 1.001-3.000                 | ---                   | 22.0 | ---                 | ---  | 16          |
| T4                                                                                             | 0.006-0.007                 | 30.0                  | ---  | 16.0                | ---  | 10          |
|                                                                                                | 0.008-0.009                 | 30.0                  | ---  | 16.0                | ---  | 12          |
|                                                                                                | 0.010-0.020                 | 30.0                  | ---  | 16.0                | ---  | 14          |
|                                                                                                | 0.021-0.249                 | 30.0                  | ---  | 16.0                | ---  | 16          |
| T451                                                                                           | 0.250-1.000                 | 30.0                  | ---  | 16.0                | ---  | 18          |
|                                                                                                | 1.001-3.000                 | 30.0                  | ---  | 16.0                | ---  | 16          |
| T42                                                                                            | 0.006-0.007                 | 30.0                  | ---  | 14.0                | ---  | 10          |
|                                                                                                | 0.008-0.009                 | 30.0                  | ---  | 14.0                | ---  | 12          |
|                                                                                                | 0.010-0.020                 | 30.0                  | ---  | 14.0                | ---  | 14          |
|                                                                                                | 0.021-0.249                 | 30.0                  | ---  | 14.0                | ---  | 16          |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| 6061 (Continued)                                                                               |                             |                       |      |                     |      |             |
| T42 (continued)                                                                                | 0.250-1.000                 | 30.0                  | ---  | 14.0                | ---  | 18          |
|                                                                                                | 1.001-3.000                 | 30.0                  | ---  | 14.0                | ---  | 16          |
| T6, T62                                                                                        | 0.006-0.007                 | 42.0                  | ---  | 35.0                | ---  | 4           |
|                                                                                                | 0.008-0.009                 | 42.0                  | ---  | 35.0                | ---  | 6           |
|                                                                                                | 0.010-0.020                 | 42.0                  | ---  | 35.0                | ---  | 8           |
|                                                                                                | 0.021-0.249                 | 42.0                  | ---  | 35.0                | ---  | 10          |
|                                                                                                | 0.250-0.499                 | 42.0                  | ---  | 35.0                | ---  | 10          |
| T62, T651                                                                                      | 0.500-1.000                 | 42.0                  | ---  | 35.0                | ---  | 9           |
|                                                                                                | 1.001-2.000                 | 42.0                  | ---  | 35.0                | ---  | 8           |
|                                                                                                | 2.001-4.000                 | 42.0                  | ---  | 35.0                | ---  | 6           |
|                                                                                                | 4.001-6.000                 | 40.0                  | ---  | 35.0                | ---  | 6           |
|                                                                                                | F                           | 0.250-3.000           | ---  | ---                 | ---  | ---         |
| Alclad Alloy 6061                                                                              |                             |                       |      |                     |      |             |
| O                                                                                              | 0.010-0.020                 | ---                   | 20.0 | ---                 | 12.0 | 14          |
|                                                                                                | 0.021-0.128                 | ---                   | 20.0 | ---                 | 12.0 | 16          |
|                                                                                                | 0.129-0.499                 | ---                   | 20.0 | ---                 | 12.0 | 18          |
|                                                                                                | 0.500-1.000                 | ---                   | 22.0 | ---                 | ---  | 18          |
|                                                                                                | 1.001-3.000                 | ---                   | 22.0 | ---                 | ---  | 16          |
| T4                                                                                             | 0.010-0.020                 | 27.0                  | ---  | 14.0                | ---  | 14          |
|                                                                                                | 0.021-0.249                 | 27.0                  | ---  | 14.0                | ---  | 16          |
| T451                                                                                           | 0.250-0.499                 | 27.0                  | ---  | 14.0                | ---  | 18          |
|                                                                                                | 0.500-1.000                 | 30.0                  | ---  | 16.0                | ---  | 18          |
|                                                                                                | 1.001-3.000                 | 30.0                  | ---  | 16.0                | ---  | 16          |
| T42                                                                                            | 0.010-0.020                 | 27.0                  | ---  | 12.0                | ---  | 14          |
|                                                                                                | 0.021-0.249                 | 27.0                  | ---  | 12.0                | ---  | 16          |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| Alclad Alloy 6061 (Continued)                                                                  |                             |                       |      |                     |      |             |
| T42 (continued)                                                                                | 0.250-0.499                 | 27.0                  | ---  | 12.0                | ---  | 18          |
|                                                                                                | 0.500-1.000                 | 30.0                  | ---  | 14.0                | ---  | 18          |
|                                                                                                | 1.001-3.000                 | 30.0                  | ---  | 14.0                | ---  | 16          |
| T6, T62                                                                                        | 0.010-0.020                 | 38.0                  | ---  | 32.0                | ---  | 8           |
|                                                                                                | 0.021-0.249                 | 38.0                  | ---  | 32.0                | ---  | 10          |
| T62, T651                                                                                      | 0.250-0.499                 | 38.0                  | ---  | 32.0                | ---  | 10          |
|                                                                                                | 0.500-1.000                 | 42.0                  | ---  | 35.0                | ---  | 9           |
|                                                                                                | 1.001-2.000                 | 42.0                  | ---  | 35.0                | ---  | 8           |
|                                                                                                | 2.001-4.000                 | 42.0                  | ---  | 35.0                | ---  | 6           |
|                                                                                                | 4.001-5.000                 | 40.0                  | ---  | 35.0                | ---  | 6           |
| F                                                                                              | 0.250-3.000                 | ---                   | ---  | ---                 | ---  | ---         |
| 7075                                                                                           |                             |                       |      |                     |      |             |
| O                                                                                              | 0.015-0.499                 | ---                   | 40.0 | ---                 | 21.0 | 10          |
|                                                                                                | 0.500-2.000                 | ---                   | 40.0 | ---                 | ---  | 10          |
| T6, T62                                                                                        | 0.008-0.011                 | 74.0                  | ---  | 63.0                | ---  | 5           |
|                                                                                                | 0.012-0.039                 | 76.0                  | ---  | 67.0                | ---  | 7           |
|                                                                                                | 0.040-0.125                 | 78.0                  | ---  | 68.0                | ---  | 8           |
|                                                                                                | 0.126-0.249                 | 78.0                  | ---  | 69.0                | ---  | 8           |
|                                                                                                | 0.250-0.499                 | 78.0                  | ---  | 67.0                | ---  | 9           |
| T62, T651                                                                                      | 0.500-1.000                 | 78.0                  | ---  | 68.0                | ---  | 7           |
|                                                                                                | 1.001-2.000                 | 77.0                  | ---  | 67.0                | ---  | 6           |
|                                                                                                | 2.001-2.500                 | 76.0                  | ---  | 64.0                | ---  | 5           |
|                                                                                                | 2.501-3.000                 | 72.0                  | ---  | 61.0                | ---  | 5           |
|                                                                                                | 3.001-3.500                 | 71.0                  | ---  | 58.0                | ---  | 5           |
|                                                                                                | 3.501-4.000                 | 67.0                  | ---  | 54.0                | ---  | 3           |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| 7075 (Continued)                                                                               |                             |                       |      |                     |      |             |
| T73 sheet                                                                                      | 0.040-0.249                 | 67.0                  | ---  | 56.0                | ---  | 8           |
| T7351 plate                                                                                    | 0.250-1.000                 | 69.0                  | ---  | 57.0                | ---  | 7           |
|                                                                                                | 1.001-2.000                 | 69.0                  | ---  | 57.0                | ---  | 6           |
|                                                                                                | 2.001-2.500                 | 66.0                  | ---  | 52.0                | ---  | 6           |
|                                                                                                | 2.501-3.000                 | 64.0                  | ---  | 49.0                | ---  | 6           |
| T76 sheet                                                                                      | 0.125-0.249                 | 73.0                  | ---  | 62.0                | ---  | 8           |
| T7651 plate                                                                                    | 0.250-0.499                 | 72.0                  | ---  | 61.0                | ---  | 8           |
|                                                                                                | 0.500-1.000                 | 71.0                  | ---  | 60.0                | ---  | 6           |
| F                                                                                              | 0.250-4.000                 | ---                   | ---  | ---                 | ---  | ---         |
| Alclad Alloy 7075                                                                              |                             |                       |      |                     |      |             |
| O                                                                                              | 0.008-0.014                 | ---                   | 36.0 | ---                 | 20.0 | 9           |
|                                                                                                | 0.015-0.062                 | ---                   | 36.0 | ---                 | 20.0 | 10          |
|                                                                                                | 0.063-0.187                 | ---                   | 38.0 | ---                 | 20.0 | 10          |
|                                                                                                | 0.188-0.499                 | ---                   | 39.0 | ---                 | 21.0 | 10          |
|                                                                                                | 0.500-1.000                 | ---                   | 40.0 | ---                 | ---  | 10          |
| T6, T62                                                                                        | 0.008-0.011                 | 68.0                  | ---  | 58.0                | ---  | 5           |
|                                                                                                | 0.012-0.039                 | 70.0                  | ---  | 60.0                | ---  | 7           |
|                                                                                                | 0.040-0.062                 | 72.0                  | ---  | 62.0                | ---  | 8           |
|                                                                                                | 0.063-0.187                 | 73.0                  | ---  | 63.0                | ---  | 8           |
|                                                                                                | 0.188-0.249                 | 75.0                  | ---  | 64.0                | ---  | 8           |
| T62, T651                                                                                      | 0.250-0.499                 | 75.0                  | ---  | 65.0                | ---  | 9           |
|                                                                                                | 0.500-1.000                 | 78.0                  | ---  | 68.0                | ---  | 7           |
|                                                                                                | 1.001-2.000                 | 77.0                  | ---  | 67.0                | ---  | 6           |
|                                                                                                | 2.001-2.500                 | 76.0                  | ---  | 64.0                | ---  | 5           |
|                                                                                                | 2.501-3.000                 | 72.0                  | ---  | 61.0                | ---  | 5           |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| Alclad Alloy 7075 (Continued)                                                                  |                             |                       |      |                     |      |             |
| T62, T651 (continued)                                                                          | 3.001-3.500                 | 71.0                  | ---  | 58.0                | ---  | 5           |
|                                                                                                | 3.501-4.000                 | 67.0                  | ---  | 54.0                | ---  | 3           |
| T76 sheet                                                                                      | 0.125-0.187                 | 68.0                  | ---  | 57.0                | ---  | 8           |
|                                                                                                | 0.188-0.249                 | 70.0                  | ---  | 59.0                | ---  | 8           |
| T7651 plate                                                                                    | 0.250-0.499                 | 69.0                  | ---  | 58.0                | ---  | 8           |
|                                                                                                | 0.500-1.000                 | 71.0                  | ---  | 60.0                | ---  | 6           |
| F                                                                                              | 0.250-4.000                 | ---                   | ---  | ---                 | ---  | ---         |
| Alclad One-Side Alloy 7075                                                                     |                             |                       |      |                     |      |             |
| O                                                                                              | 0.015-0.062                 | ---                   | 38.0 | ---                 | 21.0 | 10          |
|                                                                                                | 0.063-0.187                 | ---                   | 39.0 | ---                 | 21.0 | 10          |
|                                                                                                | 0.188-0.499                 | ---                   | 39.0 | ---                 | 21.0 | 10          |
|                                                                                                | 0.500-1.000                 | ---                   | 40.0 | ---                 | ---  | 10          |
| T6, T62                                                                                        | 0.015-0.039                 | 73.0                  | ---  | 63.0                | ---  | 7           |
|                                                                                                | 0.040-0.062                 | 74.0                  | ---  | 64.0                | ---  | 8           |
|                                                                                                | 0.063-0.187                 | 75.0                  | ---  | 65.0                | ---  | 8           |
|                                                                                                | 0.188-0.249                 | 76.0                  | ---  | 66.0                | ---  | 8           |
| T62, T651                                                                                      | 0.250-0.499                 | 76.0                  | ---  | 66.0                | ---  | 9           |
|                                                                                                | 0.500-1.000                 | 78.0                  | ---  | 68.0                | ---  | 7           |
|                                                                                                | 1.001-2.000                 | 77.0                  | ---  | 67.0                | ---  | 6           |
| F                                                                                              | 0.250-2.000                 | ---                   | ---  | ---                 | ---  | ---         |
| 7008 Alclad Alloy 7075                                                                         |                             |                       |      |                     |      |             |
| O                                                                                              | 0.015-0.499                 | ---                   | 40.0 | ---                 | 21.0 | 10          |
|                                                                                                | 0.500-2.000                 | ---                   | 40.0 | ---                 | ---  | 10          |
| T6, T62                                                                                        | 0.015-0.039                 | 73.0                  | ---  | 63.0                | ---  | 7           |
|                                                                                                | 0.040-0.187                 | 75.0                  | ---  | 65.0                | ---  | 8           |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| 7008 Alclad Alloy 7075 (Continued)                                                             |                             |                       |      |                     |      |             |
| T6, T62 (continued)                                                                            | 0.188-0.249                 | 76.0                  | ---  | 66.0                | ---  | 8           |
| T62, T651                                                                                      | 0.250-0.499                 | 76.0                  | ---  | 66.0                | ---  | 9           |
|                                                                                                | 0.500-1.000                 | 78.0                  | ---  | 68.0                | ---  | 7           |
|                                                                                                | 1.001-2.000                 | 77.0                  | ---  | 67.0                | ---  | 6           |
|                                                                                                | 2.001-2.500                 | 76.0                  | ---  | 64.0                | ---  | 5           |
|                                                                                                | 2.501-3.000                 | 72.0                  | ---  | 61.0                | ---  | 5           |
|                                                                                                | 3.001-3.500                 | 71.0                  | ---  | 58.0                | ---  | 5           |
|                                                                                                | 3.501-4.000                 | 67.0                  | ---  | 54.0                | ---  | 3           |
| T76 sheet                                                                                      | 0.040-0.062                 | 70.0                  | ---  | 59.0                | ---  | 8           |
|                                                                                                | 0.063-0.187                 | 71.0                  | ---  | 60.0                | ---  | 8           |
|                                                                                                | 0.188-0.249                 | 72.0                  | ---  | 61.0                | ---  | 8           |
| T7651 plate                                                                                    | 0.250-0.499                 | 71.0                  | ---  | 60.0                | ---  | 8           |
|                                                                                                | 0.500-1.000                 | 71.0                  | ---  | 60.0                | ---  | 6           |
| F                                                                                              | 0.250-4.000                 | ---                   | ---  | ---                 | ---  | ---         |
| 7178                                                                                           |                             |                       |      |                     |      |             |
| O                                                                                              | 0.015-0.499                 | ---                   | 40.0 | ---                 | 21.0 | 10          |
|                                                                                                | 0.500                       | ---                   | 40.0 | ---                 | ---  | 10          |
| T6, T62                                                                                        | 0.015-0.044                 | 83.0                  | ---  | 72.0                | ---  | 7           |
|                                                                                                | 0.045-0.249                 | 84.0                  | ---  | 73.0                | ---  | 8           |
| T62, T651                                                                                      | 0.250-0.499                 | 84.0                  | ---  | 73.0                | ---  | 8           |
|                                                                                                | 0.500-1.000                 | 84.0                  | ---  | 73.0                | ---  | 6           |
|                                                                                                | 1.001-1.500                 | 84.0                  | ---  | 73.0                | ---  | 4           |
|                                                                                                | 1.501-2.000                 | 80.0                  | ---  | 70.0                | ---  | 3           |
| T76                                                                                            | 0.045-0.249                 | 75.0                  | ---  | 64.0                | ---  | 8           |
| T7651                                                                                          | 0.250-0.499                 | 74.0                  | ---  | 63.0                | ---  | 8           |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM HEAT-TREATABLE ALLOYS - SHEET & PLATE (Continued) |                             |                       |      |                     |      |             |
|------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|---------------------|------|-------------|
| ASTM B 209<br>Alloy/Temper                                                                     | Specified Thickness,<br>in. | Tensile Strength, ksi |      | Yield Strength, ksi |      | % El<br>min |
|                                                                                                |                             | min                   | max  | min                 | max  |             |
| 7178 (Continued)                                                                               |                             |                       |      |                     |      |             |
| T7651 (continued)                                                                              | 0.500-1.000                 | 73.0                  | ---  | 62.0                | ---  | 6           |
| F                                                                                              | 0.250-2.000                 | ---                   | ---  | ---                 | ---  | ---         |
| Alclad Alloy 7178                                                                              |                             |                       |      |                     |      |             |
| O                                                                                              | 0.015-0.062                 | ---                   | 36.0 | ---                 | 20.0 | 10          |
|                                                                                                | 0.063-0.187                 | ---                   | 38.0 | ---                 | 20.0 | 10          |
|                                                                                                | 0.188-0.499                 | ---                   | 40.0 | ---                 | 21.0 | 10          |
|                                                                                                | 0.500                       | ---                   | 40.0 | ---                 | ---  | 10          |
| T6, T62                                                                                        | 0.015-0.044                 | 76.0                  | ---  | 66.0                | ---  | 7           |
|                                                                                                | 0.045-0.062                 | 78.0                  | ---  | 68.0                | ---  | 8           |
|                                                                                                | 0.063-0.187                 | 80.0                  | ---  | 70.0                | ---  | 8           |
|                                                                                                | 0.188-0.249                 | 82.0                  | ---  | 71.0                | ---  | 8           |
| T62, T651                                                                                      | 0.250-0.499                 | 82.0                  | ---  | 71.0                | ---  | 8           |
|                                                                                                | 0.500-1.000                 | 84.0                  | ---  | 73.0                | ---  | 6           |
|                                                                                                | 1.001-1.500                 | 84.0                  | ---  | 73.0                | ---  | 4           |
|                                                                                                | 1.501-2.000                 | 80.0                  | ---  | 70.0                | ---  | 3           |
| T76                                                                                            | 0.045-0.062                 | 71.0                  | ---  | 60.0                | ---  | 8           |
|                                                                                                | 0.063-0.187                 | 71.0                  | ---  | 60.0                | ---  | 8           |
|                                                                                                | 0.188-0.249                 | 73.0                  | ---  | 61.0                | ---  | 8           |
| T7651                                                                                          | 0.250-0.499                 | 72.0                  | ---  | 60.0                | ---  | 8           |
|                                                                                                | 0.500-1.000                 | 73.0                  | ---  | 62.0                | ---  | 6           |
| F                                                                                              | 0.250-2.000                 | ---                   | ---  | ---                 | ---  | ---         |

See ASTM B 209 for more testing details.



| MECHANICAL PROPERTIES OF ALUMINUM HEAT-TREATABLE ALLOY 2124-T851 - SHEET & PLATE |                             |                 |                       |     |                     |     |             |
|----------------------------------------------------------------------------------|-----------------------------|-----------------|-----------------------|-----|---------------------|-----|-------------|
| ASTM B 209<br>Alloy/Temper                                                       | Specified Thickness,<br>in. | Axis of<br>Test | Tensile Strength, ksi |     | Yield Strength, ksi |     | % El<br>min |
|                                                                                  |                             |                 | min                   | max | min                 | max |             |
| 2124                                                                             |                             |                 |                       |     |                     |     |             |
| T851                                                                             | 1.500-2.000                 | L               | 66.0                  | --- | 57.0                | --- | 6           |
|                                                                                  |                             | LT              | 66.0                  | --- | 57.0                | --- | 5           |
|                                                                                  |                             | ST              | 64.0                  | --- | 55.0                | --- | 1.5         |
|                                                                                  | 2.001-3.000                 | L               | 65.0                  | --- | 57.0                | --- | 5           |
|                                                                                  |                             | LT              | 65.0                  | --- | 57.0                | --- | 4           |
|                                                                                  |                             | ST              | 63.0                  | --- | 55.0                | --- | 1.5         |
|                                                                                  | 3.001-4.000                 | L               | 65.0                  | --- | 56.0                | --- | 5           |
|                                                                                  |                             | LT              | 65.0                  | --- | 56.0                | --- | 4           |
|                                                                                  |                             | ST              | 62.0                  | --- | 54.0                | --- | 1.5         |
|                                                                                  | 4.001-5.000                 | L               | 64.0                  | --- | 55.0                | --- | 5           |
|                                                                                  |                             | LT              | 64.0                  | --- | 55.0                | --- | 4           |
|                                                                                  |                             | ST              | 61.0                  | --- | 53.0                | --- | 1.5         |
|                                                                                  | 5.001-6.000                 | L               | 63.0                  | --- | 54.0                | --- | 5           |
|                                                                                  |                             | LT              | 63.0                  | --- | 54.0                | --- | 4           |
|                                                                                  |                             | ST              | 58.0                  | --- | 51.0                | --- | 1.5         |

L - Longitudinal; LT - Long Transverse; ST - Short Transverse. See ASTM B 209 for more testing details.

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM ALLOYS - DRAWN SEAMLESS TUBES |                             |                       |      |                            |                           |                      |
|----------------------------------------------------------------------------|-----------------------------|-----------------------|------|----------------------------|---------------------------|----------------------|
| ASTM B 210<br>Alloy/Temper                                                 | Specified<br>Thickness, in. | Tensile Strength, ksi |      | Yield Strength<br>ksi, min | % El, min<br>Full-Section | % El, min<br>Cut-Out |
|                                                                            |                             | min                   | max  |                            |                           |                      |
| 1060                                                                       |                             |                       |      |                            |                           |                      |
| O                                                                          | 0.018-0.500                 | 8.5                   | 13.5 | 2.5                        | ---                       | ---                  |
| H12                                                                        |                             | 10.0                  | ---  | 4.0                        | ---                       | ---                  |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM ALLOYS - DRAWN SEAMLESS TUBES (Continued) |                             |                       |      |                            |                           |                      |
|----------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|----------------------------|---------------------------|----------------------|
| ASTM B 210<br>Alloy/Temper                                                             | Specified<br>Thickness, in. | Tensile Strength, ksi |      | Yield Strength<br>ksi, min | % El, min<br>Full-Section | % El, min<br>Cut-Out |
|                                                                                        |                             | min                   | max  |                            |                           |                      |
| 1060 (Continued)                                                                       |                             |                       |      |                            |                           |                      |
| H14                                                                                    | 0.018-0.500                 | 12.0                  | ---  | 10.0                       | ---                       | ---                  |
| H18                                                                                    |                             | 16.0                  | ---  | 13.0                       | ---                       | ---                  |
| H113                                                                                   |                             | 8.5                   | ---  | 2.5                        | ---                       | ---                  |
| 1100                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.500                 | 11.0                  | 15.5 | 3.5                        | ---                       | ---                  |
| H12                                                                                    |                             | 14.0                  | ---  | 11.0                       | ---                       | ---                  |
| H14                                                                                    |                             | 16.0                  | ---  | 14.0                       | ---                       | ---                  |
| H16                                                                                    |                             | 19.0                  | ---  | 17.0                       | ---                       | ---                  |
| H18                                                                                    |                             | 22.0                  | ---  | 20.0                       | ---                       | ---                  |
| H113                                                                                   |                             | 11.0                  | ---  | 3.5                        | ---                       | ---                  |
| 2011                                                                                   |                             |                       |      |                            |                           |                      |
| T3                                                                                     | 0.018-0.049                 | 47.0                  | ---  | 40.0                       | ---                       | ---                  |
|                                                                                        | 0.050-0.500                 | 47.0                  | ---  | 40.0                       | 10                        | 8                    |
| T4511                                                                                  | 0.018-0.049                 | 44.0                  | ---  | 25.0                       | ---                       | ---                  |
|                                                                                        | 0.050-0.259                 | 44.0                  | ---  | 25.0                       | 20                        | 18                   |
|                                                                                        | 0.260-0.500                 | 44.0                  | ---  | 25.0                       | 20                        | 20                   |
| 2014                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.500                 | ---                   | 32.0 | 16.0 max                   | ---                       | ---                  |
| T4, T42                                                                                | 0.018-0.024                 | 54.0                  | ---  | 30.0                       | 10                        | ---                  |
|                                                                                        | 0.025-0.049                 | 54.0                  | ---  | 30.0                       | 12                        | 10                   |
|                                                                                        | 0.050-0.259                 | 54.0                  | ---  | 30.0                       | 14                        | 10                   |
|                                                                                        | 0.260-0.500                 | 54.0                  | ---  | 30.0                       | 16                        | 12                   |
|                                                                                        | T6, T62                     | 0.018-0.024           | 65.0 | ---                        | 55.0                      | 7                    |
| 0.025-0.049                                                                            |                             | 65.0                  | ---  | 55.0                       | 7                         | 6                    |
| 0.050-0.259                                                                            |                             | 65.0                  | ---  | 55.0                       | 8                         | 7                    |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM ALLOYS - DRAWN SEAMLESS TUBES (Continued) |                             |                       |      |                            |                           |                      |
|----------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|----------------------------|---------------------------|----------------------|
| ASTM B 210<br>Alloy/Temper                                                             | Specified<br>Thickness, in. | Tensile Strength, ksi |      | Yield Strength<br>ksi, min | % El, min<br>Full-Section | % El, min<br>Cut-Out |
|                                                                                        |                             | min                   | max  |                            |                           |                      |
| 2014 (Continued)                                                                       |                             |                       |      |                            |                           |                      |
| T6,T62 (continued)                                                                     | 0.260-0.500                 | 65.0                  | ---  | 55.0                       | 9                         | 8                    |
| 2024                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.500                 | ---                   | 32.0 | 15.0 max                   | ---                       | ---                  |
| T3                                                                                     | 0.018-0.024                 | 64.0                  | ---  | 42.0                       | 10                        | ---                  |
|                                                                                        | 0.025-0.049                 | 64.0                  | ---  | 42.0                       | 12                        | 10                   |
|                                                                                        | 0.050-0.259                 | 64.0                  | ---  | 42.0                       | 14                        | 10                   |
|                                                                                        | 0.260-0.500                 | 64.0                  | ---  | 42.0                       | 16                        | 12                   |
| T42                                                                                    | 0.018-0.024                 | 64.0                  | ---  | 40.0                       | 10                        | ---                  |
|                                                                                        | 0.025-0.049                 | 64.0                  | ---  | 40.0                       | 12                        | 10                   |
|                                                                                        | 0.050-0.259                 | 64.0                  | ---  | 40.0                       | 14                        | 10                   |
|                                                                                        | 0.260-0.500                 | 64.0                  | ---  | 40.0                       | 16                        | 12                   |
| 3003                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.010-0.024                 | 14.0                  | 19.0 | 5.0                        | ---                       | ---                  |
|                                                                                        | 0.025-0.049                 | 14.0                  | 19.0 | 5.0                        | 30                        | 20                   |
|                                                                                        | 0.050-0.259                 | 14.0                  | 19.0 | 5.0                        | 35                        | 25                   |
|                                                                                        | 0.260-0.500                 | 14.0                  | 19.0 | 5.0                        | ---                       | 30                   |
| H12                                                                                    | 0.010-0.500                 | 17.0                  | ---  | 12.0                       | ---                       | ---                  |
| H14                                                                                    | 0.010-0.024                 | 20.0                  | ---  | 17.0                       | 3                         | ---                  |
|                                                                                        | 0.025-0.049                 | 20.0                  | ---  | 17.0                       | 5                         | 3                    |
|                                                                                        | 0.050-0.259                 | 20.0                  | ---  | 17.0                       | 8                         | 4                    |
|                                                                                        | 0.260-0.500                 | 20.0                  | ---  | 17.0                       | ---                       | ---                  |
| H16                                                                                    | 0.010-0.024                 | 24.0                  | ---  | 21.0                       | ---                       | ---                  |
|                                                                                        | 0.025-0.049                 | 24.0                  | ---  | 21.0                       | 3                         | 2                    |
|                                                                                        | 0.050-0.259                 | 24.0                  | ---  | 21.0                       | 5                         | 4                    |
|                                                                                        | 0.260-0.500                 | 24.0                  | ---  | 21.0                       | ---                       | ---                  |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM ALLOYS - DRAWN SEAMLESS TUBES (Continued) |                             |                       |      |                            |                           |                      |
|----------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|----------------------------|---------------------------|----------------------|
| ASTM B 210<br>Alloy/Temper                                                             | Specified<br>Thickness, in. | Tensile Strength, ksi |      | Yield Strength<br>ksi, min | % El, min<br>Full-Section | % El, min<br>Cut-Out |
|                                                                                        |                             | min                   | max  |                            |                           |                      |
| 3003 (Continued)                                                                       |                             |                       |      |                            |                           |                      |
| H18                                                                                    | 0.010-0.024                 | 27.0                  | ---  | 24.0                       | 2                         | ---                  |
|                                                                                        | 0.025-0.049                 | 27.0                  | ---  | 24.0                       | 3                         | 2                    |
|                                                                                        | 0.050-0.259                 | 27.0                  | ---  | 24.0                       | 5                         | 3                    |
|                                                                                        | 0.260-0.500                 | 27.0                  | ---  | 24.0                       | ---                       | ---                  |
| H113                                                                                   | 0.010-0.500                 | 14.0                  | ---  | 5.0                        | ---                       | ---                  |
| Alclad 3003                                                                            |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.010-0.024                 | 13.0                  | 19.0 | 4.5                        | ---                       | ---                  |
|                                                                                        | 0.025-0.049                 | 13.0                  | 19.0 | 4.5                        | 30                        | 20                   |
|                                                                                        | 0.050-0.259                 | 13.0                  | 19.0 | 4.5                        | 35                        | 25                   |
|                                                                                        | 0.260-0.500                 | 13.0                  | 19.0 | 4.5                        | ---                       | 30                   |
| H14                                                                                    | 0.010-0.024                 | 19.0                  | ---  | 16.0                       | ---                       | ---                  |
|                                                                                        | 0.025-0.049                 | 19.0                  | ---  | 16.0                       | 5                         | ---                  |
|                                                                                        | 0.050-0.259                 | 19.0                  | ---  | 16.0                       | 8                         | 4                    |
|                                                                                        | 0.260-0.500                 | 19.0                  | ---  | 16.0                       | ---                       | ---                  |
| H18                                                                                    | 0.010-0.500                 | 26.0                  | ---  | 23.0                       | ---                       | ---                  |
| H113                                                                                   | 0.050-0.500                 | 13.0                  | ---  | 4.5                        | ---                       | ---                  |
| 3102                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.049                 | 11.0                  | 17.0 | 3.5                        | 30                        | 20                   |
|                                                                                        | 0.050-0.065                 | 11.0                  | 17.0 | 3.5                        | 35                        | 25                   |
| Alclad 3102                                                                            |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.049                 | 10.0                  | 17.0 | 3.5                        | 30                        | 20                   |
|                                                                                        | 0.050-0.065                 | 10.0                  | 17.0 | 3.5                        | 35                        | 25                   |
| 3303                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.010-0.024                 | 14.0                  | 19.0 | 5.0                        | ---                       | ---                  |
|                                                                                        | 0.025-0.049                 | 14.0                  | 19.0 | 5.0                        | 30                        | 20                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM ALLOYS - DRAWN SEAMLESS TUBES (Continued) |                             |                       |      |                            |                           |                      |
|----------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|----------------------------|---------------------------|----------------------|
| ASTM B 210<br>Alloy/Temper                                                             | Specified<br>Thickness, in. | Tensile Strength, ksi |      | Yield Strength<br>ksi, min | % El, min<br>Full-Section | % El, min<br>Cut-Out |
|                                                                                        |                             | min                   | max  |                            |                           |                      |
| 3303 (Continued)                                                                       |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.050-0.065                 | 14.0                  | 19.0 | 5.0                        | 35                        | 25                   |
| Alclad 3303                                                                            |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.010-0.024                 | 13.0                  | 19.0 | 4.5                        | ---                       | ---                  |
|                                                                                        | 0.025-0.049                 | 13.0                  | 19.0 | 4.5                        | 30                        | 20                   |
|                                                                                        | 0.050-0.065                 | 13.0                  | 19.0 | 4.5                        | 35                        | 25                   |
| 5005                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.500                 | 15.0                  | 21.0 | 5.0                        | ---                       | ---                  |
| 5050                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.500                 | 18.0                  | 24.0 | 6.0                        | ---                       | ---                  |
| H32                                                                                    |                             | 22.0                  | ---  | 16.0                       | ---                       | ---                  |
| H34                                                                                    |                             | 25.0                  | ---  | 20.0                       | ---                       | ---                  |
| H36                                                                                    |                             | 27.0                  | ---  | 22.0                       | ---                       | ---                  |
| H38                                                                                    |                             | 29.0                  | ---  | 24.0                       | ---                       | ---                  |
| 5052                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.450                 | 25.0                  | 35.0 | 10.0                       | ---                       | ---                  |
| H32                                                                                    |                             | 31.0                  | ---  | 23.0                       | ---                       | ---                  |
| H34                                                                                    |                             | 34.0                  | ---  | 26.0                       | ---                       | ---                  |
| H36                                                                                    |                             | 37.0                  | ---  | 29.0                       | ---                       | ---                  |
| H38                                                                                    |                             | 39.0                  | ---  | 24.0                       | ---                       | ---                  |
| 5083                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.450                 | 39.0                  | 51.0 | 16.0                       | ---                       | 14                   |
| 5086                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.450                 | 35.0                  | 46.0 | 14.0                       | ---                       | ---                  |
| H32                                                                                    |                             | 40.0                  | ---  | 28.0                       | ---                       | ---                  |
| H34                                                                                    |                             | 44.0                  | ---  | 34.0                       | ---                       | ---                  |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM ALLOYS - DRAWN SEAMLESS TUBES (Continued) |                             |                       |      |                            |                           |                      |
|----------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|----------------------------|---------------------------|----------------------|
| ASTM B 210<br>Alloy/Temper                                                             | Specified<br>Thickness, in. | Tensile Strength, ksi |      | Yield Strength<br>ksi, min | % El, min<br>Full-Section | % El, min<br>Cut-Out |
|                                                                                        |                             | min                   | max  |                            |                           |                      |
| 5086 (Continued)                                                                       |                             |                       |      |                            |                           |                      |
| H36                                                                                    | 0.018-0.450                 | 47.0                  | ---  | 38.0                       | ---                       | ---                  |
| 5154                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.010-0.450                 | 30.0                  | 41.0 | 11.0                       | 10                        | 10                   |
| H34                                                                                    |                             | 39.0                  | ---  | 29.0                       | 5                         | 5                    |
| H38                                                                                    |                             | 45.0                  | ---  | 34.0                       | ---                       | ---                  |
| 5456                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018                       | 41.0                  | 53.0 | 19.0                       | ---                       | 14                   |
| 6061                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.500                 | ---                   | 22.0 | 14.0 max                   | 15                        | 15                   |
| T4                                                                                     | 0.025-0.049                 | 30.0                  | ---  | 16.0                       | 16                        | 14                   |
|                                                                                        | 0.050-0.259                 | 30.0                  | ---  | 16.0                       | 18                        | 16                   |
|                                                                                        | 0.260-0.500                 | 30.0                  | ---  | 16.0                       | 20                        | 18                   |
|                                                                                        | T42                         | 0.025-0.049           | 30.0 | ---                        | 14.0                      | 16                   |
| 0.050-0.259                                                                            |                             | 30.0                  | ---  | 14.0                       | 18                        | 16                   |
| 0.260-0.500                                                                            |                             | 30.0                  | ---  | 14.0                       | 20                        | 18                   |
| T6,T62                                                                                 | 0.025-0.049                 | 42.0                  | ---  | 35.0                       | 10                        | 8                    |
|                                                                                        | 0.050-0.259                 | 42.0                  | ---  | 35.0                       | 12                        | 10                   |
|                                                                                        | 0.260-0.500                 | 42.0                  | ---  | 35.0                       | 14                        | 12                   |
| 6063                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.018-0.500                 | ---                   | 19.0 | ---                        | ---                       | ---                  |
| T4, T42                                                                                | 0.025-0.049                 | 22.0                  | ---  | 10.0                       | 16                        | 14                   |
|                                                                                        | 0.050-0.259                 | 22.0                  | ---  | 10.0                       | 18                        | 16                   |
|                                                                                        | 0.260-0.500                 | 22.0                  | ---  | 10.0                       | 20                        | 18                   |
|                                                                                        | T6, T62                     | 0.025-0.049           | 33.0 | ---                        | 28.0                      | 12                   |
| 0.050-0.259                                                                            |                             | 33.0                  | ---  | 28.0                       | 14                        | 10                   |

| MECHANICAL PROPERTIES OF ALUMINUM & ALUMINUM ALLOYS - DRAWN SEAMLESS TUBES (Continued) |                             |                       |      |                            |                           |                      |
|----------------------------------------------------------------------------------------|-----------------------------|-----------------------|------|----------------------------|---------------------------|----------------------|
| ASTM B 210<br>Alloy/Temper                                                             | Specified<br>Thickness, in. | Tensile Strength, ksi |      | Yield Strength<br>ksi, min | % El, min<br>Full-Section | % El, min<br>Cut-Out |
|                                                                                        |                             | min                   | max  |                            |                           |                      |
| 6063 (Continued)                                                                       |                             |                       |      |                            |                           |                      |
| T6, T62 (continued)                                                                    | 0.260-0.500                 | 33.0                  | ---  | 28.0                       | 16                        | 12                   |
| T83                                                                                    | 0.025-0.259                 | 33.0                  | ---  | 30.0                       | 5                         | ---                  |
| T831                                                                                   | 0.025-0.259                 | 28.0                  | ---  | 25.0                       | 5                         | ---                  |
| T832                                                                                   | 0.025-0.049                 | 41.0                  | ---  | 36.0                       | 8                         | 5                    |
|                                                                                        | 0.050-0.259                 | 40.0                  | ---  | 35.0                       | 8                         | 5                    |
| 6262                                                                                   |                             |                       |      |                            |                           |                      |
| T6, T62                                                                                | 0.025-0.049                 | 42.0                  | ---  | 35.0                       | 10                        | 8                    |
|                                                                                        | 0.050-0.259                 | 42.0                  | ---  | 35.0                       | 12                        | 10                   |
|                                                                                        | 0.260-0.500                 | 42.0                  | ---  | 35.0                       | 14                        | 12                   |
| T9                                                                                     | 0.025-0.375                 | 48.0                  | ---  | 44.0                       | 5                         | 4                    |
| 7075                                                                                   |                             |                       |      |                            |                           |                      |
| O                                                                                      | 0.025-0.049                 | ---                   | 40.0 | 21.0 max                   | 10                        | 8                    |
|                                                                                        | 0.050-0.500                 | ---                   | 40.0 | 21.0 max                   | 12                        | 10                   |
| T6, T62                                                                                | 0.025-0.259                 | 77.0                  | ---  | 66.0                       | 8                         | 7                    |
|                                                                                        | 0.260-0.500                 | 77.0                  | ---  | 66.0                       | 9                         | 8                    |
| T73                                                                                    | 0.025-0.259                 | 66.0                  | ---  | 56.0                       | 10                        | 8                    |
|                                                                                        | 0.260-0.500                 | 66.0                  | ---  | 56.0                       | 12                        | 10                   |

See ASTM B 210 for more testing details.

| MECHANICAL PROPERTIES OF ALUMINUM ALLOY PERMANENT MOLD CASTINGS |       |                                               |                       |                  |                                   |                  |             |                                        |
|-----------------------------------------------------------------|-------|-----------------------------------------------|-----------------------|------------------|-----------------------------------|------------------|-------------|----------------------------------------|
| ASTM B 108                                                      |       | Temper                                        | Tensile Strength, min |                  | Yield Strength <sup>b</sup> , min |                  | % El<br>min | Typical<br>Hardness<br>HB <sup>c</sup> |
| UNS                                                             | Alloy |                                               | ksi <sup>a</sup>      | MPa <sup>a</sup> | ksi <sup>a</sup>                  | MPa <sup>a</sup> |             |                                        |
| A02040                                                          | 204.0 | T4 separately cast specimens                  | 48.0                  | 331              | 29.0                              | 200              | 8.0         | ---                                    |
| A02080                                                          | 208.0 | T4                                            | 33.0                  | 228              | 15.0                              | 103              | 4.5         | 75                                     |
|                                                                 |       | T6                                            | 35.0                  | 241              | 22.0                              | 152              | 2.0         | 90                                     |
|                                                                 |       | T7                                            | 33.0                  | 228              | 16.0                              | 110              | 3.0         | 80                                     |
| A02130                                                          | 213.0 | F                                             | 23.0                  | 159              | ---                               | ---              | ---         | ---                                    |
| A02220                                                          | 222.0 | T551                                          | 30.0                  | 207              | ---                               | ---              | c           | 115                                    |
|                                                                 |       | T65                                           | 40.0                  | 276              | ---                               | ---              | c           | 140                                    |
| A02420                                                          | 242.0 | T571                                          | 34.0                  | 234              | ---                               | ---              | c           | 105                                    |
|                                                                 |       | T61                                           | 40.0                  | 276              | ---                               | ---              | c           | 110                                    |
| A03190                                                          | 319.0 | F                                             | 27.0                  | 186              | 14.0                              | 97               | 2.5         | 95                                     |
| A03320                                                          | 332.0 | T5                                            | 31.0                  | 214              | ---                               | ---              | c           | 105                                    |
| A03330                                                          | 333.0 | F                                             | 28.0                  | 193              | ---                               | ---              | c           | 90                                     |
|                                                                 |       | T5                                            | 30.0                  | 207              | ---                               | ---              | c           | 100                                    |
|                                                                 |       | T6                                            | 35.0                  | 241              | ---                               | ---              | c           | 105                                    |
|                                                                 |       | T7                                            | 31.0                  | 214              | ---                               | ---              | c           | 90                                     |
| A03360                                                          | 336.0 | T551                                          | 31.0                  | 214              | ---                               | ---              | c           | 105                                    |
|                                                                 |       | T65                                           | 40.0                  | 276              | ---                               | ---              | c           | 125                                    |
| A03540                                                          | 354.0 | T61                                           |                       |                  |                                   |                  |             |                                        |
|                                                                 |       | separately cast specimens                     | 48.0                  | 331              | 37.0                              | 255              | 3.0         | ---                                    |
|                                                                 |       | castings, designated area <sup>d</sup>        | 47.0                  | 324              | 36.0                              | 248              | 3.0         | ---                                    |
|                                                                 |       | castings, no location designated <sup>d</sup> | 43.0                  | 297              | 33.0                              | 228              | 2.0         | ---                                    |
| A03540                                                          | 354.0 | T62                                           |                       |                  |                                   |                  |             |                                        |
|                                                                 |       | separately cast specimens                     | 52.0                  | 359              | 42.0                              | 290              | 2.0         | ---                                    |
|                                                                 |       | castings, designated area <sup>d</sup>        | 50.0                  | 344              | 42.0                              | 290              | 2.0         | ---                                    |
|                                                                 |       | castings, no location designated <sup>d</sup> | 43.0                  | 297              | 33.0                              | 228              | 2.0         | ---                                    |



| MECHANICAL PROPERTIES OF ALUMINUM ALLOY PERMANENT MOLD CASTINGS (Continued) |        |                                               |                       |                  |                                   |                  |             |                                        |
|-----------------------------------------------------------------------------|--------|-----------------------------------------------|-----------------------|------------------|-----------------------------------|------------------|-------------|----------------------------------------|
| ASTM B 108                                                                  |        | Temper                                        | Tensile Strength, min |                  | Yield Strength <sup>b</sup> , min |                  | % El<br>min | Typical<br>Hardness<br>HB <sup>c</sup> |
| UNS                                                                         | Alloy  |                                               | ksi <sup>a</sup>      | MPa <sup>a</sup> | ksi <sup>a</sup>                  | MPa <sup>a</sup> |             |                                        |
| A03550                                                                      | 355.0  | T51                                           | 27.0                  | 186              | ---                               | ---              | c           | 75                                     |
|                                                                             |        | T62                                           | 42.0                  | 290              | ---                               | ---              | c           | 105                                    |
|                                                                             |        | T7                                            | 36.0                  | 248              | ---                               | ---              | c           | 90                                     |
|                                                                             |        | T71                                           | 34.0                  | 234              | 27.0                              | 186              | c           | 80                                     |
| A33550                                                                      | C355.0 | T61                                           |                       |                  |                                   |                  |             |                                        |
|                                                                             |        | separately cast specimens                     | 40.0                  | 276              | 30.0                              | 207              | 3.0         | 85-90                                  |
|                                                                             |        | castings, designated area <sup>d</sup>        | 40.0                  | 276              | 30.0                              | 207              | 3.0         | ---                                    |
|                                                                             |        | castings, no location designated <sup>d</sup> | 37.0                  | 255              | 30.0                              | 207              | 1.0         | 85                                     |
| A03560                                                                      | 356.0  | F                                             | 21.0                  | 145              | 10.0                              | 69               | 3.0         | ---                                    |
|                                                                             |        | T6                                            | 33.0                  | 228              | 22.0                              | 152              | 3.0         | 85                                     |
|                                                                             |        | T71                                           | 25.0                  | 172              | ---                               | ---              | 3.0         | 70                                     |
| A13560                                                                      | A356.0 | T61                                           |                       |                  |                                   |                  |             |                                        |
|                                                                             |        | separately cast specimens                     | 38.0                  | 262              | 26.0                              | 179              | 5.0         | 80-90                                  |
|                                                                             |        | castings, designated area <sup>d</sup>        | 33.0                  | 228              | 26.0                              | 179              | 5.0         | ---                                    |
|                                                                             |        | castings, no location designated <sup>d</sup> | 28.0                  | 193              | 26.0                              | 179              | 3.0         | ---                                    |
| ---                                                                         | 357.0  | T6                                            | 45.0                  | 310              | ---                               | ---              | 3.0         | ---                                    |
| A13570                                                                      | A357.0 | T61                                           |                       |                  |                                   |                  |             |                                        |
|                                                                             |        | separately cast specimens                     | 45.0                  | 310              | 36.0                              | 248              | 3.0         | 100                                    |
|                                                                             |        | castings, designated area <sup>d</sup>        | 46.0                  | 317              | 36.0                              | 248              | 3.0         | ---                                    |
|                                                                             |        | castings, no location designated <sup>d</sup> | 41.0                  | 283              | 31.0                              | 214              | 3.0         | ---                                    |
| A03590                                                                      | 359.0  | T61                                           |                       |                  |                                   |                  |             |                                        |
|                                                                             |        | separately cast specimens                     | 45.0                  | 310              | 34.0                              | 234              | 4.0         | 90                                     |
|                                                                             |        | castings, designated area <sup>d</sup>        | 45.0                  | 310              | 34.0                              | 234              | 4.0         | ---                                    |
|                                                                             |        | castings, no location designated <sup>d</sup> | 40.0                  | 276              | 30.0                              | 207              | 3.0         | ---                                    |

| MECHANICAL PROPERTIES OF ALUMINUM ALLOY PERMANENT MOLD CASTINGS (Continued) |        |                                               |                       |                  |                                   |                  |             |                                        |
|-----------------------------------------------------------------------------|--------|-----------------------------------------------|-----------------------|------------------|-----------------------------------|------------------|-------------|----------------------------------------|
| ASTM B 108                                                                  |        | Temper                                        | Tensile Strength, min |                  | Yield Strength <sup>b</sup> , min |                  | % El<br>min | Typical<br>Hardness<br>HB <sup>c</sup> |
| UNS                                                                         | Alloy  |                                               | ksi <sup>a</sup>      | MPa <sup>a</sup> | ksi <sup>a</sup>                  | MPa <sup>a</sup> |             |                                        |
| A03590                                                                      | 359.0  | T62                                           |                       |                  |                                   |                  |             |                                        |
|                                                                             |        | separately cast specimens                     | 47.0                  | 324              | 38.0                              | 262              | 3.0         | 100                                    |
|                                                                             |        | castings, designated area <sup>d</sup>        | 47.0                  | 324              | 38.0                              | 262              | 3.0         | ---                                    |
|                                                                             |        | castings, no location designated <sup>d</sup> | 40.0                  | 276              | 30.0                              | 207              | 3.0         | ---                                    |
| A04430                                                                      | 443.0  | F                                             | 21.0                  | 145              | 7.0                               | 49               | 2.0         | 45                                     |
| A24430                                                                      | B443.0 | F                                             | 21.0                  | 145              | 6.0                               | 41               | 2.5         | 45                                     |
| A14440                                                                      | A444.0 | T4-separately cast specimens                  | 20.0                  | 138              | ---                               | ---              | 20          | ---                                    |
|                                                                             |        | T4-castings, designated area <sup>d</sup>     | 20.0                  | 138              | ---                               | ---              | 20          | ---                                    |
| A05130                                                                      | 513.0  | F                                             | 22.0                  | 152              | 12.0                              | 83               | 2.5         | 60                                     |
| A05350                                                                      | 535.0  | F                                             | 35.0                  | 241              | 18.0                              | 124              | 8.0         | ---                                    |
| A07050                                                                      | 705.0  | T1 or T5                                      | 37.0                  | 255              | 17.0                              | 117              | 10.0        | ---                                    |
| A07070                                                                      | 707.0  | T1                                            | 42.0                  | 290              | 25.0                              | 173              | 4.0         | ---                                    |
|                                                                             |        | T7                                            | 45.0                  | 310              | 35.0                              | 241              | 3.0         | ---                                    |
| A07110                                                                      | 711.0  | T1                                            | 28.0                  | 193              | 18.0                              | 124              | 7.0         | 70                                     |
| A07130                                                                      | 713.0  | T1 or T5                                      | 32.0                  | 221              | 22.0                              | 152              | 4.0         | ---                                    |
| A08500                                                                      | 850.0  | T5                                            | 18.0                  | 124              | ---                               | ---              | 8.0         | ---                                    |
| A08510                                                                      | 851.0  | T5                                            | 17.0                  | 117              | ---                               | ---              | 3.0         | ---                                    |
|                                                                             |        | T6                                            | 18.0                  | 124              | ---                               | ---              | 8.0         | ---                                    |
| A08520                                                                      | 852.0  | T5                                            | 27.0                  | 186              | ---                               | ---              | 3.0         | ---                                    |

a. SI units for information only.

b. Yield strength to be evaluated only when specified in contract or purchase order.

c. Not required.

d. These properties apply only to castings having section thicknesses not greater than 2 in. except that section thicknesses of ¾ in., maximum, shall apply to Alloy A444.0.

| ASME P-No. - BASE METAL ALUMINUM & ALUMINUM ALLOYS |                        |               |                |                     |                             |
|----------------------------------------------------|------------------------|---------------|----------------|---------------------|-----------------------------|
| ASME Spec.                                         | Size or Thickness (in) | UTS ksi (min) | AA Designation | Nominal Composition | Product Form                |
| <b>P No. 21</b>                                    |                        |               |                |                     |                             |
| SB-209                                             | 0.051-3.000            | 8             | 1060           | 99.6 min Al         | Sheet, Plate                |
| SB-209                                             | 0.006-3.000            | 11            | 1100           | 99.0 Min Al         | Sheet, Plate                |
| SB-209                                             | 0.051-3.000            | 14            | 3003           | 1.2Mn               | Sheet, Plate                |
| SB-209                                             | 0.051-0.499            | 13            | Alclad 3003    | 1.2Mn               | Sheet, Plate                |
| SB-210                                             | All                    | 8.5           | 1060           | 99.6 min Al         | Bar, Rod, Shape, Tube       |
| SB-210                                             | All                    | 14            | 3003           | 1.2Mn               | Bar, Rod, Shape, Pipe, Tube |
| SB-210                                             | All                    | 13            | Alclad 3003    | 1.2Mn               | Tube                        |
| SB-221                                             | All                    | 8.5           | 1060           | 99.6 min Al         | Bar, Rod, Shape, Tube       |
| SB-221                                             | All                    | 11            | 1100           | 99.0 min Al         | Bar, Rod, Shape, Tube       |
| SB-221                                             | All                    | 14            | 3003           | 1.2Mn               | Bar, Rod, Shape, Pipe, Tube |
| SB-234                                             | All                    | 8.5           | 1060           | 99.6 min Al         | Bar, Rod, Shape, Tube       |
| SB-234                                             | All                    | 14            | 3003           | 1.2Mn               | Bar, Rod, Shape, Pipe, Tube |
| SB-234                                             | All                    | 13            | Alclad 3003    | 1.2Mn               | Tube                        |
| SB-241                                             | All                    | 8.5           | 1060           | 99.6 min Al         | Bar, Rod, Shape, Tube       |
| SB-241                                             | All                    | 11            | 1100           | 99.0 min Al         | Bar, Rod, Shape, Tube       |
| SB-241                                             | All                    | 14            | 3003           | 1.2Mn               | Bar, Rod, Shape, Pipe, Tube |
| SB-241                                             | All                    | 13            | Alclad 3003    | 1.2Mn               | Tube                        |
| SB-247                                             | Up thru 4.000          | 14            | 3003           | 1.2Mn               | Die Forging                 |
| SB-247                                             | 0.500-3.000            | 14            | Alclad 3003    | 1.2Mn               | Plate                       |
| <b>P No. 22</b>                                    |                        |               |                |                     |                             |
| SB-209                                             | 0.006-3.000            | 22            | 3004           | 1.2Mn-1.0Mg         | Sheet, Plate                |
| SB-209                                             | 0.051-0.499            | 21            | Alclad 3004    | 1.2Mn-1.0Mg         | Sheet, Plate                |
| SB-209                                             | 0.500-3.000            | 22            | Alclad 3004    | 1.2Mn-1.0Mg         | Plate                       |
| SB-209                                             | 0.051-3.000            | 25            | 5052           | 2.5Mg-0.25Cr        | Sheet, Plate                |
| SB-209                                             | 0.051-3.000            | 30            | 5254           | 3.5Mg-0.25Cr-Al     | Sheet, Plate                |

| ASME P-No. - BASE METAL ALUMINUM & ALUMINUM ALLOYS (Continued) |                        |               |                |                     |                             |
|----------------------------------------------------------------|------------------------|---------------|----------------|---------------------|-----------------------------|
| ASME Spec.                                                     | Size or Thickness (in) | UTS ksi (min) | AA Designation | Nominal Composition | Product Form                |
| <b>P No. 22 (Continued)</b>                                    |                        |               |                |                     |                             |
| SB-209                                                         | 0.051-3.000            | 30            | 5154           | 3.5Mg-0.25Cr        | Sheet, Plate                |
| SB-209                                                         | 0.051-3.000            | 31            | 5454           | 2.75Mg-0.8Mn-0.10Cr | Sheet, Plate                |
| SB-209                                                         | 0.051-3.000            | 25            | 5652           | 2.5Mg-0.25Cr-0.01Mn | Sheet, Plate                |
| SB-210                                                         | 0.018-0.450            | 25            | 5052           | 2.5Mg-0.25Cr        | Seamless Tube               |
| SB-210                                                         | All                    | 30            | 5154           | 3.5Mg-0.25Cr        | Bar, Rod, Shape, Tube       |
| SB-221                                                         | All                    | 30            | 5154           | 3.5Mg-0.25Cr        | Bar, Rod, Shape, Tube       |
| SB-221                                                         | All                    | 31            | 5454           | 2.75Mg-0.8Mn-0.10Cr | Bar, Rod, Shape, Tube       |
| SB-234                                                         | All                    | 25            | 5052           | 2.5Mg-0.25Cr        | Tube                        |
| SB-234                                                         | All                    | 31            | 5454           | 2.75Mg-0.8Mn-0.10Cr | Bar, Rod, Shape, Tube       |
| SB-241                                                         | All                    | 25            | 5052           | 2.5Mg-0.25Cr        | Tube                        |
| SB-241                                                         | All                    | 31            | 5454           | 2.75Mg-0.8Mn-0.10Cr | Bar, Rod, Shape, Tube       |
| <b>P No. 23</b>                                                |                        |               |                |                     |                             |
| SB-209                                                         | 0.051-6.000            | 24            | 6061           | 1.0Mg-0.6Si-0.25Cr  | Sheet, Plate                |
| SB-209                                                         | 0.051-5.000            | 24            | Alclad 6061    | 1.0Mg-0.6Si-0.25Cr  | Sheet, Plate                |
| SB-210                                                         | All                    | 24            | 6061           | 1.0Mg-0.6Si-0.25Cr  | Bar, Rod, Shape, Pipe, Tube |
| SB-210                                                         | All                    | 17            | 6063           | 0.7Mg-0.4Si         | Bar, Rod, Shape, Pipe, Tube |
| SB-211                                                         | All                    | 24            | 6061           | 1.0Mg-0.6Si-0.25Cr  | Bar, Rod, Shape, Pipe, Tube |
| SB-221                                                         | All                    | 24            | 6061           | 1.0Mg-0.6Si-0.25Cr  | Bar, Rod, Shape, Pipe, Tube |
| SB-221                                                         | All                    | 17            | 6063           | 0.7Mg-0.4Si         | Bar, Rod, Shape, Pipe, Tube |
| SB-234                                                         | All                    | 24            | 6061           | 1.0Mg-0.6Si-0.25Cr  | Bar, Rod, Shape, Pipe, Tube |
| SB-241                                                         | All                    | 24            | 6061           | 1.0Mg-0.6Si-0.25Cr  | Bar, Rod, Shape, Pipe, Tube |
| SB-241                                                         | All                    | 17            | 6063           | 0.7Mg-0.4Si         | Bar, Rod, Shape, Pipe, Tube |
| SB-247                                                         | Up thru 8.000          | 24            | 6061           | 1.0Mg-0.6Si-0.25Cr  | Forging                     |
| SB-308                                                         | All                    | 24            | 6061           | 1.0Mg-0.6Si-0.25Cr  | Bar, Rod, Shape, Pipe, Tube |

| ASME P-No. - BASE METAL ALUMINUM & ALUMINUM ALLOYS (Continued) |                        |               |                |                     |                       |
|----------------------------------------------------------------|------------------------|---------------|----------------|---------------------|-----------------------|
| ASME Spec.                                                     | Size or Thickness (in) | UTS ksi (min) | AA Designation | Nominal Composition | Product Form          |
| <b>P No. 25</b>                                                |                        |               |                |                     |                       |
| SB-209                                                         | 0.051-1.500            | 40            | 5083           | 4.5Mg-0.8Mn-0.15Cr  | Sheet, Plate          |
| SB-209                                                         | 1.501-3.000            | 39            | 5083           | 4.5Mg-0.8Mn-0.15Cr  | Plate                 |
| SB-209                                                         | 3.001-5.000            | 38            | 5083           | 4.5Mg-0.8Mn-0.15Cr  | Plate                 |
| SB-209                                                         | 5.001-7.000            | 37            | 5083           | 4.5Mg-0.8Mn-0.15Cr  | Plate                 |
| SB-209                                                         | 7.001-8.000            | 36            | 5083           | 4.5Mg-0.8Mn-0.15Cr  | Plate                 |
| SB-209                                                         | 0.020-2.000            | 35            | 5086           | 4.0Mg-0.5Mn-0.15Cr  | Sheet, Plate          |
| SB-209                                                         | 0.051-1.500            | 42            | 5456           | 5.1Mg-0.8Mn-0.10Cr  | Sheet, Plate          |
| SB-221                                                         | Up thru 5.000          | 39            | 5083           | 4.5Mg-0.8Mn-0.15Cr  | Bar, Rod, Shape, Tube |
| SB-221                                                         | Up thru 5.000          | 41            | 5456           | 5.1Mg-0.8Mn-0.10Cr  | Bar, Rod, Shape, Tube |
| SB-241                                                         | Up thru 5.000          | 39            | 5083           | 4.5Mg-0.8Mn-0.15Cr  | Bar, Rod, Shape, Tube |
| SB-241                                                         | Up thru 5.000          | 35            | 5086           | 4.0Mg-0.5Mn-0.15Cr  | Tube                  |
| SB-241                                                         | 1.501-3.000            | 41            | 5456           | 5.1Mg-0.8Mn-0.10Cr  | Plate                 |
| SB-241                                                         | 3.001-5.000            | 40            | 5456           | 5.1Mg-0.8Mn-0.10Cr  | Plate                 |
| SB-241                                                         | 5.001-7.000            | 39            | 5456           | 5.1Mg-0.8Mn-0.10Cr  | Plate                 |
| SB-241                                                         | 7.001-8.000            | 38            | 5456           | 5.1Mg-0.8Mn-0.10Cr  | Plate                 |
| SB-241                                                         | Up thru 5.000          | 41            | 5456           | 5.1Mg-0.8Mn-0.10Cr  | Bar, Rod, Shape, Tube |
| SB-247                                                         | Up thru 4.000          | 38            | 5083           | 4.5Mg-0.8Mn-0.15Cr  | Forging               |
| SB-247                                                         | 2.001-3.000            | 34            | 5086           | 4.0Mg-0.5Mn-0.15Cr  | Plate                 |

| ASME F No. - WELDING FILLER METAL ALUMINUM & ALUMINUM ALLOYS |                |                                             |
|--------------------------------------------------------------|----------------|---------------------------------------------|
| F No.                                                        | ASME Spec. No. | AWS Classification                          |
| 21                                                           | SFA-5.10       | ER 1100                                     |
| 22                                                           | SFA-5.10       | ER 5554, ER 5356, ER 5556, ER 5183, ER 5654 |
| 23                                                           | SFA-5.10       | ER 4043, ER 4047, ER 4145                   |
| 24                                                           | SFA-5.10       | R-SC 51A, R356.0                            |

| INTERNATIONAL CROSS REFERENCES - ALUMINUM & ALUMINUM ALLOYS <sup>a</sup> |          |           |          |               |          |        |
|--------------------------------------------------------------------------|----------|-----------|----------|---------------|----------|--------|
| USA                                                                      | BRITAIN  | GERMANY   | FRANCE   | INTERNATIONAL | JAPAN    | CANADA |
| AA                                                                       | BS       | DIN       | NF       | ISO           | JIS      | CSA    |
| 1050                                                                     | 1B       | Al99.5    | A5       | Al 99.5       | A 1050 P | 9950   |
| 1100                                                                     | ---      | ---       | A45      | Al 99.0 Cu    | A 1100 P | 990C   |
| 1350                                                                     | 1E       | E-Al99.5  | A5/L     | E-Al 99.5     | ---      | ---    |
| 2011                                                                     | FC1      | AlCuBiPb  | A-U4Pb   | Al Cu6BiPb    | ---      | CB60   |
| 2014                                                                     | H15      | AlCuSiMn  | A-U4SG   | Al Cu4SiMg    | A 2014 P | CS41N  |
| 2024                                                                     | ---      | AlCuMg2   | A-U4G1   | Al Cu4Mg1     | ---      | CG42   |
| 3003                                                                     | N3       | AlMn      | A-M1     | Al Mn1Cu      | A 3003 P | MC10   |
| 3004                                                                     | ---      | AlMn1Mg1  | A-M1G    | Al Mn1Mg1     | A 3004 P | ---    |
| 4043                                                                     | N21      | AlSi5     | A-S5     | Al Si5        | ---      | S5     |
| 5005                                                                     | N41      | AlMg1     | A-G0.6   | Al Mg1(B)     | A 5005 P | ---    |
| 5050                                                                     | 3L44     | ---       | A-G1     | Al Mg1.5(C)   | ---      | ---    |
| 5052                                                                     | ---      | AlMg2.5   | A-G2.5C  | Al Mg2.5      | A 5052 P | GR20   |
| 5056                                                                     | N6 2L.58 | AlMg5     | ---      | Al Mg5Cr      | A 5056 W | GM50R  |
| 5083                                                                     | N8       | AlMg4.5Mn | ---      | Al Mg4.5Mn0.7 | A 5083 P | GM41   |
| 5154                                                                     | N5       | ---       | A-G3C    | Al Mg3.5      | ---      | GR40   |
| 5454                                                                     | N51      | AlMg2.7Mn | A-G2.5MC | Al Mg3Mn      | A 5454 P | GM31N  |
| 6061                                                                     | H20      | AlMg1SiCu | A-G5UC   | Al Mg1SiCu    | A 6061 P | GS11N  |

| INTERNATIONAL CROSS REFERENCES - ALUMINUM & ALUMINUM ALLOYS <sup>a</sup> (Continued) |            |             |        |               |           |        |
|--------------------------------------------------------------------------------------|------------|-------------|--------|---------------|-----------|--------|
| USA                                                                                  | BRITAIN    | GERMANY     | FRANCE | INTERNATIONAL | JAPAN     | CANADA |
| AA                                                                                   | BS         | DIN         | NF     | ISO           | JIS       | CSA    |
| 6063                                                                                 | H19        | AlMgSi0.5   | A-GS   | Al Mg0.7Si    | A 6063 BE | GS10   |
| 6101                                                                                 | 91E        | E-AlMgSi0.5 | A-GS/L | E-Al MgSi     | ---       | ---    |
| 7075                                                                                 | L.95, L.96 | AlZnMgCu1.5 | A-Z5GU | Al Zn5.5MgCu  | A 7075 P  | ZG62   |

a. It is not practical to directly correlate the various metal designations from country to country, let alone comparing several countries and their metal designations; from the view that chemical composition may be similar, but not identical, and that manufacturing technologies may differ greatly. Consequently, the cross references made in this table are, at best, only listed as a guide to assist in finding comparable metal designations, rather than equivalent metal designations.

AA - The Aluminum Association; BS - British Standards; DIN - Deutsches Institut für Normung; NF - Normes Françaises; ISO - International Organization for Standardization; JIS - Japanese Industrial Standards; CSA - Canadian Standards Association.

# Chapter 2

## ***NICKEL & NICKEL ALLOYS***

Metallic nickel was first isolated by the Swedish scientist A.F. Cronstedt in 1751, and since then it has become one of the most useful metals. Among the attractive properties of nickel and its alloys are excellent ductility and formability, good resistance to oxidation and corrosion and good high temperature strength. In addition it is ferromagnetic up to its Curie temperature of 358°C (676°F). Its relatively high cost, however, has restricted its use to specialized applications, generally involving severe service conditions.

Commercially important nickel ores include sulphides, oxides, and silicates. In all of these ores the nickel content is low, generally less than 3%, and the mineralogy and extraction processes are often complex. Many different smelting processes are used for the production of nickel including pyrometallurgical, hydrometallurgical, and vapour phase metallurgical processes. The vapour phase process involves the formation and decomposition of nickel carbonyl, and the metallic nickel produced is often referred to as carbonyl nickel.

More than half of the world's nickel production is used as an alloying addition in stainless steel, where its presence stabilizes the austenitic structure, giving improved formability and toughness, and resistance to corrosion and oxidation in particular environments. Approximately one-sixth of the nickel produced is used in nickel-based alloys. Nickel is also used as a plating material and as an alloy addition to carbon steel and copper-based alloys.

One of the many interesting aspects of nickel use is that unlike many other alloy systems, such as those based on aluminium or titanium which normally contain less than 15% total alloy content, useful nickel alloys have a wide range of nickel content. In some cases alloys with as little as 30% nickel are considered to be nickel-based alloys. Some of these alloys have been developed by experimentation with alloy additions to nickel, while others have been developed by increasing the nickel content of iron-based alloys, notably stainless steel.



Uses of commercial purity nickel are relatively restricted; however, an enormous range of nickel alloys is available, the most important being nickel-copper alloys, and nickel-chromium (and nickel-iron-chromium) alloys, many of which contain other alloying elements such as titanium, aluminum and molybdenum. The common presence of cobalt in nickel ores, and the similar behaviour of nickel and cobalt during extraction processes, has led to the specification of combined nickel plus cobalt in some alloy compositions rather than simply nickel.

Pure nickel has a face-centered cubic (fcc) crystal structure at all temperatures, and this is also true of most nickel alloys, but alloying elements have different influences on the microstructure and properties. Some produce solid solution hardening. Some form carbide or nitride particles within the nickel-based solid solution matrix. Some form brittle intermetallic phases which are detrimental to properties, and some form precipitates which provide useful precipitation hardening. Most alloying elements can contribute to several of these effects. Perhaps the most important is the precipitation of particles of the ordered fcc  $\gamma'$  (*gamma prime*) phase, which is generally of the form  $\text{Ni}_3(\text{Ti},\text{Al})$ . This is referred to as *gamma prime* to differentiate it from the fcc matrix phase which is conventionally termed *gamma*. Precipitation hardening by this phase contributes strength at intermediate temperatures because the  $\gamma'$  particles are very stable and have low energy interfaces with the matrix solid solution. Most of the nickel-based alloys which are strengthened by  $\gamma'$  belong to the category of "superalloys". These are alloys designed specifically for jet aircraft engine and gas turbine applications requiring high temperature strength and creep resistance as well as resistance to corrosion, oxidation, and carburization. The nickel alloy groups will be discussed in the following sections.

### **Commercial Purity Nickel And Low Alloy Nickels**

The highest purity nickels commercially available are Nickel 270 (UNS N02270) and Nickel 290 (UNS N02290), which contain at least 99.95% Ni. This material finds applications in the electronics industry. The standard commercial purity nickels are Nickel 200 (UNS N02200) and Nickel 201 (UNS N02201); both of these contain 99.5% combined Ni + Co, but Nickel 201 has a lower maximum carbon content, 0.02%, to avoid the formation of graphite, which embrittles the material during extended use at temperatures above about 300°C (572°F). In addition to coinage and electronic industry uses, these materials find applications in chemical processing, especially for the handling of hot concentrated caustic soda and dry chlorine. A comparable material, Nickel 205 (UNS N02205), has controlled low levels of magnesium for improved electronic characteristics.

All of the above materials are solid solutions and are strengthened only by work hardening. However, two low-alloy nickels have alloy additions which provide higher strengths by precipitation hardening, making them useful for springs and other applications where both corrosion resistance and strength are required. These are Permanickel 300 (UNS N03300), which has titanium added, and Duranickel 301 (UNS N03301) which has both aluminum and titanium additions.

### **Nickel Copper Alloys**

Nickel and copper form a complete range of solid solutions at all compositions, although some commercial nickel-copper alloys contain other alloying elements to encourage precipitation hardening. Nickel-copper alloys have excellent fabrication properties and a range of electrical properties, magnetic properties, and colour across the range of compositions. Many applications of these alloys are based on their corrosion resistance in reducing environments and in sea water, for example in the chemical and hydrocarbon processing industries and in marine engineering. Both castings and wrought products are available including pipe, shafts, tools, pumps, valves and fasteners. The most important alloys in this category are Monel 400 (UNS N04400 - 66%Ni+Co, 32%Cu), Monel R-405 (UNS N04405) which is similar but has added sulphur to make it free machining, and Monel K-500 (UNS N05500) which again has 66% Ni+Co with 30% Cu but in addition contains aluminum and titanium to provide precipitation hardening by the formation of  $\text{Ni}_3(\text{Ti},\text{Al})$ . Especially high strength is obtained when the latter alloy is cold worked before the precipitation hardening; it finds uses where a higher strength is required in a corrosion resistant application, for example for tools and springs.

### **Solid Solution Nickel-Chromium and Nickel-Chromium-Iron Alloys**

A wide range of nickel-bearing alloys contain chromium in the approximate range of 15% to 23%, with varying amounts of iron and other elements such as molybdenum. At one extreme are the common austenitic stainless steels, having nickel contents which can be less than 10%. As the nickel content is raised and the iron content falls, the cost increases, but so does the maximum useful operating temperature, typically from around 1000°C (1832°F) to around 1200°C (2192°F), depending in part on reactions with the operating environments.

This section will consider these solid solution alloys starting with the higher nickel materials. Many of these were originally developed in response to the materials problems in jet engines. The major role of

chromium in these alloys is to provide a stable surface oxide layer which protects the material against further oxidation. Of the other alloying elements, some such as molybdenum, niobium, and tungsten, provide strength by solution strengthening, while others are there for resistance to various types of corrosion, carburization, and other reactions with the environment.

Inconel alloy 600 (UNS N06600 - 76%Ni, 15%Cr, 8%Fe) is the basic alloy in this category. It is a solid solution alloy, not heat treatable, although it may exhibit precipitated chromium carbides and/or titanium carbides and nitrides. It finds applications in furnace components, such as muffles and baskets, as well as in chemical and food processing equipment.

Inconel alloy 601 (UNS N06601 - 61%Ni, 23%Cr, 14%Fe) has minor additions of aluminum and silicon, which give it improved resistance to oxidation and nitriding. The oxides of aluminum and chromium together can form a more protective surface layer as the aluminum oxide forms protrusions which prevent the chromium oxide layer from scaling. Inconel alloy 601GC is a grain-controlled modification with additional high temperature service benefits. These alloys are used as furnace parts and fixtures, radiant tubes, strand annealing tubes, furnace hearth roller tubes, and retorts for service up to 1260°C (2300°F).

Haynes alloy 214 (UNS N07214 - 75%Ni, 16%Cr, 4%Al, 3%Fe) has high temperature strength and oxidation resistance to 1260°C (2300°F). It can be precipitation hardened but is intended for use in the solution treated condition, for example in industrial heating applications.

Inconel alloy 617 (UNS N06617 - 53%Ni, 11%Cr, 12%Co, 9%Mo) combines metallurgical stability, strength, and oxidation resistance at high temperatures. This alloy is used in gas turbine applications, and in the petrochemical and thermal processing industries.

Inconel alloy 625 (UNS N06625 - 61%Ni, 22%Cr, 3%Fe, 9%Mo, 4%Nb) has improved strength compared to the 600 and 601 alloys because of the solution strengthening effects of the molybdenum and niobium additions. The molybdenum also improves its resistance to pitting corrosion in chloride-bearing environments as is the case in many chromium-containing alloys. The niobium contributes to weldability by tying up the carbon as niobium carbides thereby avoiding the formation of chromium carbides whose presence at grain boundaries can lead to intergranular corrosion as in the sensitization of stainless steel. Under some circumstances there is a possibility of the formation of the body-centered tetragonal  $\gamma'$  (*gamma double prime*) precipitate in this alloy, but it is more frequently a solid solution with some carbide precipitates. Inconel

alloy 625LCF (UNS N06625) is a modification designed to optimize low cycle fatigue resistance; this alloy is used extensively for bellows.

Inconel alloy 690 (UNS N06690 - 60%Ni, 30%Cr, 10%Fe) finds uses based on its resistance to nitric acid or mixtures of nitric and hydrofluoric acid, as well as at high temperatures in sulphur-bearing gases.

Haynes alloy HR-160 (UNS N12160 - 37%Ni, 28%Cr, 29%Co, 2%Fe, 3%Si) combines high temperature strength with resistance to most forms of high temperature corrosion including attack by sulphur, chloride, vanadium and other salt deposits for applications in the chemical process, waste incineration and other industries.

Hastelloy C-22 (UNS N06022 - 52%Ni, 22%Cr, 6%Fe, 13%Mo, 4%W, 3%Co) has superior corrosion resistance in oxidizing acid chlorides and wet chlorine. It also has good resistance to pitting, crevice corrosion, and stress corrosion cracking, and finds uses in the pulp and paper industry, petrochemical industry and in pollution control equipment.

Hastelloy C-276 (UNS N10276 - 54%Ni, 16%Cr, 6%Fe, 16%Mo, 4%W, 3%Co) has good resistance to seawater corrosion as well as to pitting and crevice corrosion, and is used in equipment for chemical processing, pollution control and waste treatment.

Hastelloy G-3 (UNS N06985 - 42%Ni, 22%Cr, 20%Fe, 7%Mo, 1%W, 5%Co, 2%Cu). The Mo provides resistance to pitting and crevice corrosion, and helps maintain the corrosion resistance after welding. This alloy is used for flue gas scrubbers and where resistance to phosphoric and sulphuric acids is required. Other Hastelloy G alloys include G-30 (UNS N06030 - 38%Ni, 30%Cr, 15%Fe, 6%Mo, 3%W, 5%Co, 2%Cu) which has excellent corrosion resistance in wet phosphoric acid and other mixed acids, and Hastelloy G-50 (UNS N06950 - 48%Ni, 20%Cr, 18%Fe, 9%Mo, 1%W, 3%Co) was designed specifically for sour gas service.

Hastelloy S (UNS N06635 - 62%Ni, 16%Cr, 3%Fe, 15%Mo, 1%W, 2%Co) was developed for resistance to cyclic heating.

Haynes alloy 230 (55%Ni, 22%Cr, 14%W, 5%Co, 3%Fe) has outstanding oxidation resistance to 1150°C (2102°F) and is used for gas turbine components as well as in petrochemical plants, power plants and industrial heating applications.

Hastelloy X (UNS N06002 - 49%Ni, 22%Cr, 18%Fe, 9%Mo, 1%W, 2%Co) has excellent strength and oxidation resistance to 1200°C (2192°F). Its

fabrication properties are also excellent, and it is used for components of furnaces and aircraft engines and in the petrochemical industry.

### **Solid Solution Nickel-Molybdenum Alloys**

The Hastelloy B alloys have low chromium and high (28%) molybdenum contents. Here the chromium level is too low to permit the formation of a protective chromium oxide film, so that these materials are not corrosion resistant in oxidizing environments. However the presence of molybdenum provides them with superior corrosion resistance in hydrochloric acid, and very good resistance to many nonoxidizing acids and most organic acids as well as to nonoxidizing salts. These alloys include the basic Hastelloy B (UNS N10001 - 64%Ni, 28%Mo, 1%Cr, 5%Fe, 1%Si) and its modifications Hastelloy B-2 (UNS N10665 - 68%Ni, 28%Mo, 1%Cr, 2%Fe) and Hastelloy B-3 (UNS N10675 - 68%Ni, 28%Mo, 2%Cr, 2%Fe).

### **Solid Solution Iron-Nickel-Chromium Alloys**

These solid solution alloys are similar to the nickel-chromium-iron alloys discussed above but with higher iron and lower nickel contents, to give lower cost materials with reduced but still useful resistance to high temperatures and corrosive environments. All of these alloys exhibit good strength and resistance to oxidation and carburization at high temperatures. They include Incoloy alloy 800 (UNS N08800 - 33%Ni, 21%Cr, 46%Fe) and its modifications alloy 800H (UNS N08810) and alloy 800HT (UNS N08811) which have restricted grain size and composition limits. These are used for process piping, heat exchanger and vessel bodies. Incoloy alloy 800 is generally used for applications at temperatures below about 620°C (1148°F) and alloys 800H and 800HT at higher temperatures. Incoloy alloy 801 (UNS N08801 - 32%Ni, 21%Cr, 45%Fe) is similar but also contains titanium, which stabilizes it against sensitization and thus intergranular corrosion. Incoloy alloy 803 (35%Ni, 27%Cr, 35%Fe with minor Ti and Al) has improved resistance to carburization and oxidation and sulphidation for applications in the petrochemical industry, including pyrolysis tubing in high-severity ethylene furnaces. Incoloy alloy 825 (UNS N08825 - 42%Ni, 22%Cr, 30%Fe, 3%Mo, 2%Cu with minor Ti) contains additional nickel which improves resistance to chloride stress corrosion cracking and to polythionic acid cracking. Haynes alloy 556 (20%Ni, 22%Cr, 31%Fe, 18%Co, 3%Mo, 3%W) and Haynes alloy HR-120 (UNS R30556 - 37%Ni, 25%Cr, 33%Fe, 3%Co, 2%Mo, 2%W) both have good high temperature strength to 1095°C (2000°F) as well as resistance to oxidizing, carburizing and sulphidizing atmospheres. Other alloys in this category which were developed for corrosion resistance include Carpenter 20Cb-3 (UNS

N08020 - 35%Ni, 20%Cr, 38%Fe, 2%Mo, 1%Nb, 3%Cu) which is resistant to chlorides and acid environments; Alloy 20Mo-4 (UNS N08024 - 38%Ni, 24%Cr, 32%Fe, 4%Mo, 1%Cu), designed for improved resistance to pitting and crevice corrosion and Carpenter 20Mo-6 (UNS N08026 - 35%Ni, 24%Cr, 46%Fe, 6%Mo, 3%Cu) which has particularly good resistance to hot chlorides at low pH.

### **Precipitation Hardening Nickel-Based Superalloys**

The range of precipitation hardening nickel-based superalloys is broad, and a correspondingly wide range of properties is attainable. The individual alloying elements in these alloys play even more complex and multiple roles than they do in the solid solution alloys. These roles can include, in addition to solution strengthening of the matrix and of the  $\gamma'$  phase, control of the amount of  $\gamma'$ , of the rate at which it coarsens at high temperature, and of the resistance to oxidation and corrosion.

The earliest of the precipitation hardenable nickel-based superalloys was Nimonic 80, (UNS N07080 - 77%Ni, 20%Cr with minor Ti and Al), developed in Britain in the early 1940s for jet engine component applications. Materials developments since then have resulted in a large number of nickel-based superalloys, available in cast and wrought forms, as well as nickel-iron-based and cobalt-based superalloys.

The basic microstructure of these alloys consists of a face-centered cubic nickel-based alloy matrix, solution strengthened by chromium, molybdenum, and other elements. In addition, heat treating causes the precipitation of the  $\gamma'$  phase in the form of particles typically 1 micrometer or less in dimension with a high volume fraction. These  $\gamma'$  particles are based on  $\text{Ni}_3(\text{Ti}, \text{Al})$  but can be considerably more complex, with elements such as Fe and Co substituting for some of the Ni, and other elements such as Nb substituting for some of the Ti and Al. The precipitation of this phase gives a strengthening which, unlike most strengthening mechanisms, increases with increasing temperature up to about 800°C (1472°F). The heat treatments used to strengthen these alloys are designed in part to control the dispersion and morphology of the  $\gamma'$  particles.

The other common microstructural constituent is alloy carbide particles. Several different types of alloy carbide particles form in these alloys depending on their composition and thermal treatment. Carbide particles can form within the grains and along grain boundaries. The carbide morphology on grain boundaries is particularly critical to the high temperature mechanical properties. Discontinuous chains of carbides along grain boundaries is the optimum condition; the total

absence of boundary carbides permits grain boundary sliding at high temperatures, while a complete boundary network of carbide provides a continuous fracture path. The carbide distribution is, like the  $\gamma'$  dispersion, controlled by the heat treatment.

In nickel-based superalloys in which the alloy composition or heat treatment is faulty, brittle intermetallic phases can form during heat treatment or service, degrading mechanical properties. The best known of these is the sigma phase, a variant of the intermetallic compound FeCr.

In order to develop the optimum microstructure, therefore, the thermal and mechanical processing is critical. A typical heat treatment involves a solution anneal followed by a slow cool and then an aging or, more typically, a double aging treatment to develop the optimum dispersion of  $\gamma'$  precipitates along with the appropriate carbide distribution while avoiding the formation of brittle intermetallic phases.

Examples of the common wrought nickel-based superalloys include Inconel alloy X-750 (UNS N07750 -70%Ni, 15%Cr, 7%Fe with minor Ti, Al and Nb), Inconel alloy 718 (UNS N07718 -53%Ni, 19%Cr, 19%Fe, 5%Nb, 3%Mo with minor Ti and Al) in which the Ti and Al in the  $\gamma'$  phase is largely replaced by Nb, Inconel alloy 725 (UNS N07725 - 57%Ni, 21%Cr, 9%Fe, 8%Mo, 3%Nb), Waspaloy (UNS N07001 -58%Ni, 20%Cr, 14%Co, 4%Mo, 3%Ti, 1%Al), Udimet 500 (UNS N07500 -54%Ni, 18%Cr, 19%Co, 4%Mo, 3%Ti, 3%Al), and various Nimonic alloys.

Cast nickel-based superalloys include MAR-M200 (UNS N13009 -60%Ni, 9%Cr, 10%Co, 12%W, 5%Ti, 2%Al), Inconel alloy 738 (61%Ni, 16%Cr, 9%Co, 2%Mo, 3%W, 3%Ti, 3%Al, 2%Ta) and René 77 (58%Ni, 15%Cr, 15%Co, 4%Mo, 3%Ti, 4%Al). Some of the cast alloys are designed to be used in the as-cast condition, whereas others are heat treated after casting.

These alloys are used for many different jet engine and gas turbine components, including discs, blades, and fasteners. They also find applications in the chemical and petrochemical industries.

### **Precipitation Hardening Iron-Nickel-Based Superalloys**

In comparison with the nickel-based superalloys discussed above, these materials generally have more of the nickel content replaced by iron. This lowers the material cost but also lowers the maximum service temperatures. These materials have austenitic matrices which are solution strengthened by such alloying elements as Cr and Mo, and

precipitation hardened by several different phases, including the  $\gamma$  phase. They are more susceptible to the precipitation of the detrimental brittle intermetallic phases such as FeCr. As in the case of the nickel-based superalloys, these alloys are strengthened by a precipitation hardening heat treatment generally consisting of solution heat treating, quenching, and double aging. Examples include Incoloy alloy 901 (UNS N09901 - 42%Ni, 13%Cr, 36%Fe, 6%Mo, 3%Ti), Incoloy alloy 925 (UNS N09925 - 44%Ni, 21%Cr, 28%Fe, 3%Mo, 2%Ti), Pyromet 860 (43%Ni, 13%Cr, 30%Fe, 6%Mo, 3%Ti, 1% Al, 4%Co) and Discaloy (UNS N66220 - 26%Ni, 14%Cr, 54%Fe, 3%Mo, 2%Ti).

The major applications for these materials are as aircraft engine and gas turbine components.

### **Nickel Alloys For Controlled Thermal Expansion Applications**

Nickel-iron alloys containing 36%Ni have the lowest thermal expansion coefficient of any metal in the temperature range to 230°C (446°F). In nickel-iron alloys near this composition, the thermal expansion coefficients can be selected by selecting the nickel content. Low thermal expansion makes these alloys important for glass-to-metal seals, for example in the lamp and electronics industries. The commercially important alloys are Invar - Alloy 36 (UNS K93600 - 64%Fe, 36%Ni), Alloy 42 (UNS K94100 - 58%Fe-41%Ni) whose thermal expansion matches well with alumina, beryllia, and vitreous glass, and Alloy 52 (UNS K14052 - 48%Fe-51%Ni) which matches vitreous potash-soda-lead glass. These alloys find other uses in the electronics industry, for example for thermomechanical control and switchgear devices.

In addition, several nickel-iron-chromium and iron-nickel-cobalt alloys are available commercially. Alloy 902 (UNS N09902 - 50%Fe, 42%Ni, 5%Cr with minor Ti and Al) is a precipitation hardening alloy with a controllable thermoelastic coefficient for use in spring, pressure sensor and instrumentation applications. Incoloy alloy 903 (UNS N19903), Alloy 907 (UNS N19907), and Alloy 909 (UNS N19909) contain 38%Ni, 42%Fe, and 13%Co with varying amounts of the precipitation hardening elements Ti, Al, and Nb. These alloys provide a combination of high strength and low thermal expansion for applications up to 650°C (1202°F), particularly in gas turbine components where close fit is important, such as with rings, seals, shrouds, casings, and vanes.

### **Miscellaneous Nickel Alloys**

Nickel and its alloys find further use as electrical resistance alloys, soft magnetic alloys, and shape memory alloys. Electrical resistance alloys



are used for measurement and regulation of electrical characteristics, and also for resistance heating elements. The requirements for heating element alloys include high melting point, high electrical resistivity, and good oxidation resistance. Alloys employed for heating elements are nickel-chromium alloys containing minor amounts of silicon (e.g. UNS N06003 - 78%Ni, 20%Cr, 1%Si, and UNS N06008 - 68%Ni, 30%Cr, 1%Si) and nickel-chromium-iron alloys containing minor Si and Nb (e.g. UNS N06004 - 57%Ni, 16%Cr, 25%Fe, 1%Si and 37-21 alloy - 37%Ni, 21%Cr, 40%Fe, 2%Si). The resistance alloys include copper-nickel alloys with up to 45%Ni, and nickel-chromium alloys with 35 - 95%Ni and minor amounts of Al, Fe, or Si. Among the properties necessary in these alloys are uniform and stable resistivity and reproducible temperature coefficient of resistivity.

Soft magnetic alloys have been developed which have high permeability and low saturation induction making them useful in applications involving magnetic shielding. Alloys containing 79%Ni, 5%Mo, 16% Fe have the highest values of permeability and low saturation induction, while lower nickel alloys (approximately 50%Ni) are also available. Applications include rotors, armatures, transformers, inductors and memory storage devices.

Nickel-titanium alloys (approximately 50%Ni, 50%Ti) have the ability to return to a previously defined shape when subjected to appropriate thermal treatment. Typically, they can be deformed at relatively low temperature, then heated to return them to their original shape. Up to 8% memory strain is possible in nickel-titanium alloys. Applications include hydraulic couplings and force actuators as well as components which must be collapsed for compactness, then expanded for service, for example blood-clot filters inserted into veins.

### **Welding Of Nickel Alloys**

Nickel alloys are generally weldable, but care must be taken, since many of the heat resistant alloys in particular can undergo cracking during welding or subsequent heat treatment. Welding by the GTAW (gas tungsten arc welding) process is the most common, but the GMAW (gas metal arc welding) and SMAW (shielded metal arc welding) processes are also used. Wrought nickel alloys are welded using techniques similar to those applicable to stainless steel. Cast alloys are weldable but generally require more care than their wrought counterparts. In both cases, the optimum situation is to weld with the alloys in the solution annealed condition.

Solid solution alloys are generally welded in the annealed condition without post-weld heat treatment. Precipitation hardening alloys are also normally annealed before welding, especially if they have been cold formed. Furthermore, if the welding induces residual stresses, or if the alloy is welded in the precipitation hardened condition, these alloys will require a post-weld heat treatment, consisting of solution treatment (with rapid heating to temperature) followed by aging. The SMAW process is not widely used for precipitation hardening alloys.

A problem which can arise when these alloys are welded (or improperly heat treated) is a susceptibility to intergranular corrosion known as sensitization. This phenomenon, which is also a problem in stainless steels, can develop if the alloy spends time (e.g. during slow cooling) in the critical temperature range between 425 and 760°C (797 and 1400°F). The precipitation of chromium carbide particles at the grain boundaries of the alloy removes chromium from solution in the adjacent matrix which thus becomes anodic with respect to the remainder of the grain and therefore becomes the site of localized intergranular corrosion. This problem is countered by three strategies: (1) keeping the carbon content low so that chromium carbides do not precipitate; (2) adding strong carbide-forming elements such as niobium to promote the formation of carbides other than chromium carbide; and finally (3) ensuring that a minimum amount of time is spent in the critical temperature range, by selecting appropriate thermal treatments and cooling rates. The sensitization can be removed if the alloy is heated above the critical range to redissolve the carbides, then cooled rapidly enough to avoid reprecipitation.

| <b>SAE/AMS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS</b> |                                                                                                                                                |
|------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                 | <b>Title</b>                                                                                                                                   |
| 2261                                                       | Tolerances Nickel, Nickel Alloy, And Cobalt Alloy Bars, Rods, And Wire                                                                         |
| 2262                                                       | Tolerances Nickel, Nickel Alloy, And Cobalt Alloy Sheet, Strip, And Plate                                                                      |
| 2263                                                       | Tolerances Nickel, Nickel Alloy, And Cobalt Alloy Tubing                                                                                       |
| 2268                                                       | Chemical Check Analysis Limits Cast Nickel And Nickel Alloys                                                                                   |
| 2269                                                       | Chemical Check Analysis Limits Wrought Nickel Alloys And Cobalt Alloys                                                                         |
| 2280                                                       | Trace Element Control Nickel Alloy Castings                                                                                                    |
| 2316                                                       | Metallographic Evaluation Of Grain Size In Wrought Nickel And Heat Resistant Alloys                                                            |
| 2399                                                       | Electroless Nickel-Boron Plating                                                                                                               |
| 2403                                                       | Nickel Plating General Purpose                                                                                                                 |
| 2404                                                       | Electroless Nickel Plating                                                                                                                     |
| 2405                                                       | Electroless Nickel Plating Low Phosphorus                                                                                                      |
| 2410                                                       | Silver Plating Nickel Strike, High Bake                                                                                                        |
| 2416                                                       | Nickel-Cadmium Plating Diffused                                                                                                                |
| 2417                                                       | Nickel-Zinc Alloy Plating                                                                                                                      |
| 2423                                                       | Plating, Nickel Hard Deposit                                                                                                                   |
| 2424                                                       | Nickel Plating Low- Stressed Deposit                                                                                                           |
| 2433                                                       | Electroless Nickel- Thallium-Boron Or Nickel-Boron Plating                                                                                     |
| 2675                                                       | Nickel Alloy Brazing                                                                                                                           |
| 4574                                                       | Nickel-Copper Alloy Tubing, Seamless, Corrosion Resistant, 67Ni - 31Cu Annealed, UNS N04400                                                    |
| 4575                                                       | Nickel-Copper Alloy Tubing, Brazed, Corrosion Resistant, 67Ni - 31Cu Annealed, UNS N04400                                                      |
| 4674                                                       | Bars and Forgings, Free-Machining, Corrosion Resistant, 67Ni - 30Cu - 0.04S, UNS N04405                                                        |
| 4675                                                       | Nickel-Copper Alloy Bars & Forgings, Corrosion Resistant, 67Ni - 30Cr, UNS N04400                                                              |
| 4676                                                       | Nickel-Copper Alloy Bars & Forgings, Corrosion Resistant 66.5Ni-3Al-0.62Ti-28Cu, Hot-Finished, Precipitation Hardenable, UNS N05500            |
| 4677                                                       | Nickel-Copper Alloy Bars And Forgings, Corrosion Resistant 66.5Ni - 2.9Al - 30Cu Annealed, UNS N05502                                          |
| 4730                                                       | Nickel-Copper Alloy Wire, Corrosion Resistant 67Ni - 31Cu Annealed, UNS N04400                                                                 |
| 4731                                                       | Nickel-Copper Alloy Wire And Ribbon, Corrosion Resistant, 67Ni - 31Cu, Annealed, UNS N04400                                                    |
| 4775                                                       | Nickel Alloy Brazing Filler Metal 73Ni - 0.75C - 4.5Si - 14Cr - 3.1B - 4.5Fe 1790 to 1970°F (977 to 1077°C) Solidus-Liquidus Range, UNS N99600 |

| <b>SAE/AMS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                                                |
|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                             | <b>Title</b>                                                                                                                                                                                   |
| 4776                                                                   | Nickel Alloy Brazing Filler Metal 73Ni - 4.5Si - 14Cr - 3.1B - 4.5Fe (Low Carbon) 1790 to 1970°F (977 to 1077°C) Solidus- Liquidus Range, UNS N99610                                           |
| 4777                                                                   | Nickel Alloy Brazing Filler Metal 82Ni - 4.5Si - 7.0Cr - 3.1B - 3.0Fe 1780 to 1830°F (971 to 999°C) Solidus-Liquidus Range, UNS N99620                                                         |
| 4778                                                                   | Nickel Alloy Brazing Filler Metal 92Ni - 4.5Si - 3.1B 1800 to 1900°F Solidus-Liquidus Range, UNS N99630                                                                                        |
| 4779                                                                   | Nickel Alloy Brazing Filler Metal 94Ni - 3.5Si - 1.8B 1800 to 1950°F (982 to 1066°C) Solidus-Liquidus Range, UNS N99640                                                                        |
| 4782                                                                   | Nickel Alloy Brazing Filler Metal 71Ni - 10Si - 19Cr 1975 to 2075°F (1080 to 1135°C) Solidus-Liquidus Range, UNS N99650                                                                        |
| 4892                                                                   | Alloy Castings, Sand and Centrifugal, Corrosion and Heat Resistant 66Ni - 29Cu - 4.0Si as Cast, UNS N04019                                                                                     |
| 4893                                                                   | Alloy Castings, Sand and Centrifugal, Corrosion and Heat Resistant 66Ni - 29Cu - 4.0Si Solution Treated, UNS N04019                                                                            |
| 5377                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 73Ni - 12Cr - 4.5Mo - 2.0Cb - 0.70Ti - 6.0Al - 0.010b - 0.10Zr, Vacuum Melted, As Cast, UNS N07713                                   |
| 5383                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 52.5Ni - 19Cr - 3.0Mo - 5.1(Cb+Ta) - 0.90Ti - 0.60Al - 18Fe, Vacuum Melted, Homogenization and Solution Heat Treated, UNS N07718     |
| 5384                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 53Ni - 18Cr - 18Co - 4.0Mo - 2.9Ti - 2.9Al - 0.006B, Vacuum Melted, Vacuum Cast, Solution and Precipitation Heat Treated, UNS N07500 |
| 5388                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 53.5Ni - 16.5Cr - 17Mo - 4.5W - 5.8Fe - 0.40V, As Cast, UNS N10002                                                                   |
| 5389                                                                   | Alloy Castings, Sand, Corrosion and Heat Resistant 55Ni - 16.5Cr - 17Mo - 4.5W - 5.8Fe - 0.40V Solution Heat Treated, UNS N10002                                                               |
| 5390                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 47.5Ni - 22Cr - 1.5Co - 9Mo - 0.60W - 18.5Fe, As Cast, UNS N06002                                                                    |
| 5391                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 73Ni - 13Cr - 4.5Mo - 2.3(Cb+Ta) - 0.75Ti - 6.0Al - 0.010B - 0.10Zr Vacuum Melted, As Cast, UNS N07713                               |
| 5396                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 65Ni - 28Mo - 5.5Fe - 0.40V, As Cast, UNS N10001                                                                                     |
| 5397                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 50Ni - 9.5Cr - 15Co - 3.0Mo - 4.8Ti - 5.5Al - 0.015B - 0.95V - 0.06Zr, Vacuum Melted, Vacuum Cast, As Cast, UNS N13100               |
| 5399                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 52Ni - 19Cr - 11Co - 9.8Mo - 3.2Ti - 1.6Al - 0.006B, Vacuum Melted, Vacuum Cast, Solution Heat Treated, UNS N07041                   |
| 5401                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 62Ni - 21.5Cr - 9.0Mo - 3.6(Cb+Ta), Vacuum Melted, Vacuum Cast, As Cast, UNS N06625                                                  |
| 5402                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 62Ni - 21.5Cr - 9.0Mo - 3.6(Cb+Ta), As Cast, UNS N06625                                                                              |

| <b>SAE/AMS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                                                                                    |
|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                             | <b>Title</b>                                                                                                                                                                                                                       |
| 5403                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 60Ni - 14Cr - 9.5Co - 4.0Mo - 4.0W - 5.0Ti - 3.0Al - 0.015B - 0.06Zr, Vacuum Melted, Vacuum Cast                                                                         |
| 5404                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 59Ni - 12.6Cr - 9.0Co - 1.9Mo - 4.2W - 4.0Ti - 4.2Ta - 3.4Al - 0.015B - 0.10Zr - 0.90Hf, Vacuum Melted, Vacuum Cast, Solution and Precipitation Heat Treated, UNS N07013 |
| 5405                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 64Ni - 8.0Cr - 10Co - 6.0Mo - 1.0Ti - 4.2Ta - 6.0Al - 0.15B - 0.008Zr, Vacuum Melted, Vacuum Cast, As Cast, UNS N13010                                                   |
| 5406                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 63Ni - 8.0Cr - 10Co - 6.0Mo - 1.0Ti - 4.2Ta - 6.0Al - 0.015B - 0.03Zr - 1.2Hf, Vacuum Melted, Vacuum Cast, As Cast, UNS N13010                                           |
| 5407                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 60Ni - 9.0Cr - 10Co - 12.5W - 1.0Cb - 2.0Ti - 5.0Al - 0.015B - 0.06Zr, Vacuum Melted, Vacuum Cast, As Cast, UNS N13009                                                   |
| 5408                                                                   | Alloy Castings, Centrifugal, Corrosion and Heat Resistant 64Ni - 16Cr - 15Mo - 0.30Al - 0.05La Solution Heat Treated                                                                                                               |
| 5409                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 61Ni - 16Cr - 8.5Co - 1.8Mo - 2.6W - 0.8Cb - 3.4Ti - 1.8Ta - 3.4Al - 0.010B - 0.06Zr, (0.03-0.08C), Vacuum Melted, Vacuum Cast, As Cast                                  |
| 5410                                                                   | Alloy Castings, Investment, Corrosion and Heat Resistant, 61Ni - 16Cr - 8.5Co - 1.8Mo - 2.6W - 0.85Cb - 3.4Ti - 1.8Ta - 3.4Al - 0.010B - 0.05Zr, Vacuum Melted, Vacuum Cast, As Cast                                               |
| 5536                                                                   | Alloy Sheet, Strip and Plate, 58Ni - 15.5Cr - 16Mo - 3.8w - 5.5fE, Solution Heat Treated, UNS N06002                                                                                                                               |
| 5540                                                                   | Alloy Sheet, Strip and Plate, 74Ni - 15.5Cr - 8.0Fe, Annealed, UNS N06600                                                                                                                                                          |
| 5541                                                                   | Nickel Alloy, Corrosion and Heat Resistant, Sheet and Strip 73Ni - 15.5Cr - 2.4Ti - 0.7Al - 7.0Fe Annealed, UNS N07722                                                                                                             |
| 5542                                                                   | Alloy Sheet, Strip and Plate, 72Ni - 15.5Cr - 0.95(Cb+Ta) - 2.5Ti - 0.70Al - 7.0Fe, Annealed, UNS N07750                                                                                                                           |
| 5544                                                                   | Alloy Sheet, Strip and Plate, 57Ni - 19.5Cr - 13.5Co - 4.2Mo - 3.0Ti - 1.4Al - 0.05Zr - 0.006B, Consumable Electrode or Vacuum Induction Melted, Annealed, UNS N07001                                                              |
| 5545                                                                   | Alloy Sheet, Strip and Plate, Corrosion and Heat Resistant, 54Ni - 19Cr - 11Co - 9.8Mo - 3.2Ti - 1.5Al - 0.006B, Vacuum Induction and Consumable Electrode Melted, Solution Heat Treated, Precipitation Heat Treatable, UNS N07041 |
| 5550                                                                   | Alloy Sheet, Strip, Corrosion and Heat Resistant, 80Ni - 15.5Cr - 0.62Ti - 3.2Al, Annealed, UNS N07702                                                                                                                             |
| 5552                                                                   | Alloy Sheet, Strip, and Plate, Corrosion and Heat Resistant, 46Fe - 20.5Cr - 32Ni - 1.1Ti, UNS N08801                                                                                                                              |
| 5553                                                                   | Nickel Sheet and Strip Low (0.02 Max) Carbon Annealed, UNS N02201                                                                                                                                                                  |
| 5555                                                                   | Nickel Wire and Ribbon 99Ni, UNS N02205                                                                                                                                                                                            |
| 5580                                                                   | Alloy Tubing, Seamless, Corrosion and Heat Resistant 74Ni - 15.5Cr - 8.0Fe Annealed, UNS N06600                                                                                                                                    |

| <b>SAE/AMS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                                                                            |
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| <b>AMS</b>                                                             | <b>Title</b>                                                                                                                                                                                                               |
| 5581                                                                   | Nickel Alloy, Corrosion and Heat Resistant, Seamless or Welded Tubing 62Ni - 21.5Cr - 9.0Mo - 3.7Cb Annealed, UNS N06625                                                                                                   |
| 5582                                                                   | Alloy Tubing, Seamless, Corrosion and Heat Resistant 72Ni - 15.5Cr - 0.95 (Cb+Ta) - 2.5Ti - 0.70Al - 7.0Fe Annealed, UNS N07750                                                                                            |
| 5583                                                                   | Alloy Tubing, Seamless, Corrosion and Heat Resistant 72Ni - 15.5Cr - 0.95(Cb + Ta) - 2.6Ti - 0.70Al - 7.0Fe Solution Heat Treated, UNS N07750                                                                              |
| 5586                                                                   | Alloy Tubing, Welded, Corrosion and Heat Resistant 57Ni - 19.5Cr - 13.5Co - 4.2Mo - 2.9Ti - 1.4Al - 0.08Zr - 0.006B Consumable Electrode or Vacuum Induction Melted, Annealed, UNS N07001                                  |
| 5587                                                                   | Nickel Alloy, Corrosion and Heat Resistant, Seamless Tubing 47.5Ni - 22Cr - 1.5Co - 9.0Mo - 0.60W - 18.5Fe Solution Heat Treated, UNS N06002                                                                               |
| 5588                                                                   | Alloy Tubing, Welded and Drawn, Corrosion and Heat Resistant 47.5Ni - 22Cr - 1.5Co - 9.0Mo - 0.60W - 18.5Fe Solution Heat Treated, UNS N06002                                                                              |
| 5589                                                                   | Alloy Tubing, Seamless, Corrosion and Heat Resistant 52.5Ni - 19Cr - 3.0Mo - 5.1(Cb + Ta) - 0.90Ti - 0.50Al - 18Fe Consumable Electrode or Vacuum Induction Melted 1750°F (955°C) Solution Heat Treated, UNS N07718        |
| 5590                                                                   | Alloy Tubing, Seamless, Corrosion and Heat Resistant 52.5Ni - 19Cr - 3.0Mo - 5.1 (Cb + Ta) - 0.90Ti - 0.50Al - 18Fe Consumable Electrode or Vacuum Induction Melted 1950°F (1065°C) Solution Heat Treated, UNS N07718      |
| 5592                                                                   | Alloy Sheet, Strip, and Plate, 18.5Cr - 35Ni - 1.15Si, Solution Heat Treated, UNS N08330                                                                                                                                   |
| 5593                                                                   | Alloy Sheet, Strip, Plate Corrosion and Heat Resistant, 45.5Ni - 25.5Cr - 3.2Co - 3.2Mo - 3.2W - 18.5Fe, Solution Heat Treated, UNS N06333                                                                                 |
| 5596                                                                   | Alloy Sheet, Strip, Plate Corrosion and Heat Resistant, 52.5Ni - 19Cr - 3.0Mo - 5.1(Cb+Ta) - 0.90Ti - 0.50Al - 18Fe, Consumable Electrode or Vacuum Induction Melted 1750°F (955°C) Solution Heat Treated, UNS N07718      |
| 5597                                                                   | Alloy Sheet, Strip, Plate Corrosion and Heat Resistant, 52.5Ni - 19Cr - 3.0Mo - 5.1(Cb+Ta) - 0.90Ti - 0.50Al - 18Fe, Consumable Electrode or Vacuum Induction Melted 1950°F (1067°C) Solution Heat Treated, UNS N07718     |
| 5598                                                                   | Alloy Sheet, Strip, Plate Corrosion and Heat Resistant, 72Ni - 15.5Cr - 0.95(Cb+Ta) - 2.5Ti - 0.70Al - 7.0Fe, Consumable Electrode or Vacuum Induction Melted, Solution Heat Treated, Precipitation Hardenable, UNS N07750 |
| 5599                                                                   | Alloy Sheet, Strip, Plate Corrosion and Heat Resistant, 62Ni - 21.5Cr - 9.0Mo - 3.7(Cb+Ta), Annealed, UNS N06625                                                                                                           |
| 5605                                                                   | Nickel Alloy, Corrosion and Heat Resistant, Sheet, Strip, and Plate 41.5Ni - 16Cr - 37Fe - 2.9Cb - 1.8Ti Consumable Electrode or Vacuum Induction Melted 1800°F (982°C) Solution Heat Treated, UNS N09706                  |
| 5606                                                                   | Sheet, Strip, Plate, 41.5Ni - 16Cr - 37Fe - 2.9Cb - 1.8Ti, Consumable Electrode or Vacuum Induction Melted 1759°F (954°C) Solution Heat Treated, UNS N09706                                                                |
| 5607                                                                   | Sheet, Strip, Plate, 73Ni - 7.0Cr - 16.5Mo, Solution Treated, UNS N10003                                                                                                                                                   |
| 5633                                                                   | Alloy Bars and Forgings, 38Fe - 13.2Cr - 38Ni - 5.5Mo - 0.85Cb - 2.5Ti - 1.6Al - 0.009B, Consumable Electrode Melted, Solution Heat Treated, UNS N09027                                                                    |

| <b>SAE/AMS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                         |
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| <b>AMS</b>                                                             | <b>Title</b>                                                                                                                                                                                                                                            |
| 5634                                                                   | Alloy Bars and Forgings, 38Fe - 13.2Cr - 38Ni - 5.5Mo - 0.85Cb - 2.5Ti - 1.6Al - 0.009B, Consumable Electrode Melted, Solution and Precipitation Heat Treated, UNS N09027                                                                               |
| 5660                                                                   | Alloy Bars, Forgings, and Rings 42.5Ni - 12.5Cr - 6.0Mo - 2.7Ti - 34Fe, Consumable Electrode or Vacuum Induction Melted Solution, Stabilization, and Precipitation Heat Treated, UNS N09901                                                             |
| 5661                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant 42.5Ni - 12.5Cr - 5.8Mo - 2.9Ti - 0.015B - 35Fe Consumable Electrode or Vacuum Induction Melted Solution, Stabilization, and Precipitation Heat Treated, UNS N09901                       |
| 5662                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant 52.5Ni - 19Cr - 3.0Mo - 5.1(Cb+Ta) - 0.90Ti - 0.50Al - 18Fe, UNS N07718                                                                                                                   |
| 5663                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant 52.5Ni - 19Cr - 3.0Mo - 5.1(Cb+Ta) - 0.90Ti - 0.50Al - 19Fe, Consumable Electrode or Vacuum Induction Melted, 1775°F (968°C) Solution and Precipitation Heat Treated, UNS N07718          |
| 5664                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant 52.5Ni - 19Cr - 3.0Mo - 5.1(Cb+Ta) - 0.90Ti - 0.50Al - 19Fe, Consumable Electrode or Vacuum Induction Melted, 1950°F (1066°C) Solution Heat Treated, Precipitation Hardenable, UNS N07718 |
| 5665                                                                   | Alloy Bars, Forgings, and Rings 74Ni - 15.5Cr - 8.0Fe, Solution Heat Treated, UNS N0660                                                                                                                                                                 |
| 5666                                                                   | Bars, Forgings, Extrusions, and Rings 62Ni - 21.5Cr - 9.0Mo - 3.65 (Cb+Ta) Annealed, UNS N06625                                                                                                                                                         |
| 5667                                                                   | Alloy Bars, Forgings, and Rings 72Ni - 15.5Cr - 0.95(Cb+Ta) - 2.5Ti - 0.70Al - 7.0Fe, Equalized, Precipitation Hardenable, UNS N07750                                                                                                                   |
| 5668                                                                   | Alloy Bars, Forgings, and Rings 72Ni - 15.5Cr - 7Fe - 2.5Ti - 1(Cb+Ta) - 0.7Al, 2100°F (1095°C) Solution and Precipitation Heat Treated, UNS N07750                                                                                                     |
| 5669                                                                   | Alloy Bars, Corrosion and Heat Resistant Nickel Base - 15.5Cr - 0.95 (Cb+Ta) - 2.5Ti - 0.70Al - 7.0Fe Consumable Electrode or Vacuum Induction Melted NONCURRENT July 1987, UNS N07750                                                                  |
| 5670                                                                   | Alloy Bars, Forgings, and Rings 72Ni - 15.5Cr - 0.95(Cb+Ta) - 2.5Ti - 0.70Al - 7.0Fe, 1800°F (980°C) Solution Heat Treated, Precipitation Hardenable, UNS N07750                                                                                        |
| 5671                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 72Ni - 15.5Cr - 0.95(Cb+Ta) - 2.5Ti - 0.70Al - 7.0Fe, Consumable Electrode or Vacuum Induction Melted, 1800°F (982°C) Solution Heat Treated, Precipitation Hardenable, UNS N07750        |
| 5675                                                                   | Alloy Welding Wire, Corrosion and Heat Resistant, 70Ni - 2.4Mn - 15.5Cr - 3.0Ti - 7.0Fe, UNS N07092                                                                                                                                                     |
| 5676                                                                   | Alloy Welding Wire, Corrosion and Heat Resistant, 80Ni - 20Cr, UNS N06003                                                                                                                                                                               |
| 5677                                                                   | Alloy Covered Welding Electrodes, Corrosion and Heat Resistant, 75Ni - 19.5Cr - 1.6(Cb+Ta), UNS N06003                                                                                                                                                  |
| 5679                                                                   | Nickel Alloy Welding Wire, Corrosion and Heat Resistant, 73Ni - 15.5Cr - 2.2Cb - 8.0Fe, UNS N06062                                                                                                                                                      |
| 5682                                                                   | Coating Alloy, Corrosion and Heat Resistant, 78Ni - 20Cr, UNS N06003                                                                                                                                                                                    |
| 5684                                                                   | Alloy Welding Electrodes, Covered, Corrosion and Heat Resistant, 72Ni - 15Cr - 9.0Fe - 2.8(Cb+Ta), UNS W86132                                                                                                                                           |

| <b>SAE/AMS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                                                  |
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| <b>AMS</b>                                                             | <b>Title</b>                                                                                                                                                                                                                                                                     |
| 5687                                                                   | Alloy Wire, Corrosion and Heat Resistant, 74Ni - 15.5Cr - 8.0Fe, Annealed, UNS N06600                                                                                                                                                                                            |
| 5698                                                                   | Alloy Wire, Corrosion and Heat Resistant, 72Ni - 15.5Cr - 0.95(Cb+Ta) - 2.5Ti - 0.70Al - 7.0Fe, No. 1 Temper, Precipitation Hardenable, UNS N07750                                                                                                                               |
| 5699                                                                   | Alloy Wire, Corrosion and Heat Resistant, 72Ni - 15.5Cr - 0.95(Cb+Ta) - 2.5Ti - 0.70Al - 7.0Fe, Spring Temper, Precipitation Hardenable, UNS N07750                                                                                                                              |
| 5701                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 41.5Ni - 16Cr - 37Fe - 2.9Cb - 1.8Ti, Consumable Electrode or Vacuum Induction Melted 1800°F (980°C) Solution Heat Treated, UNS N09706                                                                            |
| 5702                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 41.5Ni - 16Cr - 37Fe - 2.9Cb - 1.8Ti, Consumable Electrode or Vacuum Induction Melted 1750°F (955°C) Solution Heat Treated, UNS N09706                                                                            |
| 5703                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 41.5Ni - 16Cr - 37Fe - 2.9Cb - 1.8Ti, Consumable Electrode or Vacuum Induction Melted 1750°F (955°C) Solution, Stabilization, and Precipitation Heat Treated, UNS N09706                                          |
| 5704                                                                   | Alloy Forgings, Corrosion and Heat Resistant, 57Ni - 19.5Cr - 13.5Co - 4.3Mo - 3.0Ti - 1.4Al - 0.05Zr - 0.006B, Consumable Electrode or Vacuum Induction Melted, 1828°-1900°F (995°-1040°C) Solution, Stabilization, and Precipitation Heat Treated, UNS N07001                  |
| 5706                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 57Ni - 19.5Cr - 13.5Co - 4.3Mo - 3.0Ti - 1.4Al - 0.006B - 0.05Zr, Consumable Electrode or Vacuum Induction Melted, 1828°-1900°F (995°-1040°C) Solution Heat Treated, UNS N07001                                   |
| 5707                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 58Ni - 19.5Cr - 13.5Co - 4.3Mo - 3.0Ti - 1.4Al - 0.05Zr - 0.006B, Consumable Electrode or Vacuum Induction Melted, 1828°-1900°F (996°-1038°C) Solution, Stabilization, and Precipitation Heat Treated, UNS N07001 |
| 5708                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 58Ni - 19.5Cr - 13.5Co - 4.3Mo - 3.0Ti - 1.4Al, Consumable Electrode or Vacuum Induction Melted, 1975°F (1079°C) Solution Heat Treated, UNS N07001                                                                |
| 5709                                                                   | Alloy Bars, Forgings, Corrosion and Heat Resistant, 58Ni - 19.5Cr - 13.5Co - 4.3Mo - 3.0Ti - 1.4Al - 0.05Zr - 0.006B, Consumable Electrode or Vacuum Induction Melted, 1975°F (1079°C) Solution, Stabilization, and Precipitation Heat Treated, UNS N07001                       |
| 5711                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 65Ni - 15.8Cr - 15.2Mo - 0.30Al - 0.05La Solution Heat Treated, UNS N06635                                                                                                                                        |
| 5712                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 53Ni - 19Cr - 11Co - 9.8Mo - 3.2Ti - 1.6Al - 0.006B, Vacuum Melted, Solution Heat Treated, UNS N07041                                                                                                             |
| 5713                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 53Ni - 19Cr - 11Co - 9.8Mo - 3.2Ti - 1.6Al - 0.006B, Vacuum Melted, Solution and Precipitation Heat Treated, UNS N07041                                                                                           |
| 5714                                                                   | Bars, Forgings, and Rings, Corrosion and Heat Resistant 73Ni - 15.5Cr - 2.5Ti - 0.70Al - 7.0Fe Precipitation Hardenable, UNS N07722                                                                                                                                              |
| 5715                                                                   | Nickel Alloy, Corrosion and Heat Resistant, Bars, Forgings, and Rings 60.5Ni - 23Cr - 14Fe - 1.4Al Annealed, UNS N06601                                                                                                                                                          |
| 5716                                                                   | Alloy Bars, Wire, Forgings, and Rings, Heat Resistant, 44Fe - 18.5Cr - 35.5Ni - 1.1Si, Solution Heat Treated, UNS N08330                                                                                                                                                         |



| <b>SAE/AMS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                                                                                              |
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| <b>AMS</b>                                                             | <b>Title</b>                                                                                                                                                                                                                                 |
| 5717                                                                   | Nickel Alloy, Corrosion and Heat Resistant, Bars, Forgings, and Rings 45.5Ni - 25.5Cr - 3.2Co - 3.2Mo - 3.2W - 18.5Fe Solution Heat Treated, UNS N06333                                                                                      |
| 5746                                                                   | Alloy Bars, Forgings, Corrosion and Heat Resistant, 15Cr - 45Ni - 4.1Mo - 4.1W - 3.0Ti - 1.0Al - 31Fe, Consumable Electrode, Vacuum Melted, Solution and Precipitation Heat Treated, UNS N09979                                              |
| 5747                                                                   | Nickel Alloy, Corrosion and Heat Resistant, Bars, Forgings, and Rings 72Ni - 15.5Cr - 0.95Cb - 2.5Ti - 0.70Al - 7.0Fe Solution Heat Treated, Precipitation Hardenable, UNS N07750                                                            |
| 5750                                                                   | Nickel Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant Nickel Base - 15.5Cr - 16Mo - 3.8W - 5.5Fe Solution Heat Treated, NONCURRENT July 1981, UNS N10002                                                                      |
| 5751                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 54Ni - 17.5Cr - 16.5Co - 4.0Mo - 2.9Ti - 2.9Al - 0.006B, Solution, Stabilization, and Precipitation Heat Treated, Consumable Electrode or Vacuum Induction Melted, UNS N07500 |
| 5753                                                                   | Alloy Bars, and Forgings, Corrosion and Heat Resistant, 54Ni - 17.5Cr - 16.5Co - 4.0Mo - 2.9Ti - 2.9Al - 0.006B, Vacuum Melted, Solution Heat Treated, UNS N07500                                                                            |
| 5754                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 47.5Ni - 22Cr - 1.5Co - 9.0Mo - 0.60W - 18.5Fe, Solution Heat Treated, UNS N06002                                                                                             |
| 5755                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 64Ni - 5.0Cr - 24.5Mo - 5.5Fe, Solution Heat Treated, UNS N10004                                                                                                              |
| 5766                                                                   | Alloy Bars, and Forgings, Corrosion and Heat Resistant, 21Cr - 32.5Ni - 0.38Al - 45Fe, Solution Heat Treated, UNS N08800                                                                                                                     |
| 5771                                                                   | Alloy Bars, Forgings, and Rings, 74Ni - 7.0Cr - 16.5Mo, Solution Heat Treated, UNS N10003                                                                                                                                                    |
| 5778                                                                   | Alloy Welding Wire, Corrosion and Heat Resistant 72Ni - 15.5Cr - 1.0(Cb + Ta) - 2.4Ti - 0.70Al - 7.0Fe, UNS N07069                                                                                                                           |
| 5779                                                                   | Alloy Welding Electrodes, Covered, Corrosion and Heat Resistant 75Ni - 15Cr - 1.5 (Cb + Ta) - 1.9Ti - 0.55Al - 5.5Fe, UNS N07750                                                                                                             |
| 5786                                                                   | Welding Wire, 62.5Ni - 5.0Cr - 24.5Mo - 5.5Fe, UNS N10004                                                                                                                                                                                    |
| 5787                                                                   | Alloy Covered Welding Electrode, 63Ni - 5Cr - 24.5Mo - 5.5Fe, NONCURRENT January 1987, UNS W80004                                                                                                                                            |
| 5798                                                                   | Welding Wire, Corrosion and Heat Resistant, 47.5Ni - 22Cr - 1.5Co - 9.0Mo - 0.60W - 18.5Fe, UNS N06002                                                                                                                                       |
| 5799                                                                   | Alloy Covered Welding Electrodes, 48Ni - 22Cr - 1.5Co - 9.0Mo - 0.60W - 18.5Fe, UNS N06002                                                                                                                                                   |
| 5800                                                                   | Welding Wire, 54Ni - 19Cr - 11Mo - 3.2Ti - 1.5Al - 0.006B, UNS N07041                                                                                                                                                                        |
| 5802                                                                   | Alloy Welding Wire, 41Fe - 37.5Ni - 14Co - 4.8(Cb+Ta) - 1.5Ti, Vacuum Melted, Low Expansion, UNS N19907                                                                                                                                      |
| 5806                                                                   | Welding Wire, Low Expansion Alloy, 42Fe - 38Ni - 15Co - 3.0(Cb+Ta) - 1.4Ti - 0.92Al, Vacuum Melted, UNS N19903                                                                                                                               |
| 5828                                                                   | Alloy Welding Wire, 57Ni - 19.5Cr - 13.5Co - 4.2Mo - 3.1Ti - 1.4Al - 0.006B, Vacuum Induction Melted, Solution Heat Treated, UNS N07001                                                                                                      |
| 5829                                                                   | Alloy Welding Wire, 56Ni - 19.5Cr - 18Co - 2.5Ti - 1.5Al, Vacuum Induction Melted, UNS N07090                                                                                                                                                |

| <b>SAE/AMS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                                                       |
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| <b>AMS</b>                                                             | <b>Title</b>                                                                                                                                                                                          |
| 5830                                                                   | Welding Wire, Corrosion and Heat Resistant Alloy 12.5Cr - 42.5Ni - 6.0Mo - 2.7Ti - 0.015B - 35Fe, UNS N09901                                                                                          |
| 5832                                                                   | Welding Wire, 52.5Ni - 19Cr - 5.1(Cb+Ta) - 0.90Ti - 0.50Al - 18Fe, Consumable Electrode or Vacuum Induction Melted, UNS N07718                                                                        |
| 5836                                                                   | Alloy Welding Wire, 72Ni - 20Cr - 2.5Mn - 2.5Cb, UNS N06082                                                                                                                                           |
| 5837                                                                   | Welding Wire, 62Ni - 21.5Cr - 9.0Mo - 3.7(Cb+Ta), UNS N06625                                                                                                                                          |
| 5838                                                                   | Alloy Welding Wire, 65Ni - 16Cr - 15Mo - 0.30Al - 0.06La, UNS N06635                                                                                                                                  |
| 5846                                                                   | Alloys Bars and Forgings, 53Ni - 15Cr - 18.5Co - 5.0Mo - 3.2Ti - 4.2Al - 0.03B, Double Vacuum Melted, Solution Stabilization, and Precipitation Heat Treated, UNS N13020                              |
| 5851                                                                   | Alloy Powder 55Ni - 15Cr - 17Co - 5.0Mo - 3.5Ti - 4.0Al - 0.025B, as Fabricated, UNS N13017                                                                                                           |
| 5852                                                                   | Alloy Billets and Preforms, 55Ni - 15Cr - 17Co - 5.0Mo - 3.5Ti - 4.0Al - 0.025B, Powder Metallurgy Product, Hot Isostatically Pressed, UNS N13017                                                     |
| 5854                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant 61Ni - 20.5Cr - 8.5Mo - 3.4Cb - 1.3Ti - 5.0Fe Consumable Electrode or Vacuum Induction Melted Solution Heat Treated, UNS N07716         |
| 5856                                                                   | Alloy Billets and Preforms, 59.5Ni - 12Cr - 10Co - 3.0Mo - 6.0W - 3.0Ti - 1.5Ta - 4.5Al - 0.015B - 0.10Zr (0.30-0.35C), Powder Metallurgy Product, UNS N07012                                         |
| 5865                                                                   | Nickel Sheet and Strip, Corrosion and Heat Resistant Thoria Dispersion Strengthened 2.2ThO <sub>2</sub> , UNS N03260                                                                                  |
| 5869                                                                   | Alloy Sheet, Strip, and Plate, Corrosion and Heat Resistant 62Ni - 21.5Cr - 9.0Mo - 3.7(Cb+Ta) Solution Heat Treated, UNS N06625                                                                      |
| 5870                                                                   | Alloy Sheet, Strip, and Plate, Corrosion and Heat Resistant, 60.5Ni - 23Cr - 14Fe - 0.35Ti - 1.4Al, Solution Heat Treated, UNS N06601                                                                 |
| 5871                                                                   | Alloy Sheet, Strip, and Plate, Corrosion and Heat Resistant, 21Cr - 32.5Ni - 0.38Ti - 0.38Al - 45Fe, Solution Heat Treated, UNS N08800                                                                |
| 5872                                                                   | Sheet, Strip, and Plate, Corrosion and Heat Resistant, 48Ni - 20Cr - 20Co - 5.9Mo - 2.2Ti - 0.45Al, Solution Heat Treated, UNS N07263                                                                 |
| 5873                                                                   | Alloy Sheet, Strip, Plate, Corrosion and Heat Resistant, 65Ni - 15.8Cr - 15.2Mo - 0.30Al - 0.05La, Consumable Electrode Melted, Solution Heat Treated, UNS N06635                                     |
| 5878                                                                   | Alloy Sheet, Strip, and Plate, Corrosion and Heat Resistant, 59Ni - 22Cr - 2Mo - 14W - 0.35Al - 0.03La, Solution Heat Treated, UNS N06230                                                             |
| 5879                                                                   | Sheet, Strip, and Foil, Corrosion and Heat Resistant Alloy, 62Ni - 21.5Cr - 9.0Mo - 3.7(Cb+Ta) Cold Rolled and Annealed, UNS N06625                                                                   |
| 5882                                                                   | Alloy Forgings, Corrosion and Heat Resistant, 55Ni - 15Cr - 17Co - 5.0Mo - 3.5Ti - 4.0Al - 0.025B, Solution, Stabilization, and Precipitation Heat Treated, Powder Metallurgy Product, UNS N13017     |
| 5884                                                                   | Iron-Nickel Alloy, Bars, Forgings, and Rings 42Fe - 37.5Ni - 14Co - 4.8(Cb + Ta) - 1.6Ti Solution Heat Treated, Precipitation Hardenable Multiple Melted, High Temperature, Low Expansion, UNS N19909 |

| <b>SAE/AMS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                                                               |
|------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                             | <b>Title</b>                                                                                                                                                                                                  |
| 5886                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 50Ni - 20Cr - 20Co - 5.8Mo - 2.2Ti - 0.45Al, Consumable Electrode or Vacuum Induction Melted 2100°F (1149°C) Solution Heat Treated, UNS N07263 |
| 5887                                                                   | Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant 54Ni - 22Cr - 12.5Co - 9.0Mo - 1.2Al Consumable Electrode or Vacuum Induction Melted Annealed, UNS N06617                                       |
| 5888                                                                   | Alloy Plate, Corrosion and Heat Resistant 54Ni - 22Cr - 12.5Co - 9.0Mo - 1.2Al Annealed, UNS N06617                                                                                                           |
| 5889                                                                   | Alloy Sheet and Strip, Corrosion and Heat Resistant 54Ni - 22Cr - 12.5Co - 9.0Mo - 1.2Al Consumable Electrode or Vacuum Induction Melted Annealed, UNS N06617                                                 |
| 5890                                                                   | Nickel Bars, Forgings, and Extrusions, Corrosion and Heat Resistant Thoria Dispersion Strengthened 2.2ThO <sub>2</sub> Stress-Relieved, UNS N03260                                                            |
| 5891                                                                   | Nickel Alloy, Corrosion and Heat Resistant, Bars, Forgings, and Rings 60Ni - 22Cr - 2.0Mo - 14W - 0.35Al - 0.03La Annealed, UNS N06230                                                                        |
| 5892                                                                   | Low Expansion, High Temperature, Alloy Sheet and Strip, 43Fe - 37Ni - 14Co - 4.5(Cb+Ta) - 1.5Ti, Multiple Melted, Solution Heat Treated, Precipitation Hardened, UNS N19909                                   |
| 5893                                                                   | Low Expansion, High Temperature, Alloy Bars, Forgings, and Rings 43Fe - 37Ni - 14Co - 4.5(Cb+Ta) - 1.5Ti Multiple Melted, Solution Heat Treated, Short-Time Precipitation Hardenable, UNS N19909              |
| 7232                                                                   | Alloy Rivets, Corrosion Resistant, 74Ni - 15.5Cr - 8.0Fe, UNS N06600                                                                                                                                          |
| 7233                                                                   | Solid Rivets, Alloy-Corrosion Resistant, 67Ni 31Cu, Superseded by AS 7233                                                                                                                                     |
| 7234                                                                   | Blind Rivets, Alloy-Corrosion Resistant, 67Ni - 31Cu, UNS N04405                                                                                                                                              |
| 7237                                                                   | Alloy Rivets, Corrosion and Heat Resistant 47.5Ni - 22Cr - 1.5Co - 9.0Mo - 0.60W - 18.5Fe Solution Heat Treated, UNS N06002                                                                                   |
| 7246                                                                   | Thread Form Inserts, Corrosion and Heat Resistant Alloy, 72Ni - 15.5Cr - 0.95(Cb+Ta) - 2.5Ti - 0.70Al - 7.0Fe, UNS N07750                                                                                     |
| 7490                                                                   | Flash Welded Rings, Corrosion and Heat Resistant Austenitic Steels and Austenitic-Type Alloys, or Precipitation Hardenable Alloys, UNS N06625                                                                 |

| <b>SAE MISCELLANEOUS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS</b> |                                                          |
|----------------------------------------------------------------------|----------------------------------------------------------|
| <b>SAE</b>                                                           | <b>Title</b>                                             |
| AS 3074                                                              | Gasket-37 Degree Flared Tube Fitting, Nickel, AMS 5553   |
| AS 3075                                                              | Gasket - 37 Degree Flared Tube Fitting, Nickel, AMS 5553 |
| AS 3282                                                              | Gasket - 37 Degree Flared Tube Fitting, Nickel, AMS 5553 |
| AS 3484                                                              | Gasket - 37 Degree Flared Tube Fitting, Nickel, AMS-5553 |

| <b>SAE MISCELLANEOUS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                      |
|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| <b>SAE</b>                                                                       | <b>Title</b>                                                                                                                         |
| AS 7253                                                                          | Nuts, Self-Locking, Nickel Alloy, UNS N07001 180 000 psi, All Metal 1400°F Use, UNJ Thread Form                                      |
| AS 7466                                                                          | Bolts and Screws, Nickel Alloy, Corrosion and Heat Resistant Forged Head, Roll Threaded, Fatigue Rated                               |
| AS 7467                                                                          | Bolts and Screws, Nickel Alloy, Corrosion and Heat Resistant Forged Head, Roll Threaded, Stress-Rupture Rated                        |
| AS 7468                                                                          | Bolts and Screws, Cobalt- Chromium-Nickel Alloy, Corrosion Resistant Forged Head, Roll Threaded After Aging, Fatigue Rated           |
| AS 7471                                                                          | Bolts and Screws, Nickel Alloy, Corrosion and Heat Resistant Forged Head, Heat Treated, Roll Threaded 1950°F Solution Heat Treatment |
| AS 8033                                                                          | Nickel Cadmium Vented Rechargeable Aircraft Batteries (Non-Sealed, Maintainable Type)                                                |
| J 207                                                                            | Electroplating of Nickel and Chromium on Metal Parts - Automotive Ornamentation and Hardware, Standard                               |
| J 470C                                                                           | Wrought Nickel and Nickel-Related Alloys, Information Report                                                                         |
| MAM 2261                                                                         | Tolerances, Metric Nickel, Nickel Alloys, and Cobalt Alloy Bars, Rods, and Wire                                                      |
| MAM 2262                                                                         | Tolerances, Metric Nickel, Nickel Alloy, and Cobalt Alloy Sheet, Strip, and Plate                                                    |
| MAM 2263                                                                         | Tolerances, Metric Nickel, Nickel Alloy, and Cobalt Alloy Tubing                                                                     |
| MAM 4778                                                                         | Nickel Alloy Brazing Filler Metal 92Ni - 4.5Si - 3.1B 980 to 1040°C Solidus-Liquidus Range                                           |
| MA 2538                                                                          | Gasket, Metal C-Ring Seal Nickel Alloy, Corrosion and Heat Resistant, Metric Procurement Specification for                           |

AS - Aerospace Standard; MAM - Metric Aerospace Material; J - SAE (Automotive) Standard.

| <b>ASTM SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS</b> |                                                                                                                                                                     |
|---------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Commercially Pure Nickel</b>                         |                                                                                                                                                                     |
| <b>ASTM</b>                                             | <b>Title</b>                                                                                                                                                        |
| B 39                                                    | Nickel                                                                                                                                                              |
| <b>Nickel and Nickel Alloy Castings</b>                 |                                                                                                                                                                     |
| A 494                                                   | Castings, Nickel and Nickel Alloy                                                                                                                                   |
| <b>Nickel and Nickel Alloy Fittings</b>                 |                                                                                                                                                                     |
| B 366                                                   | Factory-Made Wrought Nickel and Nickel Alloy Welding Fittings                                                                                                       |
| B 462                                                   | Forged or Rolled UNS N08020, UNS N08024, UNS N08026 and UNS N08367 Alloy Pipe Flanges, Forged Fittings, and Valves and Parts for Corrosive High-Temperature Service |

| <b>ASTM SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                              |
|---------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| <b>ASTM</b>                                                         | <b>Title</b>                                                                                 |
| <b>Nickel Alloy Forgings</b>                                        |                                                                                              |
| B 564                                                               | Nickel Alloy Forgings                                                                        |
| <b>Nickel and Nickel Alloy Pipes and Tubes</b>                      |                                                                                              |
| B 161                                                               | Nickel Seamless Pipe and Tube                                                                |
| B 163                                                               | Seamless Nickel and Nickel Alloy Condenser and Heat-Exchanger Tubes                          |
| B 165                                                               | Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube                                      |
| B 167                                                               | Nickel-Chromium-Iron Alloys (UNS N06600, N06601, and N06690) Seamless Pipe and Tube          |
| B 407                                                               | Nickel-Iron-Chromium Alloy Seamless Pipe and Tube                                            |
| B 423                                                               | Nickel-Iron-Chromium-Molybdenum-Copper Alloys (UNS N08825 and N08221) Seamless Pipe and Tube |
| B 445                                                               | Nickel-Chromium-Iron-Columbium-Molybdenum-Tungsten Alloy (UNS N06102) Seamless Pipe and Tube |
| B 444                                                               | Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625) Pipe and Tube                       |
| B 464                                                               | Welded UNS N08020, UNS N08024, and UNS N08026 Alloy Pipe                                     |
| B 468                                                               | Welded UNS N08020, UNS N08024, and UNS N08026 Alloy Tubes                                    |
| B 474                                                               | Electric Fusion Welded UNS N08020, UNS N08026, and UNS N08024 Nickel Alloy Pipe              |
| B 514                                                               | Welded Nickel-Iron-Chromium Alloy Pipe                                                       |
| B 515                                                               | Welded UNS N08800 and UNS N088 10 Alloy Tubes                                                |
| B 516                                                               | Welded Nickel-Chromium-Iron Alloy (UNS N06600) Tubes                                         |
| B 517                                                               | Welded Nickel-Chromium-Iron-Alloy (UNS N06600) Pipe                                          |
| B 535                                                               | Nickel-Iron-Chromium-Silicon Alloys (UNS N08330 and UNS N08332) Seamless Pipe                |
| B 546                                                               | Electric Fusion-Welded Ni-Fe-Cr-Si Alloys (UNS N08330 and UNS N08332) Pipe                   |
| B 619                                                               | Welded Nickel and Nickel-Cobalt Alloy Pipe                                                   |
| B 622                                                               | Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube                                        |
| B 626                                                               | Welded Nickel and Nickel-Cobalt Alloy Tube                                                   |
| B 668                                                               | UNS N08028 Seamless Tubes                                                                    |
| B 673                                                               | UNS N08904, UNS N08925, and UNS N08926 Welded Pipe                                           |
| B 674                                                               | UNS N08904, UNS N08925, and UNS N08926 Welded Tube                                           |
| B 675                                                               | UNS N08366 and UNS N08367 Welded Pipe                                                        |

| <b>ASTM SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                                                 |
|---------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>ASTM</b>                                                         | <b>Title</b>                                                                                                                                                                                    |
| <b>Nickel and Nickel Alloy Pipes and Tubes (Continued)</b>          |                                                                                                                                                                                                 |
| B 676                                                               | UNS N08366 and UNS N08367 Welded Tube                                                                                                                                                           |
| B 677                                                               | UNS N08904, UNS N08925, and UNS N08926 Seamless Pipe and Tube                                                                                                                                   |
| B 690                                                               | Iron-Nickel-Chromium-Molybdenum Alloys (UNS N08366 and UNS N08367) Seamless Pipe and Tube                                                                                                       |
| B 704                                                               | Welded UNS N06625 and N08825 Alloy Tubes                                                                                                                                                        |
| B 705                                                               | Nickel-Alloy (UNS N06625 and N08825) Welded Pipe                                                                                                                                                |
| B 710                                                               | Nickel-Iron-Chromium-Silicon Alloy Welded Pipe                                                                                                                                                  |
| B 720                                                               | UNS N08310 Seamless Tube                                                                                                                                                                        |
| B 722                                                               | Nickel-Chromium-Molybdenum-Cobalt-Tungsten-Iron-Silicon Alloy (UNS N06333) Seamless Pipe and Tube                                                                                               |
| B 723                                                               | Nickel-Chromium-Molybdenum-Cobalt-Tungsten-Iron-Silicon Alloy (UNS N06333) Welded Pipe                                                                                                          |
| B 725                                                               | Welded Nickel (UNS N02200/UNS N02201) and Nickel Copper Alloy (UNS N04400) Pipe                                                                                                                 |
| B 726                                                               | Nickel-Chromium-Molybdenum-Cobalt-Tungsten-Iron-Silicon Alloy (UNS N06333) Welded Tube                                                                                                          |
| B 729                                                               | Seamless UNS N08020, UNS N08026, and UNS N08024 Nickel-Alloy Pipe and Tube                                                                                                                      |
| B 730                                                               | Welded Nickel Tube                                                                                                                                                                              |
| B 739                                                               | Nickel-Iron-Chromium-Silicon Alloy Welded Tube                                                                                                                                                  |
| B 751                                                               | Nickel and Nickel Alloy Seamless and Welded Tube, General Requirements for                                                                                                                      |
| B 757                                                               | Nickel-Chromium-Molybdenum-Tungsten Alloys (UNS N06110) Welded Pipe                                                                                                                             |
| B 758                                                               | Nickel-Chromium-Molybdenum-Tungsten Alloys (UNS N06110) Welded Tube                                                                                                                             |
| B 759                                                               | Nickel-Chromium-Molybdenum-Tungsten Alloys (UNS N06110) Pipe and Tube                                                                                                                           |
| B 775                                                               | Nickel and Nickel Alloy Seamless and Welded Pipe, General Requirements for                                                                                                                      |
| B 804                                                               | UNS N08367 Welded Pipe                                                                                                                                                                          |
| B 829                                                               | General Requirements for Nickel and Nickel Alloys Seamless Pipe and Tube                                                                                                                        |
| B 834                                                               | Pressure Consolidated Powder Metallurgy Iron-Nickel-Chromium-Molybdenum (UNS N08367) and Nickel-Chromium-Molybdenum-Columbium (Nb) (UNS N06625) Alloy Pipe Flanges, Fittings, Valves, and Parts |
| <b>Nickel and Nickel Alloy Plates, Sheets, and Strips</b>           |                                                                                                                                                                                                 |
| B 127                                                               | Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip                                                                                                                                        |
| B 162                                                               | Nickel Plate, Sheet, and Strip                                                                                                                                                                  |

| <b>ASTM SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b>   |                                                                                                                                               |
|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| <b>ASTM</b>                                                           | <b>Title</b>                                                                                                                                  |
| <b>Nickel and Nickel Alloy Plates, Sheets, and Strips (Continued)</b> |                                                                                                                                               |
| B 333                                                                 | Nickel-Molybdenum Alloy Plate, Sheet, and Strip                                                                                               |
| B 409                                                                 | Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip                                                                                            |
| B 424                                                                 | Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08221) Plate, Sheet, and Strip                                                                          |
| B 434                                                                 | Nickel-Molybdenum-Chromium-Iron Alloy (UNS N10003) Plate, Sheet, and Strip                                                                    |
| B 435                                                                 | UNS N06002, UNS N06230, and UNS R30556 Plate, Sheet, and Strip                                                                                |
| B 443                                                                 | Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Plate, Sheet, and Strip                                                               |
| B 168                                                                 | Nickel-Chromium-Iron Alloys (UNS N06600, N06601, and N06690) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheet, and Strip |
| B 463                                                                 | UNS N08620, UNS N08026, and UNS N08024 Alloy Plate, Sheet, and Strip                                                                          |
| B 519                                                                 | Nickel-Chromium-Iron-Columbium-Molybdenum-Tungsten Alloy (UNS N06102) Plate, Sheet, and Strip                                                 |
| B 536                                                                 | Nickel-Iron-Chromium-Silicon Alloys (UNS N08330 and N08332) Plate, Sheet, and Strip                                                           |
| B 575                                                                 | Low-Carbon Nickel-Molybdenum-Chromium and Low-Carbon Nickel-Chromium Molybdenum Alloy Plate, Sheet, and Strip                                 |
| B 582                                                                 | Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet, and Strip                                                                          |
| B 599                                                                 | Nickel-Iron-Chromium-Molybdenum-Columbium Stabilized Alloy (UNS N08700) Plate, Sheet, and Strip                                               |
| B 620                                                                 | Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Plate, Sheet, and Strip                                                                    |
| B 625                                                                 | UNS N08904, UNS N08925, UNS N08031, UNS N08932, and UNS N08926 Plate, Sheet, and Strip                                                        |
| B 670                                                                 | Precipitation-Hardening Nickel Alloy (UNS N07718) Plate, Sheet, and Strip for High-Temperature Service (formerly A 670)                       |
| B 688                                                                 | Chromium-Nickel-Molybdenum Iron (UNS N08366 and UNS N08367) Plate, Sheet, and Strip                                                           |
| B 709                                                                 | Iron-Nickel-Chromium-Molybdenum Alloy (UNS N08028) Plate, Sheet, and Strip                                                                    |
| B 718                                                                 | Nickel-Chromium-Molybdenum-Cobalt-Tungsten-Iron-Silicon Alloy (UNS N06333) Plate, Sheet, and Strip                                            |
| B 755                                                                 | Nickel-Chromium-Molybdenum-Tungsten Alloys (UNS N06110) Plate, Sheet, and Strip                                                               |
| B 814                                                                 | Nickel-Chromium-Iron-Molybdenum-Tungsten Alloy (UNS N06920) Plate, Sheet, and Strip                                                           |
| B 818                                                                 | Cobalt-Chromium-Nickel-Molybdenum-Tungsten Alloy (UNS R31233) Plate, Sheet, and Strip                                                         |
| <b>Nickel and Nickel Alloy Rods, Bars, and Wires</b>                  |                                                                                                                                               |
| B 160                                                                 | Nickel Rod and Bar                                                                                                                            |
| B 164                                                                 | Nickel-Copper Alloy Rod, Bar, and Wire                                                                                                        |

| <b>ASTM SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                           |
|---------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| <b>ASTM</b>                                                         | <b>Title</b>                                                                                                                              |
| <b>Nickel and Nickel Alloy Rods, Bars, and Wires (Continued)</b>    |                                                                                                                                           |
| B 166                                                               | Nickel-Chromium-Iron Alloys (UNS N06600, N06601, and N06690) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire  |
| B 335                                                               | Nickel-Molybdenum Alloy Rod                                                                                                               |
| B 408                                                               | Nickel-Iron-Chromium Alloy Rod and Bar                                                                                                    |
| B 425                                                               | Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08221) Rod and Bar                                                                                  |
| B 446                                                               | Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Rod and Bar                                                                       |
| B 471                                                               | UNS N08020, UNS N08026, and UNS N08024 Nickel Alloy Spring Wire                                                                           |
| B 472                                                               | UNS N08020, UNS N08026, UNS N08024, UNS N08926, and UNS N08367 Nickel Alloy Billets and Bars for Reforging                                |
| B 473                                                               | UNS N08020, UNS N08026, and UNS N08024 Nickel Alloy Bar and Wire                                                                          |
| B 475                                                               | UNS N08020, UNS N08026, and UNS N08024 Nickel Alloy Round Weaving Wire                                                                    |
| B 511                                                               | Nickel-Iron-Chromium-Silicon Alloy Bars and Shapes                                                                                        |
| B 512                                                               | Nickel-Chromium-Silicon Alloy (UNS N08330) Billets and Bars                                                                               |
| B 518                                                               | Nickel-Chromium-Iron-Columbium-Molybdenum-Tungsten Alloy (UNS N06102) Rod and Bar                                                         |
| B 572                                                               | UNS N06002, UNS N06230, and UNS R30556 Rod                                                                                                |
| B 573                                                               | Nickel-Molybdenum-Chromium-Iron Alloy (UNS N10003) Rod                                                                                    |
| B 574                                                               | Low-Carbon Nickel-Molybdenum-Chromium and Low-Carbon Nickel-Chromium Molybdenum Alloy Rod                                                 |
| B 581                                                               | Nickel-Chromium-Iron-Molybdenum-Copper Alloy Rod                                                                                          |
| B 649                                                               | Ni-Fe-Cr-Mo-Cu Low-Carbon Alloy (UNS N08904) and Ni-Fe-Cr-Mo-Cu-N Low Carbon Alloys (UNS N08915, UNS N08030, and UNS N08926) Bar and Wire |
| B 672                                                               | Nickel-Iron-Chromium-Molybdenum-Columbium Stabilized Alloy (UNS N08700) Bar and Wire                                                      |
| B 691                                                               | Iron-Nickel-Chromium-Molybdenum Alloys (UNS N08366 and UNS N08367) Rod, Bar, and Wire                                                     |
| B 719                                                               | Nickel-Chromium-Molybdenum-Cobalt-Tungsten-Iron-Silicon Alloy (UNS N06333) Bar                                                            |
| B 756                                                               | Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06110) Rod and Bar                                                                        |
| B 621                                                               | Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Rod                                                                                    |
| B 637                                                               | Precipitation-Hardening Nickel Alloy Bars, Forgings, and Forging Stock for High-Temperature Service (formerly A 637)                      |



| <b>ASTM SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                           |
|---------------------------------------------------------------------|---------------------------------------------------------------------------|
| <b>ASTM</b>                                                         | <b>Title</b>                                                              |
| <b>Nickel and Nickel Alloy Rods, Bars, and Wires (Continued)</b>    |                                                                           |
| B 805                                                               | Precipitation Hardening Nickel Alloys UNS N07716 and N07725, Bar and Wire |
| B 815                                                               | Cobalt-Chromium-Nickel-Molybdenum-Tungsten Alloy (UNS R31233) Rod         |

| <b>AWS WELDING FILLER METAL SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS</b> |                                                                                |
|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| <b>AWS</b>                                                                  | <b>Title</b>                                                                   |
| A5.11                                                                       | Nickel and Nickel Alloy Bare Welding Electrodes for Shielded Metal Arc Welding |
| A5.14                                                                       | Nickel and Nickel Alloy Bare Welding Electrodes and Rods                       |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS</b> |                |                                           |                                                    |                                       |                                 |
|------------------------------------------------------------------------------|----------------|-------------------------------------------|----------------------------------------------------|---------------------------------------|---------------------------------|
| <b>UNS</b>                                                                   | <b>SAE/AMS</b> | <b>MILITARY</b>                           | <b>ASTM</b>                                        | <b>ASME</b>                           | <b>AWS</b>                      |
| N02016                                                                       | ---            | ---                                       | ---                                                | ---                                   | ---                             |
| N02061                                                                       | ---            | E-21562 (EN61, RN61),<br>I-23413 (MIL-61) | ---                                                | SFA-5.14 (ERNi-1),<br>SFA-5.30 (IN61) | A5.14 (ERNi-1),<br>A5.30 (IN61) |
| N02100                                                                       | ---            | ---                                       | A 494 (CZ-100)                                     | ---                                   | ---                             |
| N02200                                                                       | ---            | ---                                       | B 160, B 161, B 162, B 163,<br>B 366, B 725, B 730 | SB-160, SB-161, SB-162, SB-163        | ---                             |
| N02201                                                                       | 5553           | ---                                       | B 160, B 161, B 162, B 163,<br>B 366, B 725, B 730 | SB-160, SB-161, SB-162, SB-163        | ---                             |
| N02205                                                                       | 5555           | N-46025                                   | F 1, F 3                                           | ---                                   | ---                             |
| N02211                                                                       | ---            | ---                                       | F 290                                              | ---                                   | ---                             |
| N02215                                                                       | ---            | ---                                       | ---                                                | SFA-5.15 (ERNi-CI)                    | A5.15 (ERNi-CI)                 |
| N02216                                                                       | ---            | ---                                       | ---                                                | SFA-5.15 (ERNiFeMn-CI)                | A 5.15 (ERNiFeMn-CI)            |
| N02220                                                                       | ---            | ---                                       | F 239                                              | ---                                   | ---                             |
| N02225                                                                       | ---            | ---                                       | F 239                                              | ---                                   | ---                             |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued) |                                                |                                           |                                                                               |                                                                              |                                   |
|-------------------------------------------------------------------------------|------------------------------------------------|-------------------------------------------|-------------------------------------------------------------------------------|------------------------------------------------------------------------------|-----------------------------------|
| UNS                                                                           | SAE/AMS                                        | MILITARY                                  | ASTM                                                                          | ASME                                                                         | AWS                               |
| N02230                                                                        | ---                                            | ---                                       | F 239                                                                         | ---                                                                          | ---                               |
| N02233                                                                        | ---                                            | ---                                       | F 1, F 3, F 4                                                                 | ---                                                                          | ---                               |
| N02270                                                                        | ---                                            | ---                                       | F 1, F 3, F 239                                                               | ---                                                                          | ---                               |
| N02290                                                                        | ---                                            | ---                                       | ---                                                                           | ---                                                                          | ---                               |
| N03220                                                                        | ---                                            | ---                                       | ---                                                                           | ---                                                                          | ---                               |
| N03260                                                                        | 5865, 5890                                     | ---                                       | ---                                                                           | ---                                                                          | ---                               |
| N03300                                                                        | ---                                            | ---                                       | F 290                                                                         | ---                                                                          | ---                               |
| N03301                                                                        | ---                                            | ---                                       | ---                                                                           | ---                                                                          | ---                               |
| N03360                                                                        | ---                                            | ---                                       | ---                                                                           | ---                                                                          | ---                               |
| N04019                                                                        | 4892, 4893                                     | ---                                       | ---                                                                           | ---                                                                          | ---                               |
| N04020                                                                        | ---                                            | ---                                       | A 494 (M-35-2)                                                                | ---                                                                          | ---                               |
| N04060                                                                        | ---                                            | E-21562 (EN60, RN60),<br>I-23413 (MIL-60) | ---                                                                           | SFA-5.14 (ERNiCu-7),<br>SFA-5.30 (IN60)                                      | A5.14 (ERNiCu-7),<br>A5.30 (IN60) |
| N04400                                                                        | 4544, 4574, 4575,<br>4675, 4730, 4731,<br>7233 | T-1368, T-23520,<br>N-24106               | B 127, B 163, B 164, B 165,<br>B 366, B 564, F96,<br>F 467 (400), F 468 (400) | SB-127, SB-163, SB-164, SB-<br>165, SB-564                                   | ---                               |
| N04401                                                                        | ---                                            | ---                                       | ---                                                                           | ---                                                                          | ---                               |
| N04402                                                                        | ---                                            | ---                                       | ---                                                                           | ---                                                                          | ---                               |
| N04404                                                                        | ---                                            | ---                                       | F 96                                                                          | ---                                                                          | ---                               |
| N04405                                                                        | 4674, 7234                                     | ---                                       | B 164, F 467 (405), F 468 (405)                                               | SB-164                                                                       | ---                               |
| N05500                                                                        | 4676                                           | N-24549                                   | F 467 (500), F 468 (500)                                                      | ---                                                                          | ---                               |
| N05502                                                                        | 4677                                           | ---                                       | ---                                                                           | ---                                                                          | ---                               |
| N05504                                                                        | ---                                            | E-21562 (EN64, RN64)                      | ---                                                                           | ---                                                                          | ---                               |
| N06002                                                                        | 5390, 5536, 5587,<br>5588, 5754, 5798,<br>7237 | ---                                       | B 366, B 435, B 572, B 619,<br>B 622, B 626                                   | SB-366, SB-435, SB-572, SB-<br>619, SB-622, SB-626,<br>SFA-5.14 (ERNiCrMo-2) | A5.14 (ERNiCrMo-2)                |
| N06003                                                                        | 5676, 5677, 5682                               | ---                                       | B 344                                                                         | ---                                                                          | ---                               |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued) |                  |                                           |                                                    |                                                                                      |                                    |
|-------------------------------------------------------------------------------|------------------|-------------------------------------------|----------------------------------------------------|--------------------------------------------------------------------------------------|------------------------------------|
| UNS                                                                           | SAE/AMS          | MILITARY                                  | ASTM                                               | ASME                                                                                 | AWS                                |
| N06004                                                                        | ---              | ---                                       | B 344                                              | ---                                                                                  | ---                                |
| N06005                                                                        | SAE J775 (VF 3)  | ---                                       | ---                                                | ---                                                                                  | ---                                |
| N06006                                                                        | ---              | ---                                       | A 297 (HX)                                         | ---                                                                                  | ---                                |
| N06007                                                                        | ---              | ---                                       | B 366, B 581, B 582, B 619,<br>B 622, B 626        | SB-366, SB-619,<br>SFA-5.14 (ERNiCrMo-1)                                             | A5.14 (ERNiCrMo-1)                 |
| N06008                                                                        | ---              | ---                                       | ---                                                | ---                                                                                  | ---                                |
| N06009                                                                        | ---              | ---                                       | ---                                                | ---                                                                                  | ---                                |
| N06010                                                                        | ---              | ---                                       | ---                                                | ---                                                                                  | ---                                |
| N06013                                                                        | SAE J755 (VF 9)  | ---                                       | ---                                                | ---                                                                                  | ---                                |
| N06015                                                                        | SAE J775 (VF 10) | ---                                       | ---                                                | ---                                                                                  | ---                                |
| N06022                                                                        | ---              | ---                                       | B 366, B 564, B 574, B 575,<br>B 619, B 622, B 626 | SB-366, SB-564, SB-574, SB-575,<br>SB-619, SB-622, SB-626,<br>SFA-5.14 (ERNiCrMo-10) | A5.14 (ERNiCrMo-10)                |
| N06030                                                                        | ---              | ---                                       | B 366, B 581, B 582, B 619,<br>B 622, B 626        | SB-366, SB-581, SB-582,<br>SB-619, SB-622, SB-626,<br>SFA-5.14 (ERNiCrMo11)          | A5.14 (ERNiCrMo-11)                |
| N06040                                                                        | ---              | ---                                       | A 494                                              | ---                                                                                  | ---                                |
| N06050                                                                        | ---              | ---                                       | A 608 (HX-50)                                      | ---                                                                                  | ---                                |
| N06052                                                                        | ---              | ---                                       | ---                                                | ---                                                                                  | ---                                |
| N06059                                                                        | ---              | ---                                       | B 564, B 574, B 575, B 619,<br>B 622, B 626        | ---                                                                                  | ---                                |
| N06060 <sup>a</sup>                                                           | ---              | ---                                       | B 622                                              | ---                                                                                  | ---                                |
| N06062                                                                        | 5679             | E-21562 (EN62, RN62),<br>I-23413 (MIL-62) | ---                                                | SFA-5.14(ERNiCrFe-5),<br>SFA-5.30 (IN62)                                             | A5.14(ERNiCrFe-5),<br>A5.30 (IN62) |
| N06075                                                                        | ---              | ---                                       | ---                                                | ---                                                                                  | ---                                |
| N06076                                                                        | ---              | E-21562 (EN6N, RN6N)                      | ---                                                | ---                                                                                  | ---                                |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued) |                                          |                                                     |                                                 |                                                                       |                                |
|-------------------------------------------------------------------------------|------------------------------------------|-----------------------------------------------------|-------------------------------------------------|-----------------------------------------------------------------------|--------------------------------|
| UNS                                                                           | SAE/AMS                                  | MILITARY                                            | ASTM                                            | ASME                                                                  | AWS                            |
| N06082                                                                        | ---                                      | E-21562(EN82, EN82H, RN82, RN82H), I-23413 (MIL-82) | ---                                             | SFA-5.14 (ERNiCr-3), SFA-5.30 (IN82)                                  | A5.14 (ERNiCr-3), A5.30 (IN82) |
| N06102                                                                        | ---                                      | ---                                                 | B 445, B 518, B 519                             | ---                                                                   | ---                            |
| N06110                                                                        | ---                                      | ---                                                 | B 564, B 755, B 756, B 757, B 758, B 759        | ---                                                                   | ---                            |
| N06132                                                                        | ---                                      | ---                                                 | ---                                             | ---                                                                   | ---                            |
| N06230                                                                        | 5891                                     | ---                                                 | B 435, B 572, B 619, B 622, B 626               | ---                                                                   | ---                            |
| N06231                                                                        | ---                                      | ---                                                 | ---                                             | SFA-5.14 (ERNiCrWMo-1)                                                | A5.14 (ERNiCrWMo-1)            |
| N06250 <sup>a</sup>                                                           | ---                                      | ---                                                 | B 622                                           | ---                                                                   | ---                            |
| N06255 <sup>a</sup>                                                           | ---                                      | ---                                                 | B 622                                           | ---                                                                   | ---                            |
| N06333                                                                        | 5593, 5717                               | ---                                                 | B 718, B 719, B 722, B 723, B 726               | ---                                                                   | ---                            |
| N06455                                                                        | ---                                      | ---                                                 | B 366, B 574, B 575, B 619, B 622, B 626        | SB-366, SB-574, SB-575, SB-619, SB-622, SB-626, SFA-5.14 (ERNiCrMo-7) | A5.14 (ERNiCrMo-7)             |
| N06600                                                                        | 5540, 5580, 5665, 5687, 7232             | T-23227, N-23228, N-23229                           | B 163, B 166, B 167, B 168, B 516, B 517, B 564 | SB-163, SB-166, SB-167, SB-168, SB-564                                | ---                            |
| N06601                                                                        | 5715, 5870                               | ---                                                 | B 166, B 167, B 168                             | ---                                                                   | ---                            |
| N06602                                                                        | ---                                      | ---                                                 | ---                                             | ---                                                                   | ---                            |
| N06617                                                                        | ---                                      | ---                                                 | ---                                             | SFA-5.14(ERNiCrCoMo-1)                                                | A5.14(ERNiCrCoMo-1)            |
| N06621 <sup>b</sup>                                                           | ---                                      | ---                                                 | ---                                             | ---                                                                   | ---                            |
| N06625                                                                        | 5401, 5402, 5581, 5599, 5666, 5837, 7490 | E-21562 (EN625, RN625)                              | B 366, B 443, B 444, B 446, B 704, B 705        | SB-443, SB-444, SB-446, SFA-5.14 (ERNiCrMo-3)                         | A5.14 (ERNiCrMo-3)             |
| N06635                                                                        | 5711, 5838, 5873                         | ---                                                 | ---                                             | ---                                                                   | ---                            |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued) |                                                                           |                                           |                                      |                                                                  |                                     |
|-------------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------------------------------|--------------------------------------|------------------------------------------------------------------|-------------------------------------|
| UNS                                                                           | SAE/AMS                                                                   | MILITARY                                  | ASTM                                 | ASME                                                             | AWS                                 |
| N06690                                                                        | ---                                                                       | ---                                       | B 163, B 166, B 167, B 168           | SB-163, SB-166, SB-167, SB-168                                   | ---                                 |
| N06782                                                                        | SAE J775 (VF 4)                                                           | ---                                       | ---                                  | ---                                                              | ---                                 |
| N06804                                                                        | ---                                                                       | ---                                       | ---                                  | ---                                                              | ---                                 |
| N06920                                                                        | ---                                                                       | ---                                       | B 814                                | ---                                                              | ---                                 |
| N06975                                                                        | ---                                                                       | ---                                       | B 581, B 582, B 619, B 622,<br>B 626 | SB-366, SB-581, SB-582, SB-619,<br>SFA-5.14 (ERNiCrMo-8)         | A5.14 (ERNiCrMo-8)                  |
| N06985                                                                        | ---                                                                       | ---                                       | B 581, B 582, B 619, B 622,<br>B 626 | SB-581, SB-582, SB-619, SB-622,<br>SB-626, SFA-5.14 (ERNiCrMo-9) | A5.14 (ERNiCrMo-9)                  |
| N07001                                                                        | 5544, 5586, 5704,<br>5706, 5707, 5708,<br>5709, 5828,<br>SAE J775 (XEV 4) | ---                                       | B 637                                | ---                                                              | ---                                 |
| N07002                                                                        | SAE J775 (HEV 2)                                                          | ---                                       | ---                                  | ---                                                              | ---                                 |
| N07012                                                                        | 5855, 5856, 5881                                                          | ---                                       | ---                                  | ---                                                              | ---                                 |
| N07013                                                                        | 5404                                                                      | ---                                       | ---                                  | ---                                                              | ---                                 |
| N07031                                                                        | SAE J775 (HEV 3)                                                          | ---                                       | ---                                  | ---                                                              | ---                                 |
| N07032                                                                        | SAE J775 (HEV 8)                                                          | ---                                       | ---                                  | ---                                                              | ---                                 |
| N07041                                                                        | 5399, 5545, 5712,<br>5713, 5800, 7469                                     | ---                                       | ---                                  | ---                                                              | ---                                 |
| N07048 <sup>a</sup>                                                           | ---                                                                       | ---                                       | ---                                  | ---                                                              | ---                                 |
| N07069                                                                        | ---                                                                       | E-21562 (RN69)                            | ---                                  | ---                                                              | ---                                 |
| N07080                                                                        | SAE J775 (HEV 5)                                                          | ---                                       | B 637                                | ---                                                              | ---                                 |
| N07090                                                                        | 5829,<br>SAE J775 (HEV 6)                                                 | ---                                       | ---                                  | ---                                                              | ---                                 |
| N07092                                                                        | 5675                                                                      | E-21562 (EN6A, RN6A),<br>I-23413 (MIL-6A) | ---                                  | SFA-5.14 (ERNiCrFe-6),<br>SFA-5.30 (IN6A)                        | A5.14 (ERNiCrFe-6),<br>A5.30 (IN6A) |
| N07214                                                                        | ---                                                                       | ---                                       | ---                                  | ---                                                              | ---                                 |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued) |                                                                                                |                            |                     |                       |                    |
|-------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|----------------------------|---------------------|-----------------------|--------------------|
| UNS                                                                           | SAE/AMS                                                                                        | MILITARY                   | ASTM                | ASME                  | AWS                |
| N07252                                                                        | ---                                                                                            | ---                        | B 637               | ---                   | ---                |
| N07263                                                                        | 5872, 5886                                                                                     | ---                        | ---                 | ---                   | ---                |
| N07500                                                                        | 5384, 5751, 5753                                                                               | ---                        | B 637               | ---                   | ---                |
| N07626 <sup>a</sup>                                                           | ---                                                                                            | ---                        | ---                 | ---                   | ---                |
| N07702                                                                        | 5550                                                                                           | ---                        | ---                 | ---                   | ---                |
| N07716 <sup>a</sup>                                                           | ---                                                                                            | ---                        | ---                 | ---                   | ---                |
| N07718                                                                        | 5383, 5589, 5590,<br>5596, 5597, 5662,<br>5663, 5664, 5832,<br>SAE J775 (XEV 1)                | ---                        | B 637, B 670,       | SFA-5.14 (ERNiFeCr-2) | A5.14 (ERNiFeCr-2) |
| N07721                                                                        | ---                                                                                            | ---                        | ---                 | ---                   | ---                |
| N07722                                                                        | 5541, 5714                                                                                     | ---                        | ---                 | ---                   | ---                |
| N07725                                                                        | ---                                                                                            | ---                        | ---                 | ---                   | ---                |
| N07750                                                                        | 5542, 5582, 5583,<br>5598, 5667, 5668,<br>5669, 5670, 5671,<br>5698, 5699, 5747,<br>5779, 7246 | N-7786, S23192,<br>N-24114 | B 637               | SA-637                | ---                |
| N08031                                                                        | ---                                                                                            | ---                        | B 564, B 619, B 626 | ---                   | ---                |
| N08032 <sup>a</sup>                                                           | ---                                                                                            | ---                        | ---                 | ---                   | ---                |
| N08042 <sup>a</sup>                                                           | ---                                                                                            | ---                        | ---                 | ---                   | ---                |
| N08050                                                                        | ---                                                                                            | ---                        | A 608 (HT-50)       | ---                   | ---                |
| N08065                                                                        | ---                                                                                            | E-21562,E-21562 (RN65)     | ---                 | SFA-5.14 (ERNiFeCr-1) | A5.14 (ERNiFeCr-1) |
| N08135 <sup>a</sup>                                                           | ---                                                                                            | ---                        | B 622               | ---                   | ---                |
| N08151                                                                        | ---                                                                                            | ---                        | A 351               | SA-351                | ---                |
| N08221                                                                        | ---                                                                                            | ---                        | B 423, B 424, B 425 | ---                   | ---                |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued) |                                                      |          |                                                                     |                                          |              |
|-------------------------------------------------------------------------------|------------------------------------------------------|----------|---------------------------------------------------------------------|------------------------------------------|--------------|
| UNS                                                                           | SAE/AMS                                              | MILITARY | ASTM                                                                | ASME                                     | AWS          |
| N08310                                                                        | ---                                                  | ---      | B 720                                                               | ---                                      | ---          |
| N08320                                                                        | ---                                                  | ---      | B 619, B 620, B 621, B 622,<br>B 626                                | SB-366, SB-620, SB-621, SB-622           | ---          |
| N08321                                                                        | ---                                                  | ---      | ---                                                                 | ---                                      | ---          |
| N08330                                                                        | 5592, 5716,<br>SAE J705 (30330),<br>SAE J412 (30330) | ---      | B 366, B 511, B 512, B 535,<br>B 536, B 546, B 710, B 739           | SB-366, SB-511, SB-710                   | ---          |
| N08331                                                                        | ---                                                  | ---      | ---                                                                 | SFA-5.9 (ER330)                          | A5.9 (ER330) |
| N08332                                                                        | ---                                                  | ---      | B 511, B 535, B 536, B 546,<br>B 710, B 739                         | SB-366, SB-511, SB-535, SB-536           | ---          |
| N08334                                                                        | ---                                                  | ---      | ---                                                                 | ---                                      | ---          |
| N08366                                                                        | ---                                                  | ---      | B 675, B 676, B 688, B 690, B 691                                   | SB-675                                   | ---          |
| N08367                                                                        | ---                                                  | ---      | B 462, B 472, B 564, B 675,<br>B 676, B 688, B 690, B 691,<br>B 804 | ---                                      | ---          |
| N08421                                                                        | ---                                                  | ---      | ---                                                                 | ---                                      | ---          |
| N08535 <sup>c</sup>                                                           | ---                                                  | ---      | B 622                                                               | ---                                      | ---          |
| N08603                                                                        | ---                                                  | ---      | A 351 (HT-30)                                                       | ---                                      | ---          |
| N08604                                                                        | ---                                                  | ---      | A 297 (HL)                                                          | ---                                      | ---          |
| N08605                                                                        | ---                                                  | ---      | A 297 (HT)                                                          | ---                                      | ---          |
| N08613                                                                        | ---                                                  | ---      | A 608 (HL-30)                                                       | ---                                      | ---          |
| N08614                                                                        | ---                                                  | ---      | A 608 (HL-30)                                                       | ---                                      | ---          |
| N08700                                                                        | ---                                                  | ---      | B 599, B 672                                                        | SB-599, SB-672                           | ---          |
| N08705                                                                        | ---                                                  | ---      | A 297 (HP)                                                          | ---                                      | ---          |
| N08800                                                                        | 5766, 5871                                           | ---      | B 163, B 366, B 407, B 408,<br>B 409, B 514, B 515, B 564           | SB-163, SB-407, SB-408,<br>SB-409, SB564 | ---          |
| N08801                                                                        | 5552                                                 | ---      | ---                                                                 | ---                                      | ---          |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued) |                                 |          |                                                                         |                                                        |                  |
|-------------------------------------------------------------------------------|---------------------------------|----------|-------------------------------------------------------------------------|--------------------------------------------------------|------------------|
| UNS                                                                           | SAE/AMS                         | MILITARY | ASTM                                                                    | ASME                                                   | AWS              |
| N08802                                                                        | ---                             | ---      | ---                                                                     | ---                                                    | ---              |
| N08810                                                                        | ---                             | ---      | B 163, B 407, B 408, B 409,<br>B 514, B 564                             | SB-163, SB-407, SB-408,<br>SB-409, SB-514, SB-564      | ---              |
| N08811                                                                        | ---                             | ---      | B 407, B 408, B 409                                                     | ---                                                    | ---              |
| N08825                                                                        | ---                             | ---      | B 163, B 423, B 424, B 425,<br>B 564, B 704, B 705                      | SB-163, SB-423, SB-424, SB-425                         | ---              |
| N08826                                                                        | ---                             | ---      | B 163, B 423, B 425                                                     | ---                                                    | ---              |
| N08904                                                                        | ---                             | ---      | B 625, B 649, B 673, B 674,<br>B 677                                    | SB-625, SB-649, SB-673,<br>SB-674, SB-677              | ---              |
| N08925                                                                        | ---                             | ---      | B 625, B 649, B 673, B 674,<br>B 677                                    | SB-625, SB-649, SB-673,<br>SB-674, SB-677              | ---              |
| N08926                                                                        | ---                             | ---      | B 366, B 625, B 649, B 673,<br>B 674, B 677                             | SB-366, SB-625, SB-649,<br>SB-673, SB-674, SB-677      | ---              |
| N08932                                                                        | ---                             | ---      | B 625                                                                   | ---                                                    | ---              |
| N09027                                                                        | 5633, 5634                      | ---      | ---                                                                     | ---                                                    | ---              |
| N09706                                                                        | 5605, 5606, 5701,<br>5702, 5703 | ---      | ---                                                                     | ---                                                    | ---              |
| N09901                                                                        | 5660, 5661                      | ---      | ---                                                                     | ---                                                    | ---              |
| N09902                                                                        | 5221, 5223, 5225                | ---      | ---                                                                     | ---                                                    | ---              |
| N09911                                                                        | ---                             | ---      | ---                                                                     | ---                                                    | ---              |
| N09925                                                                        | ---                             | ---      | ---                                                                     | ---                                                    | ---              |
| N09926                                                                        | ---                             | ---      | ---                                                                     | ---                                                    | ---              |
| N09979                                                                        | 5746,<br>SAE J467 (D-979)       | ---      | ---                                                                     | ---                                                    | ---              |
| N10001                                                                        | 5396                            | ---      | B 333, B 335, B 366, B 619,<br>B 622, B 626, F 467 (335),<br>F468 (335) | SB-333, SB-335, SB-366,<br>SB-619, SFA-5.14 (ERNiMo-1) | A5.14 (ERNiMo-1) |



| AMERICAN CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued) |                        |          |                                                                           |                                                                               |                    |
|-------------------------------------------------------------------------------|------------------------|----------|---------------------------------------------------------------------------|-------------------------------------------------------------------------------|--------------------|
| UNS                                                                           | SAE/AMS                | MILITARY | ASTM                                                                      | ASME                                                                          | AWS                |
| N10002                                                                        | 5388, 5389, 5530, 5750 | ---      | ---                                                                       | ---                                                                           | ---                |
| N10003                                                                        | 5607, 5771             | ---      | B 366, 434, B 573                                                         | SB-366, SB-434, SB-573, SFA-5.14 (ERNiMo-2)                                   | A5.14 (ERNiMo-2)   |
| N10004                                                                        | 5755, 5786             | ---      | ---                                                                       | SFA-5.14 (ERNiMo-3)                                                           | A5.14 (ERNiMo-3)   |
| N10276                                                                        | ---                    | ---      | B 366, B 564, B 574, B 575, B 619, B 622, B 626, F 467 (276), F 468 (276) | SB-366, SB-564, SB-574, SB-575, SB-619, SB-622, SB-626, SFA-5.14 (ERNiCrMo-4) | A5.14 (ERNiCrMo-4) |
| N10665                                                                        | ---                    | ---      | B 333, B 335, B 366, B 619, B 622, B 626                                  | SB-333, SB-335, SB-366, SB-619, SB-622, SB-626, SFA-5.14 (ERNiMo-7)           | A5.14 (ERNiMo-7)   |
| N10675                                                                        | ---                    | ---      | B 333, B 335, B 366, B 564, B 619, B 622, B 626                           | ---                                                                           | ---                |
| N13009                                                                        | 5407                   | ---      | ---                                                                       | ---                                                                           | ---                |
| N13010                                                                        | 5405, 5406             | ---      | ---                                                                       | ---                                                                           | ---                |
| N13017                                                                        | 5851, 5852, 5882       | ---      | ---                                                                       | ---                                                                           | ---                |
| N13020                                                                        | 5846                   | ---      | ---                                                                       | ---                                                                           | ---                |
| N13021                                                                        | ---                    | ---      | ---                                                                       | ---                                                                           | ---                |
| N13100                                                                        | 5397                   | ---      | ---                                                                       | ---                                                                           | ---                |
| N13246                                                                        | ---                    | ---      | ---                                                                       | ---                                                                           | ---                |
| N14052                                                                        | ---                    | ---      | F 30 (52)                                                                 | ---                                                                           | ---                |
| N19903                                                                        | 5806                   | ---      | ---                                                                       | ---                                                                           | ---                |
| N19907                                                                        | ---                    | ---      | ---                                                                       | ---                                                                           | ---                |
| N19909                                                                        | ---                    | ---      | ---                                                                       | ---                                                                           | ---                |
| N24025                                                                        | ---                    | ---      | A 494                                                                     | ---                                                                           | ---                |
| N24030                                                                        | ---                    | ---      | A 494                                                                     | ---                                                                           | ---                |
| N24130                                                                        | ---                    | ---      | A 494                                                                     | ---                                                                           | ---                |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                |                       |             |                     |                  |
|------------------------------------------------------------------------------------------|----------------|-----------------------|-------------|---------------------|------------------|
| <b>UNS</b>                                                                               | <b>SAE/AMS</b> | <b>MILITARY</b>       | <b>ASTM</b> | <b>ASME</b>         | <b>AWS</b>       |
| N24135                                                                                   | ---            | ---                   | A 494       | ---                 | ---              |
| N26022                                                                                   | ---            | ---                   | A 494       | ---                 | ---              |
| N26055                                                                                   | ---            | ---                   | A 494       | ---                 | ---              |
| N26455                                                                                   | ---            | ---                   | A 494       | ---                 | ---              |
| N26625                                                                                   | ---            | ---                   | A 494       | ---                 | ---              |
| N30002                                                                                   | ---            | ---                   | A 494       | ---                 | ---              |
| N30007                                                                                   | ---            | ---                   | A 494       | ---                 | ---              |
| N30012                                                                                   | ---            | ---                   | A 494       | ---                 | ---              |
| N30107                                                                                   | ---            | ---                   | A 494       | ---                 | ---              |
| N99600                                                                                   | 4775           | B-7883 (BNi-1)        | ---         | SFA-5.8 (BNi-1)     | A5.8 (BNi-1)     |
| N99610                                                                                   | 4776           | B-7883 (BNi-1a)       | ---         | SFA-5.8 (BNi-1a)    | A5.8 (BNi-1a)    |
| N99612                                                                                   | ---            | ---                   | ---         | SFA-5.8 (BNi-9)     | A5.8 (BNi-9)     |
| N99620                                                                                   | 4777           | B-7883 (BNi-2)        | ---         | SFA-5.8 (BNi-2)     | A5.8 (BNi-2)     |
| N99622                                                                                   | ---            | ---                   | ---         | SFA-5.8 (BNi-10)    | A5.8 (BNi-10)    |
| N99624                                                                                   | ---            | ---                   | ---         | SFA-5.8 (BNi-11)    | A5.8 (BNi-11)    |
| N99630                                                                                   | 4778           | B-7883 (BNi-3)        | ---         | SFA-5.8 (BNi-3)     | A5.8 (BNi-3)     |
| N99640                                                                                   | 4779           | B-7883 (BNi-4)        | ---         | SFA-5.8 (BNi-4)     | A5.8 (BNi-4)     |
| N99644                                                                                   | ---            | ---                   | ---         | SFA-5.21 (ERNiCr-A) | A5.21 (ERNiCr-A) |
| N99645                                                                                   | ---            | R-17131 (MIL-RNiCr-B) | ---         | SFA-5.21 (ERNiCr-B) | A5.21 (ERNiCr-B) |
| N99646                                                                                   | ---            | R-17131 (MIL-RNiCr-C) | ---         | SFA-5.21 (ERNiCr-C) | A5.21 (ERNiCr-C) |
| N99650                                                                                   | 4782           | B-7883 (BNi-5)        | ---         | SFA-5.8 (BNi-5)     | A5.8 (BNi-5)     |
| N99651                                                                                   | ---            | ---                   | ---         | SFA-5.8 (BNi-5a)    | A5.8 (BNi-5a)    |
| N99700                                                                                   | ---            | ---                   | ---         | SFA-5.8 (BNi-6)     | A5.8 (BNi-6)     |
| N99710                                                                                   | ---            | ---                   | ---         | SFA-5.8 (BNi-7)     | A5.8 (BNi-7)     |
| N99800                                                                                   | ---            | ---                   | ---         | SFA-5.8 (BNi-8)     | A5.8 (BNi-8)     |

**AMERICAN CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued)**

- a. Other cross reference specification: NACE Std. MR0175.
- b. N06621 combined with N06075.
- c. N09911 combined with N09901.

This cross-reference table lists the basic specification or standard number, and since these standards are constantly being revised, it should be kept in mind that they are presented herein as a guide and may not reflect the latest revision.

**COMMON NAMES OF NICKEL & NICKEL ALLOYS WITH UNS No.**

|                                                                   |
|-------------------------------------------------------------------|
| 20Cb3 Modified; Ni-Fe-Cr Alloy Solution Strengthened; N08321      |
| 20Mo-6HS; Ni-Fe-Cr-Mo-Cu Alloy; N08036                            |
| 214; Ni-Cr Precipitation Hardenable Alloy; N07214                 |
| 46Fe-32Ni; Alloy Casting; N08151                                  |
| 6Ni-Cr-Fe Alloy, Solid Solution Strengthened (Low Carbon); N06602 |
| ACI CN-7M; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08007     |
| ACI CY-40; Ni-Cr Alloy Solid Solution Strengthened; N06040        |
| ACI CZ-100; Nickel Alloy; N02100                                  |
| ACI HL-30; Alloy Casting; N08613                                  |
| ACI HL-40; Alloy Casting; N08614                                  |
| ACI HL; Alloy Casting; N08604                                     |
| ACI HP; Alloy Casting; N08705                                     |
| ACI HT-30; Alloy Casting; N08603                                  |
| ACI HT-30; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08030     |
| ACI HT-50; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08050     |
| ACI HT-50C; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08008    |
| ACI HT; Alloy Casting; N08605                                     |
| ACI HT; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08002        |
| ACI HU-50; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08005     |

| <b>COMMON NAMES OF NICKEL &amp; NICKEL ALLOYS WITH UNS No. (Continued)</b> |
|----------------------------------------------------------------------------|
| ACI HU; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08004                 |
| ACI HW-50; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08006              |
| ACI HW; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08001                 |
| ACI HX-50; Ni-Cr Alloy Solid Solution Strengthened; N06050                 |
| ACI HX; Ni-Cr Alloy Solid Solution Strengthened; N06006                    |
| AF2-1DA; Cr-Co-Mo-W Nickel Alloy; N07012                                   |
| AL 6XN; Ni-Cr-Mo Wrought or Cast Alloy; N08367                             |
| AL-6X; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08366                  |
| Allcorr; Austenitic Corrosion Resistant Nickel Alloy; N06110               |
| Alloy 31; Ni-Fe-Cr-Mo-Cu Alloy; N08031                                     |
| Alloy 59; Low Carbon Ni-Cr-Mo Alloy; N06059                                |
| Alloy No. 230; Ni-Cr-W-Mo Alloy, Solid Solution Strengthened; N06230       |
| Alloy No. 52; Ni-Fe Alloy; N14052                                          |
| Alumel; Ni-Mn-Al Thermocouple Alloy; N02016                                |
| ARMCO 20-45-5; Ni-Fe-Cr Alloy; N08245                                      |
| Astroloy M; Co-Cr-Mo-Ni Alloy; N13017                                      |
| Austenitic Cr-Ni-Cu-Mo Alloy Welding Filler Metal; N08021                  |
| Austenitic Cr-Ni-Cu-Mo Alloy Welding Filler Metal; N08022                  |
| BNi-1; Ni-Cr-B Brazing Filler Metal; N99600                                |
| BNi-10; Ni-W-Cr-B Brazing Filler Metal; N99622                             |
| BNi-11; Ni-W-Cr-B Brazing Filler Metal; N99624                             |
| BNi-1a; Ni-Cr-B Brazing Filler Metal; N99610                               |
| BNi-2; Ni-Cr-B Brazing Filler Metal; N99620                                |
| BNi-3; Ni-Si-B Brazing Filler Metal; N99630                                |
| BNi-4; Ni-Si-B Brazing Filler Metal; N99640                                |
| BNi-5; Ni-Cr-Si Brazing Filler Metal; N99650                               |
| BNi-6; Ni-P Brazing Filler Metal; N99700                                   |
| BNi-7; Ni-Cr-P Brazing Filler Metal; N99710                                |

| <b>COMMON NAMES OF NICKEL &amp; NICKEL ALLOYS WITH UNS No. (Continued)</b> |
|----------------------------------------------------------------------------|
| BNi-8; Ni-Mn-Si-Cu Brazing Filler Metal; N99800                            |
| BNi-9; Ni-Cr-B Brazing Filler Metal; N99612                                |
| BNi5a; Ni-Cr-Si-B Brazing Filler Metal; N99651                             |
| Carpenter 20Cb3; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08020        |
| Carpenter 20Mo6; Ni-Cr Wrought Alloy; N08026                               |
| Cast Ni-Fe-Cr-Mo-Cu Alloy; N08826                                          |
| CG27; Ni-Fe-Cr Alloy Precipitation Hardenable; N09027                      |
| Chromel; Ni-Cr 10 Thermocouple Alloy; N06010                               |
| Co-Cr-Mo-Ni Alloy; N13020                                                  |
| Colmonoy 4, RNiCr-A; Ni-Cr-B Weld Filler Metal for Hard Surfacing; N99644  |
| Colmonoy 5, RNiCr-B; Ni-Cr-B Weld Filler Metal for Hard Surfacing; N99645  |
| Colmonoy 6, RNiCr-C; Ni-Cr-B Weld Filler Metal for Hard Surfacing; N99646  |
| Combined with N06075; N06621                                               |
| Combined with N09901; N09911                                               |
| Commercially Pure Be-Ni Alloy Precipitation Hardenable; N03360             |
| Commercially Pure Nickel; N02290                                           |
| Cr-Co-Mo Nickel Alloy Castings; N07013                                     |
| Cr-Ni-Fe-Mo-Cu Alloy Columbium Stabilized; N08024                          |
| Creusot UR SB 8; Ni-Fe-Cr-Mo-Cu, Low Carbon Alloy; N08932                  |
| D979; Ni-Fe-Cr Alloy Precipitation Hardenable; N09979                      |
| Duranickel 301; Nickel Alloy, Precipitation Hardenable; N03301             |
| Eatonite 3; Ni-Cr-Mo-Fe Hard Facing Alloy; N06013                          |
| Eatonite 5; Ni-Cr-Mo-Fe Hard Facing Alloy; N06015                          |
| Eatonite; Ni-Cr Alloy Solid Solution Strengthened; N06005                  |
| ER330; Ni-Fe-Cr Welding Filler Metal; N08331                               |
| ERNi-CI; Ni-Cr-Fe Weld Filler Metal for Cast Iron; N02215                  |
| ERNiCrMo-9; Ni-Cr Alloy replaced by N06985; N06017                         |
| ERNiFeMn-CI; Ni-Fe-Mn Weld Filler Metal for Cast Iron; N02216              |

| <b>COMMON NAMES OF NICKEL &amp; NICKEL ALLOYS WITH UNS No. (Continued)</b>       |
|----------------------------------------------------------------------------------|
| Fe-Ni-Co Metal-to-Ceramic Sealing Alloy; N94620                                  |
| Fe-Ni-Co Metal-to-Ceramic Sealing Alloy; N94630                                  |
| Hastelloy B-2; Ni-Mo Alloy; N10665                                               |
| Hastelloy B-3; Ni-Mo-Cr-Fe Alloy; N10675                                         |
| Hastelloy B; Ni-Mo Alloy Solid Solution Strengthened; N10001                     |
| Hastelloy C; Ni-Mo Alloy Solid Solution Strengthened; N10002                     |
| Hastelloy C-4; Ni-Cr Alloy; N06455                                               |
| Hastelloy C-22; Ni-Cr-Mo Alloy; N06022                                           |
| Hastelloy C-276; Ni-Mo Alloy Solid Solution Strengthened; N10276                 |
| Hastelloy F; Ni-Cr Alloy Solid Solution Strengthened; N06001                     |
| Hastelloy G-2; Ni-Cr Alloy; N06975                                               |
| Hastelloy G-3; Ni-Cr Alloy ERNiCrMo-9; N06985                                    |
| Hastelloy G-30- Wrought Ni-Cr-Fe-Mo-Cu Alloy Solid Solution Strengthened; N06030 |
| Hastelloy G; Ni-Cr Alloy; N06007                                                 |
| Hastelloy G-50; Ni-Cr-Fe-Mo Alloy, Solid Solution Strengthened; N06950           |
| Hastelloy H-9M; Ni-Cr-Fe-Mo-W Alloy Solid Solution Strengthened; N06920          |
| Hastelloy N; Ni-Mo Alloy Solid Solution Strengthened; N10003                     |
| Hastelloy S; Ni-Cr-Mo Alloy; N06635                                              |
| Hastelloy W; Ni-Mo Alloy Solid Solution Strengthened; N10004                     |
| Hastelloy X; Ni-Cr Alloy Solid Solution Strengthened; N06002                     |
| Haynes No. 20 Mod; Ni-Fe-Cr Alloy; N08320                                        |
| Haynes R-41; Ni-Cr Alloy Precipitation Hardenable; N07041                        |
| Haynes 230; Ni-Cr-W-Mo Alloy, Solid Solution Strengthened; N06230                |
| Haynes 230W; Ni-Cr-W-Mo Welding Filler Metal; N06231                             |
| Haynes 263; Ni-Cr Alloy Precipitation Hardenable; N07263                         |
| IN-100; Ni-Co Alloy Precipitation Hardenable; N13100                             |
| IN-102; Ni-Cr Alloy Solid Solution Strengthened; N06102                          |
| IN-713; Ni-Cr Alloy Precipitation Hardenable; N07713                             |

| <b>COMMON NAMES OF NICKEL &amp; NICKEL ALLOYS WITH UNS No. (Continued)</b> |
|----------------------------------------------------------------------------|
| INCO Alloy 032; Fe-Ni-Cr-Mo Alloy; N08032                                  |
| Incoloy 800; Fe-Ni-Cr Alloy Solid Solution Strengthened; N08800            |
| Incoloy 800H; Fe-Ni-Cr Alloy; N08810                                       |
| Incoloy 800HT; Wrought Ni-Fe-Cr Alloy; N08811                              |
| Incoloy 801; Fe-Ni-Cr Alloy Solid Solution Strengthened; N08801            |
| Incoloy 802; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08802            |
| Incoloy 804; Ni-Cr Alloy Solid Solution Strengthened; N06804               |
| Incoloy 825; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08825            |
| Incoloy 901; Ni-Fe-Cr Alloy Precipitation Hardenable; N09901               |
| Incoloy 903; Ni-Fe-Co Alloy Precipitation Hardenable; N19903               |
| Incoloy 925; Ni-Fe-Cr Alloy Precipitation Hardenable; N09925               |
| Incoloy 926; Ni-Fe-Cr-Cu Alloy Precipitation Hardenable; N09926            |
| Incoloy FM65; Ni-Fe-Cr Welding Filler Metal; N08065                        |
| Inconel 600; Ni-Cr Alloy Solid Solution Strengthened; N06600               |
| Inconel 601; Ni-Cr Alloy Solid Solution Strengthened; N06601               |
| Inconel 617; Ni-Cr Alloy Solid Solution Strengthened; N06617               |
| Inconel 625; Ni-Cr Alloy Solid Solution Strengthened; N06625               |
| Inconel 690; Ni-Cr Alloy Solid Solution Strengthened; N06690               |
| Inconel 702; Ni-Cr Alloy Precipitation Hardenable; N07702                  |
| Inconel 706; Ni-Fe-Cr Alloy Precipitation Hardenable; N09706               |
| Inconel 718; Ni-Cr Alloy Precipitation Hardenable; N07718                  |
| Inconel 721; Ni-Cr Alloy Precipitation Hardenable; N07721                  |
| Inconel 722; Ni-Cr Alloy Precipitation Hardenable; N07722                  |
| Inconel 751; Ni-Cr Alloy Precipitation Hardenable; N07751                  |
| Inconel Alloy 725; Ni-Cr-Mo Precipitation Hardenable Alloy; N07725         |
| Inconel FM52; Ni-Cr Welding Filler Metal; N06052                           |
| Inconel FM62; Ni-Cr Alloy Solid Solution Strengthened; N06062              |
| Inconel FM69; Ni-Cr Welding Filler Metal; N07069                           |

| <b>COMMON NAMES OF NICKEL &amp; NICKEL ALLOYS WITH UNS No. (Continued)</b>         |
|------------------------------------------------------------------------------------|
| Inconel FM82; Ni-Cr Welding Filler Metal; N06082                                   |
| Inconel FM92; Ni-Cr Alloy Precipitation Hardenable; N07092                         |
| Inconel Filler Metal 72; Ni-Cr Alloy Filler Metal; N06072                          |
| Inconel MA754; Ni-Cr Alloy Y Dispersion Strengthened; N07754                       |
| Inconel WE 132; Ni-Cr Alloy Solid Solution Strengthened replaced by W86132; N06132 |
| Inconel X750; Ni-Cr Alloy Precipitation Hardenable; N07750                         |
| JS 700; Fe-Ni-Cr Alloy; N08700                                                     |
| M220C; Beryllium Nickel, Precipitation Hardenable Castings; N03220                 |
| M252; Ni-Cr Alloy Precipitation Hardenable; N07252                                 |
| MAR-M-Alloy, Hf modified; Ni-W-Co-Cr Precipitation Hardenable; N13246              |
| Monel 400; Ni-Cu Alloy Solid Solution Strengthened; N04400                         |
| Monel 401; Ni-Cu Alloy, Solid Solution Strengthened; N04401                        |
| Monel 404; Ni-Cu Alloy Solid Solution Strengthened; N04404                         |
| Monel 502; Ni-Cu Alloy Precipitation Hardenable; N05502                            |
| Monel FM60; Ni-Cu Welding Filler Metal; N04060                                     |
| Monel K500; Ni-Cu Alloy Precipitation Hardenable; N05500                           |
| Monel R405; Ni-Cu Alloy Solid Solution Strengthened; N04405                        |
| Ni-20 Cr Columbium Stabilized; N06009                                              |
| Ni-Co-Cr Alloy, Precipitation Hardenable; N13021                                   |
| Ni-Co-Cr-Mo Alloy Castings; N13010                                                 |
| Ni-Cr 30 Alloy Solid Solution Strengthened; N06008                                 |
| Ni-Cr Precipitation Hardenable Alloy; N07626                                       |
| Ni-Cr Precipitation Hardenable Alloy; N07716                                       |
| Ni-Cr Welding Filler Metal; N06076                                                 |
| Ni-Cr-Bi-Sn Casting Alloy; N26055                                                  |
| Ni-Cr-Fe-Mo-Cu Alloy, Age Hardenable; N07048                                       |
| Ni-Cr-Mo Alloy; N08904                                                             |
| Ni-Cr-Mo Casting Alloy; N26022                                                     |



| <b>COMMON NAMES OF NICKEL &amp; NICKEL ALLOYS WITH UNS No. (Continued)</b> |
|----------------------------------------------------------------------------|
| Ni-Cr-Mo Casting Alloy; N26455                                             |
| Ni-Cr-Mo Casting Alloy; N26625                                             |
| Ni-Cr-Mo-Fe-Cu Alloy; N08535                                               |
| Ni-Cu Alloy Solid Solution Strengthened (Low Carbon); N04402               |
| Ni-Cu Casting Alloy; N24025                                                |
| Ni-Cu Casting Alloy; N24030                                                |
| Ni-Cu Casting Alloy; N24130                                                |
| Ni-Cu Casting Alloy; N24135                                                |
| Ni-Cu Casting Alloy (Weldable Grade); N04020                               |
| Ni-Cu Welding Filler Metal; N05504                                         |
| Ni-Fe-Co Alloy Precipitation Hardenable; N19907                            |
| Ni-Fe-Co Alloy Precipitation Hardenable; N19909                            |
| Ni-Fe-Cr-Cu Alloy; N08221                                                  |
| Ni-Fe-Cr-Mo Alloy; N08310                                                  |
| Ni-Fe-Cr-Mo-Cu Alloy, Low Carbon; N08925                                   |
| Ni-Fe-Cr-Mo-Cu Alloy; N08421                                               |
| Ni-Fe-Cr-Mo-Cu-N Alloy, Low Carbon, Nitrogen Modified; N08926              |
| Ni-Mo Casting Alloy; N30007                                                |
| Ni-Mo Casting Alloy; N30012                                                |
| Ni-Mo-Cr Casting Alloy; N30002                                             |
| Ni-Mo-Cr Casting Alloy; N30107                                             |
| Ni-Span-C 902; Ni-Fe-Cr Alloy Precipitation Hardenable; N09902             |
| Ni-W-Co-Cr Alloy Castings; N13009                                          |
| NiC 42M; Ni-Fe-Cr-Mo-Cu Alloy; N08042                                      |
| NiC 52; Ni-Cr Alloy; N06952                                                |
| Nichrome V; Ni-Cr Alloy Solid Solution Strengthened; N06003                |
| Nichrome; Ni-Cr Alloy Solid Solution Strengthened; N06004                  |
| Nickel 200; Commercially Pure Ni Alloy; N02200                             |

| <b>COMMON NAMES OF NICKEL &amp; NICKEL ALLOYS WITH UNS No. (Continued)</b> |
|----------------------------------------------------------------------------|
| Nickel 201; Commercially Pure Ni Alloy; N02201                             |
| Nickel 205; Commercially Pure Ni Alloy; N02205                             |
| Nickel 211; Nickel Alloy, Solution Strengthened; N02211                    |
| Nickel 220; Commercially Pure Ni Alloy; N02220                             |
| Nickel 225; Commercially Pure Ni Alloy; N02225                             |
| Nickel 230; Commercially Pure Ni Alloy; N02230                             |
| Nickel 233; Commercially Pure Ni Alloy; N02233                             |
| Nickel 270; Commercially Pure Ni Alloy; N02270                             |
| Nickel Base Castings; N04019                                               |
| Nickel FM61; Ni Welding Filler Metal; N02061                               |
| Nickel Thoria Dispersion Strengthened; N03260                              |
| Nimonic 75; Ni-Cr Alloy Solid Solution Strengthened; N06075                |
| Nimonic 80A; Ni-Cr Alloy Precipitation Hardenable; N07080                  |
| Nimonic 90; Ni-Cr Alloy Precipitation Hardenable; N07090                   |
| Nimonic Alloy 263; Ni-Cr Alloy Precipitation Hardenable; N07263            |
| Permanickel 300; Nickel Alloy, Precipitation Hardenable; N03300            |
| Pyromet 31; Ni-Cr Alloy Precipitation Hardenable; N07031                   |
| Pyromet 31V; Ni-Cr Alloy, Precipitation Hardenable; N07032                 |
| RA 330-04; Ni-Fe-Cr-Mn Alloy, Solid Solution Strengthened; N08334          |
| RA 330-04; Ni-Fe-Cr-Si Alloy; N08332                                       |
| RA-330; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08330                 |
| RA333; Ni-Cr Alloy Solid Solution Strengthened; N06333                     |
| Rene 41; Ni-Cr Alloy Precipitation Hardenable; N07041                      |
| Sanicro 28; Ni-Fe-Cr Alloy Solid Solution Strengthened; N08028             |
| SM 2035; Ni-Fe-Cr-Mo-W Alloy; N08135                                       |
| SM2050; Ni-Cr-Fe-Mo Alloy; N06250                                          |
| SM2060Mo; Ni-Cr-Mo-Fe Alloy; N06060                                        |
| SM2550; Ni-Cr-Fe-Mo-W Alloy; N06255                                        |

| <b>COMMON NAMES OF NICKEL &amp; NICKEL ALLOYS WITH UNS No. (Continued)</b> |  |
|----------------------------------------------------------------------------|--|
| TPM; Ni-Cr Alloy Precipitation Hardenable; N07002                          |  |
| Udimet 500; Ni-Cr Alloy Precipitation Hardenable; N07500                   |  |
| Waspaloy; Ni-Cr Alloy Precipitation Hardenable; N07001                     |  |
| X-782; Ni-Cr Alloy Solid Solution Strengthened; N06782                     |  |

| <b>BRITISH BSI GENERAL SERIES SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS</b> |                                                                                                                                             |
|-------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BSI</b>                                                                    | <b>Title</b>                                                                                                                                |
| 375                                                                           | Refined nickel                                                                                                                              |
| 558, 564                                                                      | Nickel anodes, anode nickel and nickel salts for electroplating                                                                             |
| 1224                                                                          | Electroplated coatings of nickel and chromium                                                                                               |
| 2857                                                                          | Nickel-iron transformer and choke laminations                                                                                               |
| 2901: Part 5                                                                  | Filler rods and wires for gas-shielded arc welding part 5: specification for nickel and nickel alloys                                       |
| 3071                                                                          | Nickel-copper alloy castings                                                                                                                |
| 3072                                                                          | Nickel and nickel alloys: sheet and plate                                                                                                   |
| 3073                                                                          | Nickel and nickel alloys: strip                                                                                                             |
| 3074                                                                          | Nickel and nickel alloys: seamless tube                                                                                                     |
| 3075                                                                          | Nickel and nickel alloys: wire                                                                                                              |
| 3076                                                                          | Nickel and nickel alloys: bar                                                                                                               |
| 3146: Part 2                                                                  | Corrosion and heat resisting steels, nickel and cobalt base alloys                                                                          |
| 3382: Parts 3, 4                                                              | Nickel or nickel plus chromium on steel components. nickel or nickel plus chromium on copper and copper alloy (including brass) components. |
| 3504                                                                          | Magnesium-activated nickel for cathodes for electronic tubes and valves                                                                     |
| 3727                                                                          | Methods for the analysis of nickel for use in electronic tubes and valves (Parts 1 through 22)                                              |
| 4572 Part 2                                                                   | Compression joints in nickel iron and plated copper conductors                                                                              |
| 4601                                                                          | Electroplated coatings of nickel plus chromium on plastics materials                                                                        |
| 4758                                                                          | Method for specifying electroplated coatings of nickel for engineering purposes                                                             |

| <b>BRITISH BSI GENERAL SERIES SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BSI</b>                                                                                | <b>Title</b>                                                                                                                                                                    |
| 4937: Part 4                                                                              | Nickel-chromium/nickel-aluminum thermocouples. Type K                                                                                                                           |
| 4937: Part 6                                                                              | Nickel-chromium/copper-nickel thermocouples. Type E                                                                                                                             |
| 4937: Part 8                                                                              | Nickel-chromium-silicon/nickel-silicon thermocouples including composition Type N                                                                                               |
| 5383                                                                                      | Material identification of steel, nickel alloy and titanium alloy tubes by continuous character marking and colour coding of steel tubes                                        |
| 5411: Part 9                                                                              | Measurement of coating thickness of electrodeposited nickel coatings on magnetic and non-magnetic substrates: magnetic method                                                   |
| 5932                                                                                      | Sealed nickel-cadmium cylindrical rechargeable single cells                                                                                                                     |
| 6115                                                                                      | Sealed nickel-cadmium prismatic rechargeable single cells                                                                                                                       |
| 6260                                                                                      | Open nickel-cadmium prismatic rechargeable single cells                                                                                                                         |
| 6404: Part 6                                                                              | Methods of measurement of the magnetic properties of isotropic nickel-iron soft magnetic alloys, types E1, E3 and E4                                                            |
| 6783: Part 1                                                                              | Method for determination of silver, bismuth, cadmium, cobalt, copper, iron, manganese, lead and zinc in nickel by flame atomic absorption spectrometry                          |
| 6783: Part 2                                                                              | Method for determination of nickel in ferronickel (dimethylglyoxime gravimetric method)                                                                                         |
| 6783: Part 3                                                                              | Method for determination of cobalt in ferronickel by flame atomic absorption spectrometry                                                                                       |
| 6783: Part 4                                                                              | Method for determination of silver, arsenic, bismuth, cadmium, lead, antimony, selenium, tin, tellurium and thallium in nickel by electrothermal atomic absorption spectrometry |
| 6783: Part 5                                                                              | Method for determining of carbon in nickel ferronickel and nickel alloys by infra-red absorption after induction furnace combustion                                             |
| 6783: Part 6                                                                              | Method for determining of sulphur in nickel by methylene blue molecular absorption spectrometry after generation of hydrogen sulphide                                           |
| 6783: Part 7                                                                              | Method for determining of sulphur in nickel, ferronickel and nickel alloy by infra-red absorption after induction furnace combustion                                            |
| 6783: Part 8                                                                              | Method for determination of sulphur in nickel, ferronickel and nickel alloys by iodimetric after induction furnace combustion                                                   |
| 6783: Part 9                                                                              | Method for determination of silicon in ferronickel (gravimetric method)                                                                                                         |
| 6783: Part 10                                                                             | Method for determination of iron in nickel alloys (titrimetric method using potassium dichromate)                                                                               |
| 6783: Part 11                                                                             | Method for the determination of cobalt in nickel alloys (potentiometric titration method using potassium hexacyanoferrate (III))                                                |
| 6783: Part 12                                                                             | Method for the determination of phosphorus in nickel alloys by molybdenum blue molecular absorption spectrometry                                                                |
| 6783: Part 13                                                                             | Method for the determination of phosphorus in nickel, ferronickel and nickel alloys by phosphovanadomolybdate molecular absorption spectrometry                                 |

| <b>BRITISH BSI AEROSPACE SERIES SPECIFICATIONS - HEAT RESISTING ALLOY CASTINGS</b> |                                                                                                                                                                    |
|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BSI</b>                                                                         | <b>Title</b>                                                                                                                                                       |
| HC 202                                                                             | Precipitation hardening nickel base chromium-niobium-molybdenum-iron-tungsten alloy castings (Cr 20.0, Nb 6.6, Mo 6.0, Fe 3.0, W 2.5)                              |
| 2HC 203                                                                            | Nickel-chromium-aluminum-molybdenum-niobium alloy castings (Nickel base Cr 13.0, Al 6.0, Mo 4.5, Nb 2.3)                                                           |
| 2HC 204                                                                            | Nickel-cobalt-chromium-aluminum-titanium-molybdenum alloy castings (Nickel base Co 15.0, Cr 10.0, Al 5.5, Ti 4.8, Mo 3.0)                                          |
| HC 205                                                                             | Precipitation hardening nickel base chromium-cobalt-molybdenum-titanium alloy castings (Cr 20, Co 20, Mo 6, Ti 2)                                                  |
| HC 206                                                                             | Precipitation hardening nickel base chromium-cobalt-molybdenum-titanium alloy precision castings (Cr 20, Co 20, Mo 6, Ti 2)                                        |
| 2HC 207                                                                            | Nickel-cobalt-tungsten-chromium-aluminium-tantalum-hafnium-titanium alloy castings,<br>(Nickel base Co 10.0, W 10.0, Cr 9.0, Al 5.5, Ta 2.5, Hf 1.5, Ti 1.5)       |
| 2HC 208                                                                            | Nickel-cobalt-tungsten-chromium-aluminium-molybdenum-titanium-tantalum alloy castings<br>(Nickel base Co 10.0, W 10.0, Cr 9.0, Al 5.5, Mo 2.5, Ti 1.5, Ta 1.5)     |
| 2HC 209                                                                            | Low carbon, precipitation hardening nickel-chromium-aluminium-molybdenum-niobium alloy castings (Nickel base Cr 11.5, Al 6.0, Mo 4.0, Nb 2.0)                      |
| 2HC 210                                                                            | Nickel-tungsten-aluminum-chromium-molybdenum alloy castings                                                                                                        |
| 2HC 211                                                                            | Nickel-chromium-cobalt-molybdenum-aluminum-titanium alloy castings (Nickel base Cr 15.5, Co 10.0, Mo 8.3, Al 4.2, Ti 3.6)                                          |
| 2HR 1                                                                              | Nickel-chromium-titanium-aluminum heat-resisting alloy billets, bars, forgings and parts (Nickel base, Cr 19.5, Ti 2.2, Al 1.4)                                    |
| 2HR 2                                                                              | Nickel-chromium-cobalt-titanium-aluminum heat-resisting alloy billets, bars, forgings and parts (Nickel base, Cr 19.5, Co 18.0, Ti 2.5, Al 1.5)                    |
| HR 3                                                                               | Nickel-cobalt-chromium-molybdenum-aluminum-titanium heat-resisting alloy billets, bars, forgings and parts<br>(Nickel base Co 20, Cr 14.8, Mo 5, Al 4.7, Ti 1.2)   |
| HR 4                                                                               | Nickel-chromium-cobalt-aluminum-molybdenum-titanium heat-resisting alloy billets, bars, forgings and parts<br>(Nickel base, Cr 15, Co 14.2, Al 5, Mo 4, Ti 4)      |
| HR 5                                                                               | Nickel-chromium-titanium heat-resisting alloy billets, bars forgings and parts (Nickel base Cr 19.5, Ti 0.4)                                                       |
| HR 6                                                                               | Nickel-chromium-iron-molybdenum-cobalt-tungsten heat-resisting alloy billets, bars, forgings and parts<br>(Nickel base, Cr 21.7, Fe 18.5, Mo 9, Co 1.5, W 0.6)     |
| HR 10                                                                              | Nickel-cobalt-chromium-molybdenum-titanium-aluminum heat- resisting alloy billets, bars, forgings and parts<br>(Nickel base, Co 20, Cr 20, Mo 5.9, Ti 2.1, Al 0.5) |
| 2HR 201                                                                            | Nickel-chromium-titanium-aluminum heat-resisting alloy plate, sheet, and strip (Nickel base, Cr 19.5, Ti 2.2, Al 1.4)                                              |
| 2HR 202                                                                            | Nickel-chromium-cobalt-titanium-aluminum heat-resisting alloy sheet and strip (Nickel base, Cr 19.5, Co 18.0, Ti 2.5, Al 1.5)                                      |
| HR 203                                                                             | Nickel-chromium-titanium heat-resisting alloy plate, sheet and strip (Nickel base, Cr 19.5, Ti 0.4)                                                                |
| HR 204                                                                             | Nickel-chromium-iron-molybdenum-cobalt-tungsten heat-resisting alloy plate, sheet and strip (Nickel base, Cr 22, Fe 18.5, Mo 9, Co 1.5, W 0.6)                     |

| <b>BRITISH BSI AEROSPACE SERIES SPECIFICATIONS - HEAT RESISTING ALLOY CASTINGS (Continued)</b> |                                                                                                                                                                                |
|------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BSI</b>                                                                                     | <b>Title</b>                                                                                                                                                                   |
| HR 205                                                                                         | Nickel-copper alloy sheet and strip: annealed (Nickel base, Cu 31)                                                                                                             |
| HR 206                                                                                         | Nickel-cobalt-chromium- molybdenum-titanium-aluminum heat-resisting alloy plate, sheet and strip (Nickel base, Co 20, Cr 20, Mo 5.9, Ti 2.1, Al 0.5)                           |
| HR 207                                                                                         | Nickel-iron-chromium-molybdenum-aluminum-titanium heat-resisting alloy plate, sheet, strip (Ni/Co 43.5, Cr16.5, Mo 3.3, Al 1.2, Ti 1.2, Fe remainder)                          |
| HR 208                                                                                         | Nickel-chromium-iron alloy sheet, strip and plate, annealed (Nickel base, Cr 15.5, Fe 8)                                                                                       |
| HR 209                                                                                         | Nickel-chromium-cobalt-molybdenum-titanium-aluminum heat-resisting alloy sheet, strip and plate: softened (Nickel base, Cr 18, Co 14, Mo 7, Ti 2.2, Al 2.1)                    |
| 2HR 401                                                                                        | Nickel-chromium-titanium-aluminum heat-resisting alloy cold worked and softened seamless tubes (Nickel base Cr 19.5, Ti 2.2, Al 1.4)                                           |
| HR 402                                                                                         | Nickel-chromium-cobalt-titanium-aluminum heat-resisting alloy cold worked and softened seamless tubes (Nickel base Cr 19.5, Co 18.0, Ti 2.5, Al 1.5)                           |
| HR 403                                                                                         | Nickel-chromium-titanium heat-resisting alloy cold worked and softened seamless tubes (Nickel base Cr 19.5, Ti 0.4)                                                            |
| HR 404                                                                                         | Nickel-cobalt-chromium-molybdenum-titanium-aluminum heat-resisting alloy cold worked solution treated seamless tubes (Nickel base, Co 20, Cr 20, Mo 5.9, Ti 2.1, Al 0.5)       |
| 2HR 501                                                                                        | Nickel-chromium-cobalt-titanium-aluminum heat-resisting alloy cold drawn wire for springs and springs (Nickel base Cr 19.5, Co 18.0, Ti 2.5, Al 1.5)                           |
| 2HR 502                                                                                        | Nickel-chromium-cobalt-titanium-aluminum heat-resisting alloy cold drawn and solution heat treated wire for springs and springs (Nickel base Cr 19.5, Co 18.0, Ti 2.5, Al 1.5) |
| 2HR 503                                                                                        | Nickel-chromium-cobalt-titanium-aluminum heat-resisting alloy wire for thread inserts (Nickel base, Cr 19.5, Co 18.0, Ti 2.5, Al 1.5)                                          |
| 2HR 504                                                                                        | Nickel-chromium-titanium heat-resisting alloy bar, and wire for rivets, and rivets (Nickel base, Cr 19.5, Ti 0.4)                                                              |
| HR 505                                                                                         | Nickel-chromium-iron-titanium-niobium-aluminum heat-resisting alloy round wire for thread inserts (max. dia. 2 mm) (Nickel base Cr 15.5, Fe 7.0, Ti 2.5, Nb/Ta 0.95, Al 0.70)  |
| HR 506                                                                                         | Nickel-chromium-cobalt-titanium-aluminum heat-resisting alloy wire: softened (Nickel base, Cr 19.5, Co 1.8, Ti 2.5, Al 1.5)                                                    |
| 3HR 601                                                                                        | Nickel -chromium-titanium-aluminum heat- resisting alloy bar wire manufacture of fasteners (max. dia. or minor sectional dimension 30 mm) (Nickel base Cr 19.5-Ti 2.2-Al 1.4)  |

| <b>GERMAN DIN SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS</b> |                                                                                                                                                                                 |
|---------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                    | <b>Title</b>                                                                                                                                                                    |
| EN 2952                                                       | Aerospace series; heat resisting nickel base alloy (Ni-P100 HT); solution treated and cold worked; bar for hot upset forging for fasteners $3 \leq D \leq 30$ mm                |
| EN 2959                                                       | Aerospace series; heat resisting nickel base alloy (Ni-P101 HT); solution treated and cold worked; bar for hot upset forging for fasteners $3 \leq D \leq 30$ mm                |
| EN 2960                                                       | Aerospace series; heat resisting nickel base alloy (Ni-P101 HT); solution treated and cold worked; bar for machining for fasteners $3 \leq D \leq 50$ mm                        |
| EN 2961                                                       | Aerospace series; heat resisting nickel base alloy (Ni-P100 HT); solution treated and cold worked; bar for machining for fasteners $3 \leq D \leq 50$ mm                        |
| EN 3219                                                       | Aerospace series; heat resisting nickel base alloy (Ni-P100 HT); cold worked and softened; bar and wire for continuous forging or extrusion for fasteners $3 \leq D \leq 30$ mm |
| EN 3220                                                       | Aerospace series; heat resisting nickel base alloy (Ni-P101 HT); cold worked and softened; bar and wire for continuous forging or extrusion for fasteners $3 \leq D \leq 30$ mm |
| 1702                                                          | Nickel anodes                                                                                                                                                                   |
| 17471                                                         | Resistance alloys                                                                                                                                                               |
| 17730                                                         | Nickel and nickel-copper alloys; castings                                                                                                                                       |
| 17740                                                         | Wrought nickel; chemical composition                                                                                                                                            |
| 17741                                                         | Wrought nickel alloys; low alloyed; chemical composition                                                                                                                        |
| 17742                                                         | Wrought nickel alloys with chromium; chemical composition                                                                                                                       |
| 17743                                                         | Wrought nickel alloys with copper; chemical composition                                                                                                                         |
| 17744                                                         | Wrought nickel alloys with molybdenum and chromium; chemical composition                                                                                                        |
| 17745                                                         | Wrought alloys of nickel and iron, composition                                                                                                                                  |
| 17750                                                         | Plates, strips and sheets of wrought nickel and nickel alloys; properties                                                                                                       |
| 17751                                                         | Tubes of wrought nickel and nickel alloys; properties                                                                                                                           |
| 17752                                                         | Rods and bars of wrought nickel alloys; properties                                                                                                                              |
| 17753                                                         | Wires of wrought nickel and nickel alloys; properties                                                                                                                           |
| 17754                                                         | Forgings and drop forgings of wrought nickel and nickel alloys; properties                                                                                                      |
| 50970                                                         | Electroplated coatings; nickel salts for nickel baths; requirements and testing                                                                                                 |

| <b>GERMAN DIN SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                        |
|---------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                | <b>Title</b>                                                                                                                                                           |
| 59740                                                                     | Sheets of wrought nickel and nickel alloys; hot rolled; dimensions; tolerances                                                                                         |
| 59741                                                                     | Strips of wrought nickel and nickel alloys; hot rolled; dimensions and tolerances                                                                                      |
| 59742                                                                     | Circular blanks and rings of wrought nickel and nickel alloys; hot rolled; dimensions; tolerances                                                                      |
| 59745                                                                     | Sheet of wrought nickel and nickel alloys; cold rolled; dimensions; tolerances                                                                                         |
| 59746                                                                     | Strips of wrought nickel and nickel alloys; cold rolled; dimensions; tolerances                                                                                        |
| 59755                                                                     | Tubes of wrought nickel and nickel alloys; cold worked; dimensions; tolerances                                                                                         |
| 59760                                                                     | Round rods of wrought nickel and nickel alloys; hot rolled; dimensions; tolerances                                                                                     |
| 59761                                                                     | Square rods of wrought nickel and nickel alloys; hot rolled; dimensions; tolerances                                                                                    |
| 59762                                                                     | Hexagonal bars of wrought nickel and nickel alloys; hot rolled; dimensions; tolerances                                                                                 |
| 59763                                                                     | Rectangular bars of wrought nickel and nickel alloys; hot rolled; dimensions; tolerances; static values                                                                |
| 59765                                                                     | Round rods of wrought nickel and nickel alloys; drawn; dimensions; tolerances                                                                                          |
| 59766                                                                     | Square rods of wrought nickel and nickel alloys; drawn; dimensions; tolerances                                                                                         |
| 59767                                                                     | Hexagonal rods of wrought nickel and nickel alloys; drawn; dimensions; tolerances                                                                                      |
| 59768                                                                     | Rectangular bars of wrought nickel and nickel alloys; drawn with sharp edges; dimensions; tolerances; static values                                                    |
| 59780                                                                     | Round wire of wrought nickel and nickel alloys; hot rolled; dimensions; tolerances                                                                                     |
| 59781                                                                     | Round wire of wrought nickel and nickel alloys; drawn; dimensions; tolerances                                                                                          |
| 59782                                                                     | Square wire of wrought nickel and nickel alloys; drawn; dimensions; tolerances                                                                                         |
| 59783                                                                     | Hexagonal wire of wrought nickel and nickel alloys; drawn; dimensions; tolerances                                                                                      |
| 65596                                                                     | Aerospace; chemical check analysis limits of titanium and titanium alloys                                                                                              |
| LN 9286                                                                   | Aerospace; sheet from nickel and cobalt alloys; cold rolled; dimensions; masses                                                                                        |
| LN 29516                                                                  | Hot rolled square bars from nickel and cobalt alloys; dimensions; weights                                                                                              |
| WL 2.1504                                                                 | Wrought alloy - nickel bronze; NiAlBz                                                                                                                                  |
| WL 2.4360 Part 1                                                          | Nickel-copper wrought alloy; NiCu30Fe; creep-resistant (Monel)                                                                                                         |
| WL 2.4360 Part 2                                                          | Nickel-copper wrought alloy; NiCu30Fe; creep-resistant (Monel)                                                                                                         |
| WL 2.4360 Part 2                                                          | Aerospace; wrought nickel-copper alloy with approximately 67Ni-30Cu-1Fe; lockwire; rivet wire; rivets                                                                  |
| WL 2.4360 Part 100                                                        | Aerospace; wrought nickel-copper alloy with approximately 67Ni-30Cu-1Fe; internal pressure tubes, lockwire, rivet wire, rivets; design and production data, conversion |



| GERMAN DIN SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                                             |
|----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DIN                                                            | Title                                                                                                                                                                       |
| WL 2.4370                                                      | Nickel-copper wrought alloy; NiCu30Ti; creep-resistant; filler metal (Monel 60)                                                                                             |
| WL 2.4374 Part 1                                               | Nickel-copper wrought alloy; NiCu30Al; creep-resistant (K-Monel)                                                                                                            |
| WL 2.4374 Part 2                                               | Nickel-copper wrought alloy; NiCu30Al; creep-resistant; filler metal (K-Monel)                                                                                              |
| WL 2.4630 Supp. 1                                              | High temperature nickel alloy with about 0.1C-20Cr-0.4Ti; sheets; strips; rods; forgings; pipes; wire; rivet                                                                |
| WL 2.4630 Part 1                                               | High temperature nickel alloy with about 0.1C-20Cr-0.4Ti; sheets and strips                                                                                                 |
| WL 2.4630 Part 1                                               | Aerospace; high-temperature nickel alloy with approximately 0.1C-20Cr-0.4Ti; sheet and strip                                                                                |
| WL 2.4630 Part 2                                               | High temperature nickel alloy with about 0.1C-20Cr-0.4Ti; rods and forgings                                                                                                 |
| WL 2.4630 Part 2                                               | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-0.4Ti; bar and forging                                                                                |
| WL 2.4630 Part 3                                               | High temperature nickel alloy with about 0.1C-20Cr-0.4Ti; pipes                                                                                                             |
| WL 2.4630 Part 3                                               | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-0.4Ti; tubes                                                                                          |
| WL 2.4630 Part 4                                               | High temperature nickel alloy with about 0.1C-20Cr-0.4Ti; wire; rivet                                                                                                       |
| WL 2.4630 Part 4                                               | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-0.4Ti; wire; rivets                                                                                   |
| WL 2.4630 Part 100                                             | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-0.4Ti; sheet; bar; forging; tubing; wire and rivets; notes for design and production; cross-reference |
| WL 2.4631 Supp. 1                                              | High temperature nickel alloy with about 0.1C-20Cr-2.3Ti-1.4Al; sheets; strips; rods and forgings                                                                           |
| WL 2.4631 Part 1                                               | High temperature nickel alloy with about 0.1C-20Cr-2.3Ti-1.4Al; sheets and strips                                                                                           |
| WL 2.4631 Part 1                                               | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-2.3Ti-1.4Al; sheet and strip                                                                          |
| WL 2.4631 Part 2                                               | High temperature nickel alloy with about 0.1C-20Cr-2.3Ti-1.4Al; rods and forgings                                                                                           |
| WL 2.4631 Part 2                                               | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-2.3Ti-1.4Al; bar and forging                                                                          |
| WL 2.4631 Part 100                                             | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-2.3Ti-1.4Al; sheet; strip; bar and forging; notes for design and production; cross-reference          |
| WL 2.4632 Supp. 1                                              | High temperature nickel alloy with about 0.1C-20Cr-18Co-2.5Ti-1.5Al; sheets; strips; rods; forgings; pipes and filler metal                                                 |
| WL 2.4632 Part 1                                               | High temperature nickel alloy with about 0.1C-20Cr-18Co-2.5Ti-1.5Al; sheets and strips                                                                                      |
| WL 2.4632 Part 1                                               | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-18Co-2.5Ti-1.5Al; sheets and strips                                                                   |
| WL 2.4632 Part 2                                               | High temperature nickel alloy with about 0.1C-20Cr-18Co-2.5Ti-1.5Al; rods and forgings                                                                                      |
| WL 2.4632 Part 2                                               | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-18Co-2.5Ti-1.5Al; bar and forging                                                                     |
| WL 2.4632 Part 3                                               | High temperature nickel alloy with about 0.1C-20Cr-18Co-2.5Ti-1.5Al; pipes                                                                                                  |

| GERMAN DIN SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                                                                       |
|----------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DIN                                                            | Title                                                                                                                                                                                                 |
| WL 2.4632 Part 3                                               | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-18Co-2.5Ti-1.5Al; tubes                                                                                                         |
| WL 2.4632 Part 4                                               | High temperature nickel alloy with about 0.1C-20Cr-18Co-2.5Ti-1.5Al; filler metal                                                                                                                     |
| WL 2.4632 Part 4                                               | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-18Co-2.5Ti-1.5Al; welding filler metal                                                                                          |
| WL 2.4632 Part 100                                             | Aerospace; high temperature nickel alloy with approximately 0.1C-20Cr-18Co-2.5Ti-1.5Al; sheet; strip; bar; forging; tubing and welding filler metal; notes for design and production; cross-reference |
| WL 2.4634                                                      | High temperature nickel alloy with about 0.15C-20Co-15Cr-5Mo-4.7Al-1.2Ti; rods and forgings                                                                                                           |
| WL 2.4634 Supp. 1                                              | High temperature nickel alloy with about 0.15C-20Co-15Cr-5Mo-4.7Al-1.2Ti; rods and forgings                                                                                                           |
| WL 2.4634 Part 1                                               | Aerospace; high temperature nickel alloy with approximately 0.15C-20Co-15Cr-5Mo-4.7Al-1.2Ti; bar and forging                                                                                          |
| WL 2.4634 Part 100                                             | Aerospace; high temperature nickel alloy with approximately 0.15C-20Co-15Cr-5Mo-4.7Al-1.2Ti; bar and forging; notes for design and production; cross-reference                                        |
| WL 2.4639                                                      | High temperature nickel alloy with about 0.2C-20Cr; filler metal                                                                                                                                      |
| WL 2.4639 Supp. 1                                              | High temperature nickel alloy with about 0.2C-20Cr; filler metal                                                                                                                                      |
| WL 2.4639 Part 1                                               | Aerospace; high temperature nickel alloy with approximately 0.2C-20Cr; welding filler metal                                                                                                           |
| WL 2.4639 Part 100                                             | Aerospace; high temperature nickel alloy with about 0.2C-20Cr; welding filler metal; notes for design and production, cross-reference                                                                 |
| WL 2.4650 Supp. 1                                              | High temperature nickel alloy with about 0.06C-20Co-20Cr-6Mo-2Ti-0.5Al; sheets; strips; rods and forgings                                                                                             |
| WL 2.4650 Part 1                                               | High temperature nickel alloy with about 0.06C-20Co-20Cr-6Mo-2Ti-0.5Al; sheets and strips                                                                                                             |
| WL 2.4650 Part 2                                               | High temperature nickel alloy with about 0.06C-20Co-20Cr-6Mo-2Ti-0.5Al; rods and forgings                                                                                                             |
| WL 2.4654                                                      | High temperature nickel alloy with about 0.06C-19Cr-14Co-4Mo-3Ti-1.4Al; rods and forgings                                                                                                             |
| WL 2.4654 Supp. 1                                              | High temperature nickel alloy with about 0.06C-19Cr-14Co-4Mo-3Ti-1.4Al; rods and forgings                                                                                                             |
| WL 2.4662                                                      | High temperature nickel alloy with about 0.04C-35Fe-13Cr-6Mo-3Ti; rods and forgings                                                                                                                   |
| WL 2.4662 Supp. 1                                              | High temperature nickel alloy with about 0.04C-35Fe-13Cr-6Mo-3Ti; rods and forgings                                                                                                                   |
| WL 2.4665 Supp. 1                                              | High temperature nickel alloy with about 0.1C-22Cr-18Fe-9Mo; sheets; strips; forgings and filler wire                                                                                                 |
| WL 2.4665 Part 1                                               | High temperature nickel alloy with about 0.1C-22Cr-18Fe-9Mo; sheets and strips                                                                                                                        |
| WL 2.4665 Part 2                                               | High temperature nickel alloy with about 0.1C-22Cr-18Fe-9Mo; rods and forgings                                                                                                                        |
| WL 2.4665 Part 3                                               | High temperature nickel alloy with about 0.1C-22Cr-18Fe-9Mo; filler wire                                                                                                                              |
| WL 2.4668 Supp. 1                                              | High temperature nickel alloy with about 0.05C-19Cr-18Fe-5Nb-3Mo; sheets; strips; rods; forgings and filler wire                                                                                      |
| WL 2.4668 Part 1                                               | High temperature nickel alloy with about 0.05C-19Cr-18Fe-5Nb-3Mo; sheets and strips                                                                                                                   |

| GERMAN DIN SPECIFICATIONS - NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                                                                                                                          |
|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DIN                                                            | Title                                                                                                                                                                                                                                                    |
| WL 2.4668 Part 2                                               | High temperature nickel alloy with about 0.05C-19Cr-18Fe-5Nb-3Mo; rods and forgings                                                                                                                                                                      |
| WL 2.4668 Part 3                                               | High temperature nickel alloy with about 0.05C-19Cr-18Fe-5Nb-3Mo; filler wire                                                                                                                                                                            |
| WL 2.4668 Part 4                                               | Aerospace; heat-resisting nickel alloy with approximately 0.05C-19Cr-18Fe-5Nb-3Mo; consumable electrode remelted; bars and wire for screws and bolts                                                                                                     |
| WL 2.4668 Part 100                                             | Aerospace; heat-resisting nickel alloy with approximately 0.05C-19Cr-18Fe-5Nb-3Mo; consumable electrode remelted; sheets; strips; bars; forgings; filler wire for welding and bars and wire for screws and bolts; design and production date; conversion |
| WL 2.4670                                                      | High temperature nickel cast alloy with about 0.05C-12Cr-6Al-4.5Mo-2Nb; investment casting                                                                                                                                                               |
| WL 2.4670 Supp. 1                                              | High temperature nickel cast alloy with about 0.05C-12Cr-6Al-4.5Mo-2Nb; investment casting                                                                                                                                                               |
| WL 2.4671                                                      | High temperature nickel cast alloy with about 0.15C-13Cr-6Al-4.5Mo-2.3Nb; investment casting                                                                                                                                                             |
| WL 2.4671 Supp. 1                                              | High temperature nickel cast alloy with about 0.15C-13Cr-6Al-4.5Mo-2.3Nb; investment casting                                                                                                                                                             |
| WL 2.4672                                                      | High temperature nickel cast alloy with about 0.06C-20Co-20Cr-6Mo-2Ti-0.5Al; investment casting                                                                                                                                                          |
| WL 2.4672 Supp. 1                                              | High temperature nickel cast alloy with about 0.06C-20Co-20Cr-6Mo-2Ti-0.5Al; investment casting                                                                                                                                                          |
| WL 2.4674                                                      | High temperature nickel cast alloy with about 0.2C-15Co-10Cr-6Al-5Ti-3Mo-1V; investment casting                                                                                                                                                          |
| WL 2.4674 Supp. 1                                              | High temperature nickel cast alloy with about 0.2C-15Co-10Cr-6Al-5Ti-3Mo-1V; investment casting                                                                                                                                                          |
| WL 2.4676                                                      | High temperature nickel cast alloy with about 0.15C-10Co-10W-9Cr-5.5Al-2.5Mo; investment casting                                                                                                                                                         |
| WL 2.4676 Supp.                                                | High temperature nickel cast alloy with about 0.15C-10Co-10W-9Cr-5.5Al-2.5Mo; investment casting                                                                                                                                                         |
| WL 2.4676 Part 1                                               | Aerospace; high temperature nickel cast alloy with approximately 0.15C-10Co-10W-9Cr-5.5Al-2.5Mo; precision casting                                                                                                                                       |
| WL 2.4676 Part 100                                             | Aerospace; high temperature nickel cast alloy with approximately 0.15C-10Co-10W-9Cr-5.5Al-2.5Mo; precision casting; notes for design and production; cross-reference                                                                                     |
| WB 263                                                         | Nickel-copper alloy NiCu30Fe                                                                                                                                                                                                                             |
| WB 263 Supp.                                                   | Nickel-copper alloy NiCu30Fe                                                                                                                                                                                                                             |
| WB 432/1                                                       | Highly corrosion-proof nickel base alloy NiCr21Mo; material no. 2.4858                                                                                                                                                                                   |
| WB 432/1 Supp.                                                 | Highly corrosion-proof nickel base alloy NiCr21Mo; material no. 2.4858                                                                                                                                                                                   |
| WB 432/2                                                       | Highly corrosion-proof nickel base alloy NiCr21Mo; material no. 2.4858                                                                                                                                                                                   |
| WB 432/2 Supp.                                                 | Highly corrosion-proof nickel base alloy NiCr21Mo; material no. 2.4858                                                                                                                                                                                   |
| WB 432/3                                                       | Highly corrosion-proof nickel base alloy NiCr21Mo; material no. 2.4858                                                                                                                                                                                   |
| WB 432/3                                                       | Highly corrosion-proof nickel base alloy NiCr21Mo; material no. 2.4858                                                                                                                                                                                   |

| <b>GERMAN DIN SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                     |
|---------------------------------------------------------------------------|---------------------------------------------------------------------|
| <b>DIN</b>                                                                | <b>Title</b>                                                        |
| WB 479                                                                    | Highly corrosion-proof alloy NiCr21Mo14W; material no. 2.4602       |
| WB 485                                                                    | High temperature nickel base alloy NiCr23Co12Mo; material no 2.4663 |
| WB 485 Supp.                                                              | High temperature nickel base alloy NiCr23Co12Mo; material no 2.4663 |

| <b>JAPANESE JIS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS</b> |                                                             |
|-----------------------------------------------------------------|-------------------------------------------------------------|
| <b>JIS</b>                                                      | <b>Title</b>                                                |
| C 8705                                                          | Sealed Nickel-Cadmium Cylindrical Rechargeable Single Cells |
| C 8706                                                          | Stationary Nickel Cadmium Alkaline Batteries                |
| G 3602                                                          | Nickel and Nickel Alloy Clad Steels                         |
| H 3261                                                          | Nickel Copper Alloy Sheet and Plates                        |
| H 4501                                                          | Nickel Sheets and Strips for Electronic Tube                |
| H 4502                                                          | Nickel Sheets and Strips for Cathode of Electronic Tube     |
| H 4511                                                          | Nickel Bars and Wires for Electronic Tube                   |
| H 4522                                                          | Seamless Nickel Tube for Cathode of Vacuum Tube             |
| H 4551                                                          | Nickel and Nickel Alloy Plate, Sheet and Strip              |
| H 4552                                                          | Nickel and Nickel Alloy Seamless Pipes and Tubes            |
| H 4553                                                          | Nickel and Nickel Alloy Rod and Bar                         |
| H 4554                                                          | Nickel Alloy Wire                                           |
| H 5701                                                          | Nickel and Nickel Alloy Castings                            |
| H 8617                                                          | Electroplated Coatings of Nickel and Chromium               |
| H 8645                                                          | Autocatalytic Nickel - Phosphorus Coatings on Metals        |
| K 0013                                                          | Nickel Standard Solution                                    |
| K 9062                                                          | Nickel                                                      |
| T 6101                                                          | Nickel-Chromium Alloy Wires for Dental Use                  |
| T 6102                                                          | Nickel-Chromium Alloy Plates for Dental Use                 |
| Z 3224                                                          | Nickel and Nickel-Alloy Covered Electrodes                  |

| <b>JAPANESE JIS SPECIFICATIONS - NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                               |
|-----------------------------------------------------------------------------|---------------------------------------------------------------|
| <b>JIS</b>                                                                  | <b>Title</b>                                                  |
| Z 3265                                                                      | Nickel Brazing Filler Metals                                  |
| Z 3334                                                                      | Nickel and Nickel Alloy Filler Rods and Wires for Arc Welding |

| <b>CHEMICAL COMPOSITION OF NICKEL &amp; NICKEL ALLOYS</b> |                                                                                                                                                   |
|-----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                | <b>Chemical Composition</b>                                                                                                                       |
| N02016                                                    | Ni rem Al 1.75-2.25 C 0.15 max Fe 0.50 max Mn 2.0-3.0 Si 1.6 max                                                                                  |
| N02061                                                    | Ni 93.0 min Al 1.5 max C 0.15 max Cu 0.25 max Fe 1.0 max Mn 1.0 max P 0.03 max S 0.015 max Si 0.75 max Ti 2.0-3.5                                 |
| N02100                                                    | Ni rem C 1.00 max Cu 1.25 max Fe 3.00 max Mn 1.50 max Si 2.00 max                                                                                 |
| N02200                                                    | Ni 99.0 min C 0.15 max Cu 0.25 max Fe 0.40 max Mn 0.35 max S 0.010 max Si 0.35 max                                                                |
| N02201                                                    | Ni 99.0 min C 0.02 max Cu 0.25 max Fe 0.40 max Mn 0.35 max S 0.010 max Si 0.35 max                                                                |
| N02205                                                    | Ni 99.0 min C 0.15 max Cu 0.15 max Fe 0.20 max Mg 0.01-0.08 Mn 0.35 max S 0.008 max Si 0.15 max Ti 0.01-0.05                                      |
| N02211                                                    | Ni 93.7 min C 0.20 max Cu 0.25 max Fe 0.75 max Mn 4.25-5.25 S 0.015 max Si 0.15 max                                                               |
| N02215                                                    | Ni rem C 1.0 max Cu 4.0 max Fe 4.0 max Mn 2.5 max S 0.03 max Si 0.75 max Other 1.0 max total                                                      |
| N02216                                                    | Ni 35.0-45.0 Al 1.0 max C 0.50 max Cu 2.5 max Fe rem Mn 10.0-14.0 S 0.03 max Si 1.0 max Other 1.0 max total                                       |
| N02220                                                    | Ni 99.00 min C 0.15 max Cu 0.10 max Fe 0.10 max Mg 0.01-0.08 Mn 0.20 max S 0.008 max Si 0.01-0.05 Ti 0.01-0.05                                    |
| N02225                                                    | Ni 99.00 min C 0.15 max Cu 0.10 max Fe 0.10 max Mg 0.01-0.08 Mn 0.20 max S 0.008 max Si 0.15-0.25 Ti 0.01-0.05                                    |
| N02230                                                    | Ni 99.00 min C 0.15 max Cu 0.10 max Fe 0.10 max Mg 0.04-0.08 Mn 0.15 max S 0.008 max Si 0.010-0.035 Ti 0.005 max                                  |
| N02233                                                    | Ni 99.00 min C 0.15 max Cu 0.10 max Fe 0.10 max Mg 0.01-0.10 Mn 0.30 max S 0.008 max Si 0.10 max Ti 0.005 max                                     |
| N02270                                                    | Ni 99.97 min C 0.02 max Co 0.001 max Cr 0.001 max Cu 0.001 max Fe 0.005 max Mg 0.001 max Mn 0.001 max S 0.001 max Si 0.001 max Ti 0.001 max       |
| N02290                                                    | Ni rem Al 0.001 max C 0.006 max Cr 0.001 max Cu 0.02 max Fe 0.015 max Mg 0.001 max Mn 0.001 max N 0.001 max O 0.025 max S 0.0008 max Si 0.001 max |
| N03220                                                    | Ni rem Be 1.80-2.30 C 0.30-0.50                                                                                                                   |
| N03260                                                    | Ni rem C 0.02 max Co 0.20 max Cr 0.05 max Cu 0.15 max Fe 0.05 max S 0.0025 max Ti 0.05 max Other ThO <sub>2</sub> 1.80-2.60                       |
| N03300                                                    | Ni 97.0 min C 0.40 max Cu 0.25 max Fe 0.60 max Mg 0.20-0.50 Mn 0.50 max S 0.01 max Si 0.35 max Ti 0.20-0.60                                       |

| CHEMICAL COMPOSITION OF NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                |
|------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                        | Chemical Composition                                                                                                                           |
| N03301                                                     | Ni 93.0 min Al 4.00-4.75 C 0.30 max Cu 0.25 max Fe 0.60 max Mn 0.50 max S 0.01 max Si 1.00 max Ti 0.25-1.00                                    |
| N03360                                                     | Ni rem Be 1.85-2.05 Ti 0.4-0.6                                                                                                                 |
| N04019                                                     | Ni 60.0 min C 0.25 max Cu 27.0-31.0 Fe 2.50 max Mn 1.50 max S 0.015 max Si 3.50-4.50 max                                                       |
| N04020                                                     | Ni rem Al 0.50 max C 0.35 max Cu 26.0-33.0 Fe 2.50 max Mn 1.5 max Si 2.0 max                                                                   |
| N04060                                                     | Ni 62.0-69.0 Al 1.25 max C 0.15 max Cu rem Fe 2.5 max Mn 4.0 max P 0.02 max S 0.015 max Si 1.25 max Ti 1.5-3.0                                 |
| N04400                                                     | Ni 63.00-70.00 C 0.3 max Cu rem Fe 2.50 max Mn 2.00 max S 0.024 max Si 0.50 max                                                                |
| N04401                                                     | Ni 40.0-45.0 C 0.10 max Co 0.25 max Cu rem Fe 0.75 max Mn 2.25 max S 0.015 max Si 0.25 max                                                     |
| N04402                                                     | Ni 63.0 min C 0.04 max Cu 28.0-34.0 Fe 2.5 max Mn 2.0 max S 0.025 max Si 0.5 max                                                               |
| N04404                                                     | Ni 52.0-57.0 Al 0.05 max C 0.15 max Cu rem Fe 0.50 max Mn 0.10 max S 0.024 max Si 0.10 max                                                     |
| N04405                                                     | Ni 63.0-70.0 C 0.30 max Cu rem Fe 2.5 max Mn 2.0 max S 0.025-0.060 Si 0.50 max                                                                 |
| N05500                                                     | Ni 63.0-70.0 Al 2.30-3.15 C 0.25 max Cu rem Fe 2.00 max Mn 1.50 max S 0.01 max Si 0.50 max Ti 0.35-0.85                                        |
| N05502                                                     | Ni 63.0-70.0 Al 2.50-3.50 C 0.1 0 max Cu rem Fe 2.00 max Mn 1.50 max S 0.010 max Si 0.5 max Ti 0.50 max                                        |
| N05504                                                     | Ni 63.0-70.0 Al 2.0-4.0 C 0.25 max Cu rem Fe 2.00 max Mn 1.50 max P 0.030 max Pb 0.010 max S 0.015 max Si 1.00 max Ti 0.25-1.00                |
| N06002                                                     | Ni rem C 0.05-0.15 Co 0.5-2.5 Cr 20.5-23.0 Fe 17.0-20.0 Mn 1.00 max Mo 8.0-10.0 P 0.040 max S 0.030 max Si 1.00 max W 0.20-1.0                 |
| N06003                                                     | Ni rem C 0.15 max Cr 19-21 Fe 1.0 max Mn 2.5 max S 0.01 max Si 0.75-1.6                                                                        |
| N06004                                                     | Ni 57 min C 0.15 max Cr 14-18 Fe rem Mn 1.0 max S 0.01 max Si 0.75-1.6                                                                         |
| N06005                                                     | Ni 39.00 nom C 2.40 nom Co 10.00 nom Cr 29.00 nom Fe 6.5 max Si 0.70 nom W 15.00 nom                                                           |
| N06006                                                     | Ni 64.0-68.0 C 0.35-0.75 Cr 15.0-19.0 Fe rem Mn 2.00 max Mo 0.50 max P 0.04 max S 0.04 max Si 2.50 max                                         |
| N06007                                                     | Ni rem C 0.05 max Cb 1.75-2.5 Co 2.5 max Cr 21.0-23.5 Cu 1.5-2.5 Fe 18.0-21.0 Mn 1.0-2.0 Mo 5.5-7.5 P 0.04 max S 0.03 max Si 1.0 max W 1.0 max |
| N06008                                                     | Ni rem Al 0.20 max C 0.15 max Cr 29.0-31.0 Fe 1.0 max Mn 0.10 max P 0.030 max S 0.010 max Si 0.75-1.60                                         |
| N06009                                                     | Ni rem C 0.15 max Cb 0.75-1.50 Cr 19.0-21.0 Fe 1.00 max Mn 2.5 max S 0.010 max Si 0.75-1.60                                                    |
| N06010                                                     | Ni rem Al 0.20 max C 0.15 max Cr 9.0-11.0 Fe 0.50 max Mn 0.10 max Si 1.60 max                                                                  |
| N06013                                                     | Ni rem C 1.80-2.20 Cr 28.0-30.0 Fe 1.0-8.0 Mn 1.0 max P 0.030 max S 0.030 max Si 0.80-1.20                                                     |
| N06015                                                     | Ni rem C 1.80-2.20 Cr 28.0-30.0 Fe 1.0-8.0 Mn 1.0 max Mo 7.0-9.0 P 0.030 max S 0.030 max Si 0.80-1.20                                          |
| N06017                                                     | Replaced by N06985                                                                                                                             |
| N06022                                                     | Ni rem C 0.015 max Co 2.5 max Cr 20.0-22.5 Fe 2.0-6.0 Mn 0.50 max Mo 12.5-14.5 P 0.02 max S 0.02 max Si 0.08 max V 0.35 max W 2.5-3.5          |

| CHEMICAL COMPOSITION OF NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                                                                    |
|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                        | Chemical Composition                                                                                                                                                                               |
| N06030                                                     | Ni rem C 0.03 max Cb 0.30-1.50 Co 5.0 max Cr 28.0-31.5 Cu 1.0-2.4 Fe 13.0-17.0 Mn 1.5 max Mo 4.0-6.0 P 0.04 max S 0.02 max Si 0.8 max W 1.5-4.0                                                    |
| N06040                                                     | Ni rem C 0.40 max Cr 14.0-17.0 Fe 11.0 max Mn 1.50 max Si 3.00 max                                                                                                                                 |
| N06050                                                     | Ni 64.0-68.0 C 0.40-0.60 Cr 15.0-19.0 Fe rem Mn 1.50 max Mo 0.50 max P 0.04 max S 0.04 max Si 0.50-2.00                                                                                            |
| N06052                                                     | Ni rem Al 1.10 max C 0.04 max Cr 28.0-31.5 Cb 0.10 max Cu 0.30 max Fe 7.0-11.0 Mn 1.0 max Mo 0.50 max P 0.020 max S 0.015 max Si 0.50 max Ti 1.0 max Other 0.50 max total, Al+Ti 1.50 max          |
| N06059                                                     | Ni rem Al 0.1-0.4 C 0.010 max Co 0.3 max Cr 22.0-24.0 Fe 1.5 max Mn 0.5 max Mo 15.0-16.5 P 0.015 max S 0.005 max Si 0.10 max                                                                       |
| N06060                                                     | Ni 54.0-60.0 C 0.03 max Cr 19.0-22.0 Cb 1.25 max Cu 1.00 max Fe rem Mn 1.50 max Mo 12.0-14.0 P 0.030 max Si 0.50 max S 0.005 max W 1.25 max                                                        |
| N06062                                                     | Ni 70.00 min C 0.08 max Cb 1.50-3.00 Cr 14.00-17.00 Cu 0.50 max Fe 6.00-10.00 Mn 1.00 max P 0.030 max S 0.015 max Si 0.35 max                                                                      |
| N06072                                                     | Ni rem C 0.01-0.10 Cr 42.0-46.0 Cu 0.50 max Fe 0.50 max Mn 0.20 max P 0.020 max S 0.015 max Si 0.20 max Ti 0.30-1.00 Other 0.50 max total                                                          |
| N06075                                                     | Ni rem C 0.08-0.15 Cr 18.0-21.0 Cu 0.50 max Fe 5.00 max Mn 1.00 max Si 1.00 max Ti 0.20-0.60                                                                                                       |
| N06076                                                     | Ni 75.0 min Al 0.40 max C 0.08-0.15 Cr 19.0-21.0 Cu 0.50 max Fe 2.00 max Mn 1.00 max P 0.030 max Pb 0.010 max S 0.015 max Si 0.30 max Ti 0.15-0.50                                                 |
| N06082                                                     | Ni 67.0 min C 0.10 max Cb 2.0-3.0 includes Ta, Cr 18.0-22.0 Cu 0.50 max Fe 3.0 max Mn 2.5-3.5 P 0.03 max S 0.015 max Si 0.50 max Ti 0.75 max                                                       |
| N06102                                                     | Ni rem Al 0.30-0.60 B 0.003-0.008 C 0.08 max Cb 2.75-3.25 Cr 14.0-16.0 Fe 5.0-9.0 Mg 0.01 -0.05 Mn 0.75 max Mo 2.75-3.25 P 0.010 max S 0.010 max Si 0.40 max Ti 0.40-0.70 W 2.75-3.25 Zr 0.01-0.05 |
| N06110                                                     | Ni rem Al 1.50 max C 0.15 max Cb 2.00 max Co 12.0 max Cr 27.0-33.0 Mo 8.00-12.0 Ti 1.50 max W 4.00 max                                                                                             |
| N06132                                                     | Replaced by W86132                                                                                                                                                                                 |
| N06230                                                     | Ni rem Al 0.20-0.50 B 0.015 max C 0.05-0.15 Cr 20.0-24.0 Co 5.0 max Fe 3.0 max La 0.005-0.05 Mn 0.30-1.00 Mo 1.0-3.0 P 0.03 max S 0.015 max Si 0.25-0.75 W 13.0-15.0                               |
| N06231                                                     | Ni rem Al 0.2-0.5 B 0.003 max C 0.05-0.15 Cr 20.0-24.0 Co 3.0 max Cu 0.5 max Fe 3.0 max La 0.050 max Mn 0.3-1.0 Mo 1.0-3.0 P 0.030 max S 0.015 max Si 0.25-0.75 W 13.0-15.0                        |
| N06250                                                     | Ni 50.0-53.0 C 0.020 max Cr 20.0-23.0 Cu 1.00 max Fe rem Mn 1.0 max Mo 10.1-12.0 P 0.030 max S 0.005 max Si 0.09 max W 1.00 max                                                                    |
| N06255                                                     | Ni 47.0-52.0 C 0.03 max Cr 23.0-26.0 Cu 1.20 max Fe rem Mn 1.00 max Mo 6.0-9.0 P 0.03 max S 0.03 max Si 1.0 max Ti 0.69 max W 3.0 max                                                              |
| N06333                                                     | Ni 44.00-47.00 C 0.08 max Co 2.50-4.00 Cr 24.00-27.00 Cu 0.50 max Fe rem Mn 2.00 max Mo 2.50-4.00 P 0.030 max Pb 0.025 max S 0.030 max Si 0.75-1.50 Sn 0.025 max W 2.50-4.00                       |

| CHEMICAL COMPOSITION OF NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                                                                                                                        |
|------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                        | Chemical Composition                                                                                                                                                                                                                                   |
| N06455                                                     | Ni rem C 0.015 max Co 2.0 max Cr 14.0-18.0 Fe 3.0 max Mn 1.0 max Mo 14.0-17.0 P 0.04 max S 0.03 max Si 0.08 max Ti 0.70 max                                                                                                                            |
| N06600                                                     | Ni 72.0 min C 0.15 max Cr 14.00-17.00 Cu 0.50 max Fe 6.00-10.00 Mn 1.00 max S 0.015 max Si 0.50 max                                                                                                                                                    |
| N06601                                                     | Ni 58.0-63.0 Al 1.0-1.7 C 0.1 max Cr 21.0-25.0 Cu 1.0 max Fe rem Mn 1.0 max S 0.015 max Si 0.50 max                                                                                                                                                    |
| N06602                                                     | Ni 72.0 min C 0.02 max Cr 14.0-17.0 Cu 0.5 max Fe 6.0-10.0 Mn 1.0 max S 0.015 max Si 0.5 max                                                                                                                                                           |
| N06617                                                     | Ni 44.5 min Al 0.80-1.50 B 0.006 max C 0.05-0.15 Co 10.0-15.0 Cr 20.0-24.0 Cu 0.50 max Fe 3.00 max Mn 1.00 max Mo 8.00-10.0 S 0.015 max Si 1.00 max Ti 0.60 max                                                                                        |
| N06621                                                     | Combined with N06075                                                                                                                                                                                                                                   |
| N06625                                                     | Ni rem Al 0.40 max C 0.10 max Cb 3.15-4.15 Cr 20.0-23.0 Fe 5.0 max Mn 0.50 max Mo 8.0-10.0 P 0.015 max S 0.015 max Si 0.50 max Ti 0.40 max                                                                                                             |
| N06635                                                     | Ni rem Al 0.10-0.50 B 0.015 max C 0.02 max Co 2.00 max Cr 14.5-17.0 Cu 0.35 max Fe 3.00 max Mn 0.30-1.00 Mo 14.0-16.5 P 0.020 max S 0.015 max Si 0.20-0.75 W 1.00 max Other La 0.01-0.10                                                               |
| N06690                                                     | Ni 58.0 min C 0.05 max Cr 27.0-31.0 Cu 0.50 max Fe 7.0-11.0 Mn 0.50 max S 0.015 max Si 0.50 max                                                                                                                                                        |
| N06782                                                     | Ni rem C 2.00 nom Co 0.50 nom Cr 26.00 nom Fe 4.0 max Mn 0.30 nom Si 0.30 nom W 8.75 nom                                                                                                                                                               |
| N06804                                                     | Ni 39.0-43.0 Al 0.60 max C 0.10 max Cr 28.0-31.0 Cu 0.50 max Fe rem Mn 1.50 max S 0.015 max Si 0.75 max Ti 1.20 max                                                                                                                                    |
| N06920                                                     | Ni rem C 0.03 max Co 5.0 max Cr 20.5-23.0 Fe 17.0-20.0 Mn 1.0 max Mo 8.0-10.0 P 0.040 max S 0.030 max Si 1.0 max W 1.0-2.0                                                                                                                             |
| N06950                                                     | Ni 50.0 min C 0.015 max Cb 0.5 max Co 2.5 max Cr 19.0-21.0 Cu 0.5 max Fe 15.0-20.0 Mn 1.0 max Mo 8.0-10.0 P 0.04 max S 0.015 max Si 1.0 max W 1.0 max                                                                                                  |
| N06952                                                     | Ni 48.0-56.0 C 0.03 max Cr 23.0-27.0 Cu 0.5-1.0 Fe rem Mn 1.0 max Mo 6.0-8.0 P 0.03 max S 0.003 max Ti 0.6-1.5                                                                                                                                         |
| N06975                                                     | Ni 47.0-52.0 C 0.03 max Cr 23.0-26.0 Cu 0.70-1.20 Fe rem Mn 1.0 max Mo 5.0-7.0 P 0.03 max S 0.03 max Si 1.0 max Ti 0.70-1.50                                                                                                                           |
| N06985                                                     | Ni rem C 0.015 max Co 5.0 max Cr 21.0-23.5 Cu 1.5-2.5 Fe 18.0-21.0 Mn 1.0 max Mo 6.0-8.0 P 0.04 max S 0.03 max Si 1.0 max W 1.5 max Other Cb+Ta 0.50 max                                                                                               |
| N07001                                                     | Ni rem Al 1.20-1.60 B 0.003-0.01 C 0.03-0.10 Co 12.00-15.00 Cr 18.00-21.00 Cu 0.50 max Fe 2.00 max Mn 1.00 max Mo 3.50-5.00 P 0.030 max S 0.030 max Si 0.75 max Ti 2.75-3.25 Zr 0.02-0.12                                                              |
| N07002                                                     | Ni rem Al 0.05 nom C 0.05 nom Co 0.50 nom Cr 16.00 nom Mn 2.30 nom Si 0.05 nom Ti 3.10 nom                                                                                                                                                             |
| N07012                                                     | Ni rem Al 4.20-4.80 B 0.01-0.02 Bi 0.00005 max C 0.30-0.35 Co 9.50-10.50 Cr 11.5-12.5 Fe 1.00 max Mn 0.10 max Mo 2.50-3.50 N 0.005 max O 0.010 max P 0.015 max Pb 0.002 max S 0.015 max Si 0.10 max Ta 1.00-2.00 Ti 2.75-3.25 W 5.50-6.50 Zr 0.05-0.15 |
| N07013                                                     | Ni rem Al 3.20-3.60 B 0.010-0.020 C 0.07-0.20 Cb 0.10 max Co 8.50-9.50 Cr 12.2-13.0 Fe 0.50 max Hf 0.75-1.05 Mn 0.10 max Mo 1.70-2.10 P 0.015 max S 0.015 max Si 0.10 max Ta 3.85-4.50 Ti 3.85-4.15 W 3.85-4.50 Zr 0.05-0.14 Other Al+Ti 7.30-7.70     |



| CHEMICAL COMPOSITION OF NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                                                     |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                        | Chemical Composition                                                                                                                                                                |
| N07031                                                     | Ni 55.0-58.0 Al 1.00-1.70 B 0.003-0.007 C 0.03-0.06 Cr 22.0-23.0 Cu 0.60-1.20 Fe rem Mn 0.20 max Mo 1.70-2.30 P 0.015 max S 0.015 max Si 0.20 max Ti 2.10-2.60                      |
| N07032                                                     | Ni 55.0-58.0 Al 1.15-1.40 C 0.03-0.06 Cb 0.75-0.95 Co 1.00 max Cr 22.3-22.9 Fe rem Mo 1.70-2.30 P 0.015 max S 0.015 max Ti 2.10-2.40                                                |
| N07041                                                     | Ni rem Al 1.40-1.80 B 0.0030-0.010 C 0.12 max Co 10.00-12.00 Cr 18.00-20.00 Fe 5.00 max Mn 0.10 max Mo 9.00-10.50 S 0.015 max Si 0.50 max Ti 3.00-3.30                              |
| N07048                                                     | Ni rem Al 0.4-0.9 C 0.015 max Cb 0.5 max Co 2.0 max Cr 20.0-23.5 Cu 1.0-2.2 Fe 18.0-21.0 Mn 0.8 max Mo 5.0-7.0 P 0.02 max S 0.01 max Si 0.1 max Ti 1.5-2.1                          |
| N07069                                                     | Ni 70.0 min Al 0.40-1.00 C 0.08 Cb 0.70-1.20 includes Ta, Cr 14.0-17.0 Cu 0.50 max Fe 5.0-9.0 Mn 1.0 max P 0.03 max S 0.015 max Si 0.50 max Ti 2.00-2.75                            |
| N07080                                                     | Ni rem Al 1.0-1.8 B 0.008 max C 0.10 max Co 2.0 max Cr 18.0-21.0 Cu 0.2 max Fe 3.0 max Mn 1.0 max S 0.015 max Si 1.00 max Ti 1.8-2.7 P 0.045 max                                    |
| N07090                                                     | Ni rem Al 0.8-2.0 C 0.13 max Co 15.0-21.0 Cr 18.0-21.0 Fe 3.0 max Mn 1.0 max Si 1.5 max Ti 1.8-3.0                                                                                  |
| N07092                                                     | Ni 67.00 min C 0.08 max Cr 14.00-17.00 Cu 0.50 max Fe 8.0 max Mn 2.00-2.75 P 0.030 max S 0.015 max Si 0.35 max Ti 2.50-3.50                                                         |
| N07214                                                     | Ni rem Al 4.0-5.0 B 0.006 max C 0.05 max Co 2.0 max Cr 15.0-17.0 Fe 2.0-4.0 Mn 0.5 max Mo 0.5 max P 0.015 max S 0.015 max Si 0.2 max Ti 0.5 max W 0.5 max Y 0.002-0.040 Zr 0.05 max |
| N07252                                                     | Ni rem Al 0.75-1.25 B 0.003-0.01 C 0.1 0-0.20 Co 9.00-11.00 Cr 18.00-20.00 Fe 5.00 max Mn 0.50 max Mo 9.00-10.50 P 0.015 max S 0.015 max Si 0.50 max Ti 2.25-2.75                   |
| N07263                                                     | Ni rem Al 0.3-0.6 C 0.04-0.08 Co 19.0-21.0 Cr 19.0-21.0 Cu 0.20 max Fe 0.7 max Mn 0.60 max Mo 5.6-6.1 P 0.015 max S 0.007 max Si 0.40 max Ti 1.9-2.4 Other Al+Ti 2.4-2.8            |
| N07500                                                     | Ni rem Al 2.50-3.25 B 0.003-0.01 C 0.15 max Co 13.00-20.00 Cr 15.00-20.00 Cu 0.15 max Fe 4.00 max Mn 0.75 max Mo 3.00-5.00 P 0.015 max S 0.015 max Si 0.75 max Ti 2.50-3.25         |
| N07626                                                     | Ni rem Al 0.40-0.80 C 0.05 max Cr 20.0-23.0 Co 1.00 max Cb 4.50-5.50 Cu 0.50 max Fe 6.00 max Mn 0.50 max Mo 8.0-10.0 N 0.05 max P 0.020 max S 0.015 max Si 0.50 max Ti 0.60 max     |
| N07702                                                     | Ni rem Al 2.75-3.75 C 0.10 max Cr 14.0-17.0 Cu 0.5 max Fe 2.0 max Mn 1.0 max S 0.01 max Si 0.7 max Ti 0.25-1.00                                                                     |
| N07713                                                     | Ni rem Al 5.5-6.5 B 0.005-0.015 C 0.08-0-20 Cb 1.8-2.8 Cr 12.00-14.00 Fe 2.50 max Mn 0.25 max Mo 3.8-5.2 Si 0.50 max Ti 0.5-1.0 Zr 0.05-0.15                                        |
| N07716                                                     | Ni 57.0-63.0 Al 0.35 max C 0.03 max Cr 19.0-22.0 Cb 2.75-4.00 Fe rem Mn 0.20 max Mo 7.00-9.50 P 0.015 max S 0.010 max Si 0.20 max Ti 1.00-1.60                                      |

| CHEMICAL COMPOSITION OF NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                                                     |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                        | Chemical Composition                                                                                                                                                                |
| N07718                                                     | Ni 50.0-55.0 Al 0.20-0.80 B 0.006 max C 0.08 max Cb 4.75-5-50 Co 1.00 max Cr 17.0-21.0 Cu 0.30 max Fe rem Mn 0.35 max Mo 2.80-3.30 P 0.015 max S 0.015 max Si 0.35 max Ti 0.65-1.15 |
| N07721                                                     | Ni rem Al 0.10 max C 0.07 max Cr 15.0-17.0 Cu 0.20 max Fe 8.00 max Mn 2.00-2.50 S 0.01 max Si 0.15 max Ti 2.75-3.35                                                                 |
| N07722                                                     | Ni 70.0 min Al 0.4-1.0 C 0.08 max Cr 14.0-17.0 Cu 0.5 max Fe 5.0-9.0 Mn 1.0 max S 0.01 max Si 0.07 max Ti 2.00-2.75                                                                 |
| N07725                                                     | Ni 55.0-59.0 Al 0.35 max C 0.03 max Cr 19.0-22.5 Cb 2.75-4.00 Fe rem Mn 0.35 max Mo 7.00-9.50 P 0.015 max S 0.010 max Si 0.20 max Ti 1.00-1.70                                      |
| N07750                                                     | Ni 70.0 min Al 0.40-1.0 C 0.08 max Cb 0.70-1.20 Cr 14.0-17.0 Cu 0.5 max Fe 5.0-9.0 Mn 1.0 max S 0.01 max Si 0.50 max Ti 2.25-2.75                                                   |
| N07751                                                     | Ni 70.0 min Al 0.90-1.50 C 0.10 max Cb 0.70-1.20 Cr 14.0-17.0 Cu 0.50 max Fe 5.00-9.00 Mn 1.00 max S 0.01 max Si 0.50 max Ti 2.00-2.60                                              |
| N07754                                                     | Ni rem Al 0.2-0.5 C 0.05 max Cr 19.0-23.0 Fe 2.5 max Ti 0.3-0.6 Other Y <sub>2</sub> O <sub>3</sub> 0.5-0.7                                                                         |
| N08001                                                     | Ni 58.0-62.0 C 0.35-0.75 Cr 10.0-14.0 Fe rem Mn 2.00 max Mo 0.50 max P 0.04 max S 0.04 max Si 2.50 max                                                                              |
| N08002                                                     | Ni 33.0-37.0 C 0.35-0.75 Cr 13.0-17.0 Fe rem Mn 2.00 max Mo 0.50 max P 0.04 max S 0.04 max Si 2.50 max                                                                              |
| N08004                                                     | Ni 37.0-41.0 C 0.35-0.75 Cr 17.0-21.0 Fe rem Mn 2.00 max Mo 0.50 max P 0.04 max S 0.04 max Si 2.50 max                                                                              |
| N08005                                                     | Ni 37.0-41.0 C 0.40-0.60 Cr 17.0-21.0 Fe rem Mn 1.50 max Mo 0.50 max P 0.04 max S 0.04 max Si 0.50-2.00                                                                             |
| N08006                                                     | Ni 58.0-62.0 C 0.40-0.60 Cr 10.0-14.0 Fe rem Mn 1.50 max Mo 0.50 max P 0.04 max S 0.04 max Si 0.50-2.00                                                                             |
| N08007                                                     | Ni 27.5-30.5 C 0.07 max Cr 19.0-22.0 Cu 3.00-4.00 Fe rem Mn 1.50 max Mo 2.00-3.00 Si 1.50 max                                                                                       |
| N08008                                                     | Ni 33.0-37.0 C 0.40-0.60 Cb 0.75-1-25 Cr 13.0-17.0 Fe rem Mo 0.50 max                                                                                                               |
| N08020                                                     | Ni 32.00-38.00 C 0.07 max Cb (8xC-1.00) Cr 19.00-21.00 Cu 3.00-4.00 Fe rem Mn 2.00 max Mo 2.00-3.00 P 0.045 max S 0.035 max Si 1.00 max                                             |
| N08021                                                     | Ni 32.0-36.0 C 0.07 max Cr 19.0-21.0 Cu 3.0-4.0 Mn 2.5 max Mo 2.0-3.0 P 0.03 max S 0.03 max Si 0.60 max Other Cb+Ta (8xC-1.0)                                                       |
| N08022                                                     | Ni 32.0-36.0 C 0.025 max Cr 19.0-21.0 Cu 3.0-4.0 Mn 1.5-2.0 Mo 2.0-3.0 P 0.015 max S 0.020 max Si 0.15 max Other Cb+Ta (8xC-0.40)                                                   |
| N08024                                                     | Ni 35.0-40.0 C 0.03 max Cb 0.15-0.35 Cr 22.5-25.0 Cu 0.50-1.50 Fe rem Mn 1.00 max Mo 3.50-5.00 P 0.035 max S 0.035 max Si 0.50 max                                                  |
| N08026                                                     | Ni 33.0-37.2 C 0.03 max Cr 22.0-26.0 Cu 2.00-4.00 Fe rem Mn 1.00 max Mo 5.00-6.70 N 0.10-0.16 P 0.03 max S 0.03 max Si 0.50 max                                                     |
| N08028                                                     | Ni 29.5-32.5 C 0.03 max Cr 26.0-28.0 Cu 0.6-1.4 Fe rem Mn 2.50 max Mo 3.0-4.0 P 0.030 max S 0.030 max Si 1.00 max                                                                   |
| N08030                                                     | Ni 33.0-37.0 C 0.25-0.35 Cr 13.0-17.0 Fe rem Mn 2.00 max Mo 0.50 max P 0.040 max S 0.040 max Si 2.50 max                                                                            |
| N08031                                                     | Ni 30.0-32.0 C 0.015 max Cr 26.0-28.0 Cu 1.0-1.4 Fe rem Mn 2.0 max Mo 6.0-7.0 N 0.15-0.25 P 0.03 max S 0.005 max Si 0.05 max                                                        |
| N08032                                                     | Ni 30.0-34.0 C 0.03 max Cr 20.0-23.0 Fe rem Mn 1.0 max Mo 4.0-5.0 P 0.03 max S 0.005 max Si 0.05 max                                                                                |
| N08036                                                     | Ni 33.0-37.2 C 0.06 max Cr 22.0-26.0 Cu 1.00-3.00 Fe rem Mn 1.00 max Mo 5.00-6.70 N 0.17-0.40 P 0.030 max S 0.030 max Si 0.50 max                                                   |
| N08042                                                     | Ni 40.0-44.0 C 0.03 max Cr 20.0-23.0 Cu 1.5-3.0 Fe rem Mn 1.0 max Mo 5.0-7.0 P 0.03 max S 0.003 max Si 0.5 max Ti 0.6-1.2                                                           |

| CHEMICAL COMPOSITION OF NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                             |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                        | Chemical Composition                                                                                                                                        |
| N08050                                                     | Ni 33.0-37.0 C 0.40-0.60 Cr 15.0-19.0 Fe rem Mn 1.50 max Mo 0.50 max P 0.04 max S 0.04 max Si 0.50-2.00                                                     |
| N08065                                                     | Ni 38.0-46.0 Al 0.20 max C 0.05 max Cr 19.5-23.5 Cu 1.50-3.0 Fe 22.0 min Mn 1.0 max Mo 2.5-3.5 P 0.03 max S 0.03 max Si 0.50 max Ti 0.60-1.2                |
| N08135                                                     | Ni 33.0-38.0 C 0.03 max Cr 20.5-23.5 Cu 0.70 max Fe rem Mn 1.00 max Mo 4.0-5.0 P 0.03 max S 0.03 max Si 0.75 max W 0.20-0.80                                |
| N08151                                                     | Ni 31.0-34.0 C 0.05-0.15 Cr 19.0-21.0 Cb 0.50-1.50 Fe rem Mn 0.50-1.50 P 0.03 max S 0.03 max Si 0.50-1.50                                                   |
| N08221                                                     | Ni 36.0-46.0 Al 0.20 max C 0.025 max Cr 20.0-22.0 Cu 1.50-3.00 Fe rem Mn 1.00 max Mo 5.00-6.50 S 0.03 max Si 0.50 max Ti 0.60-1.00                          |
| N08310                                                     | Ni 18.0-22.0 C 0.020 max Cr 24.0-26.0 Fe rem Mn 2.00-4.00 Mo 2.00-4.00 N 0.20-0.40 P 0.035 max S 0.015 max Si 0.050 max                                     |
| N08320                                                     | Ni 25.0-27.0 C 0.05 max Cr 21.0-23.0 Fe rem Mn 2.5 max Mo 4.0-6.0 P 0.04 max S 0.03 max Si 1.0 max Ti 4xC min                                               |
| N08321                                                     | Ni 32.0-36.0 C 0.035 max Cb (8xC-0.4) max Cr 19.0-21.0 Cu 3.0-4.0 Fe rem Mn 1.5-2.5 Mo 2.0-3.0 P 0.02 max S 0.015 max Si 0.3 max                            |
| N08330                                                     | Ni 34.0-37.0 C 0.08 max Cr 17.0-20.0 Cu 1.00 max Fe rem Mn 2.00 max P 0.03 max Pb 0.005 max S 0.03 max Si 0.75-1.50 Sn 0.025 max                            |
| N08331                                                     | Ni 34.0-37.0 C 0.18-0.25 Cr 15.0-17.0 Cu 0.75 max Fe rem Mn 1.0-2.5 Mo 0.75 max P 0.03 max S 0.03 max Si 0.30-0.65                                          |
| N08332                                                     | Ni 34.0-37.0 Al 0.10-0.50 C 0.05-0.10 Cr 17.0-20.0 Cu 1.00 max Fe rem Mn 2.00 max P 0.03 max Pb 0.005 max S 0.03 Si 0.75-1.50 Sn 0.025 max Ti 0.20-0.60     |
| N08334                                                     | Ni 33.0-37.0 C 0.18-0.29 Cr 17.0-20.0 Cu 0.5 max Fe rem Mn 4.25-6.5 Mo 0.7 max P 0.025 max S 0.02 max Si 0.65-1.3                                           |
| N08366                                                     | Ni 23.5-25.5 C 0.035 max Cr 20.0-22.0 Fe rem Mn 2.00 max Mo 6.00-7.00 P 0.030 max S 0.030 max Si 1.00 max                                                   |
| N08367                                                     | Ni 23.50-25.50 C 0.030 max Cr 20.0-22.0 Fe rem Mn 2.00 max Mo 6.00-7.00 N 0.18-0.25 P 0.040 max S 0.030 max Si 1.00 max                                     |
| N08421                                                     | Ni 39.0-41.0 Al 0.2 max C 0.025 max Cr 20.0-22.0 Cu 1.5-2.0 Fe rem Mn 1.00 max Mo 5.0-6.5 S 0.03 max Si 0.5 max Ti 0.6-1.0                                  |
| N08535                                                     | Ni 29.0-36.5 C 0.03 max Cr 24.0-27.0 Cu 1.50 max Fe rem Mn 1.00 max Mo 2.5-4.0 P 0.03 max S 0.03 max Si 0.50 max                                            |
| N08603                                                     | Ni 33.0-37.0 C 0.25-0.35 Cr 13.0-17.0 Fe rem Mn 2.00 max Mo 0.50 max P 0.040 max S 0.040 max Si 2.50 max                                                    |
| N08604                                                     | Ni 16.0-22.0 C 0.20-0.60 Cr 28.0-32.0 Fe rem Mn 2.00 max Mo 0.50 max P 0.04 max S 0.04 max Si 2.00 max                                                      |
| N08605                                                     | Ni 33.0-37.0 C 0.35-0.75 Cr 15.0-19.0 Fe rem Mn 2.00 max P 0.04 max S 0.04 max Si 2.50 max                                                                  |
| N08613                                                     | Ni 18.0-22.0 C 0.25-0.35 Cr 28.0-32.0 Fe rem Mn 1.50 max Mo 0.50 max P 0.04 max S 0.04 max Si 0.50-2.00                                                     |
| N08614                                                     | Ni 18.0-22.0 C 0.35-0.45 Cr 28.0-32.0 Fe rem Mn 1.50 max Mo 0.50 max P 0.04 max S 0.04 max Si 0.50-2.00                                                     |
| N08700                                                     | Ni 24.0-26.0 C 0.04 max Cb (8xC to 0.50) Cr 19.0-23.0 Cu 0.50 max Fe rem Mn 2.00 max Mo 4.3-5.0 P 0.04 max Pb 0.005 max S 0.03 max Si 1.00 max Sn 0.035 max |
| N08705                                                     | Ni 35.0-37.0 C 0.35-0.75 Cr 24.0-28.0 Fe rem Mn 2.00 max Mo 0.50 max P 0.04 max S 0.04 max Si 2.50 max                                                      |
| N08800                                                     | Ni 30.0-35.0 Al 0.15-0.60 C 0.10 max Cr 19.0-23.0 Cu 0.75 max Fe rem Mn 1.5 max S 0.015 max Si 1.0 max Ti 0.15-0.60                                         |
| N08801                                                     | Ni 30.0-34.0 C 0.10 max Cr 19.0-22.0 Cu 0.5 max Fe rem Mn 1.5 max S 0.015 max Si 1.0 max Ti 0.75-1.5                                                        |

| CHEMICAL COMPOSITION OF NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                                                  |
|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                        | Chemical Composition                                                                                                                                                             |
| N08802                                                     | Ni 30.0-35.0 Al 0.15-1.00 C 0.20-0.50 Cr 19.0-23.0 Cu 0.75 max Fe rem Mn 1.50 max S 0.015 max Si 0.75 max Ti 0.25-1.25                                                           |
| N08810                                                     | Ni 30.0-35.0 Al 0.15-0.60 C 0.05-0.10 Cr 19.0-23.0 Cu 0.75 max Fe rem Mn 1.5 max S 0.015 max Si 1.0 max Ti 0.15-0.60                                                             |
| N08811                                                     | Ni 30.0-35.0 Al 0.15-0.60 C 0.06-0.10 Cr 19.0-23.0 Cu 0.75 max Fe 39.5 min Mn 1.5 max S 0.015 max Si 1.0 max Ti 0.15-0.60<br>Other Al+Ti 0.85-1.20                               |
| N08825                                                     | Ni 38.0-46.0 Al 0.2 max C 0.05 max Cr 19.5-23.5 Cu 1.5-3.0 Fe rem Mn 1.0 max Mo 2.5-3.5 P 0.03 max S 0.03 max Si 0.5 max Ti 0.6-1.2                                              |
| N08826                                                     | Ni 38.0-46.0 C 0.05 max Cb 0.6-1.2 Cr 19.5-23.5 Cu 1.5-3.0 Fe 22.0 min Mn 1.00 max Mo 2.5-3.5 P 0.03 max S 0.03 max Si 1.00 max                                                  |
| N08904                                                     | Ni 23.0-28.0 C 0.020 max Cr 19.0-23.0 Cu 1.00-2.00 Fe rem Mn 2.00 max Mo 4.00-5.00 P 0.045 max S 0.035 max Si 1.00 max                                                           |
| N08925                                                     | Ni 24.0-26.0 C 0.020 max Cr 19.0-21.0 Cu 0.50-1.50 Fe rem Mn 1.00 max Mo 6.00-7.00 N 0.10-0.20 P 0.045 max S 0.030 max Si 0.50 max                                               |
| N08926                                                     | Ni 24.0-26.0 C 0.020 max Cr 19.0-21.0 Cu 0.5-1.5 Fe rem Mn 2.00 max Mo 6.0-7.0 N 0.15 max P 0.030 max S 0.010 max Si 0.50 max                                                    |
| N08932                                                     | Ni 24.0-26.0 C 0.020 max Cr 24.0-26.0 Cu 1.0-2.0 Fe rem Mn 2.0 max Mo 4.7-5.7 N 0.17-0.25 P 0.025 max S 0.010 max Si 0.50 max                                                    |
| N09027                                                     | Ni 36.50-39.50 Al 1.45-1.75 B 0.003-0.015 C 0.02-0.08 Cb 0.60- 1.10 Cr 12.50-14.00 Fe rem Mn 0.25 max Mo 5.00-6.00 P 0.015 max S 0.015 max<br>Si 0.25 max Ti 2.30-2.70           |
| N09706                                                     | Ni 39.0-44.0 Al 0.40 max B 0.006 max C 0.06 max Cb 2.5-3.3 Cr 14.5-17.5 Cu 0.30 max Fe rem Mn 0.35 max P 0.020 max S 0.015 max<br>Si 0.35 max Ti 1.5-2.0                         |
| N09901                                                     | Ni 40.00-45.00 Al 0.35 max B 0.010-0.020 C 0.10 max Cr 11.00-14.00 Cu 0.50 max Fe rem Mn 1.00 max Mo 5.00-7.00 S 0.030 max Si 0.60 max<br>Ti 2.35-3.10                           |
| N09902                                                     | Ni 41.0-43.5 Al 0.30-0.80 C 0.06 max Cr 4.90-5.75 Fe rem Mn 0.80 max P 0.04 max S 0.04 max Si 1.0 max Ti 2.20-2.75                                                               |
| N09911                                                     | Combined with N09901                                                                                                                                                             |
| N09925                                                     | Ni 38.0-46.0 Al 0.10-0.50 C 0.03 max Cb 0.50 max Cr 19.5-23.5 Cu 1.50-3.00 Fe 22.0 min Mn 1.00 max Mo 2.50-3.50 S 0.03 max Si 0.50 max<br>Ti 1.90-2.40                           |
| N09926                                                     | Ni 26.0-30.0 Al 0.3 max C 0.04 max Cr 14.0-18.0 Cu 3.5-5.5 Fe 39.0 min Mn 1.5 max Mo 2.5-3.5 S 0.015 max Si 0.75 max Ti 1.5-2.3                                                  |
| N09979                                                     | Ni 42.00-48.00 Al 0.75-1.30 B 0.008-0.016 C 0.08 max Cr 14.00-16.00 Fe rem Mn 0.75 max Mo 3.75-4.50 P 0.015 max S 0.015 max Si 0.75 max<br>Ti 2.70-3.30 W 3.75-4.50 Zr 0.050 max |
| N10001                                                     | Ni rem C 0.12 max Co 2.50 max Cr 1.00 max Fe 6.00 max Mn 1.00 max Mo 26.0-33.0 P 0.040 max S 0.030 max Si 1.00 max V 0.60 max                                                    |
| N10002                                                     | Ni rem C 0.08 max Co 2.5 max Cr 14.5-16.5 Fe 4.0-7.0 Mn 1.00 max Mo 15.0-17.0 P 0.040 max S 0.030 max Si 1.00 max V 0.35 max W 3.0-4.5                                           |
| N10003                                                     | Ni rem Al 0.50 max B 0.010 max C 0.04-0.08 Co 0.20 max Cr 6.0-8.0 Cu C.35 max Fe 5.0 max Mn 1.00 max Mo 15.0-18.0 P 0.015 max<br>S 0.020 max Si 1.00 max V 0.50 max W 0.50 max   |

| CHEMICAL COMPOSITION OF NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                                                                                                                        |
|------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                        | Chemical Composition                                                                                                                                                                                                                                   |
| N10004                                                     | Ni rem C 0.12 max Cr 4.00-6.00 Fe 4.00-7.00 Mn 1.00 max Mo 23.00-26.00 P 0.050 max S 0.050 max Si 1.00 max V 0.60 max                                                                                                                                  |
| N10276                                                     | Ni rem C 0.02 max Co 2.5 max Cr 14.5-16.5 Fe 4.0-7.0 Mn 1.0 max Mo 15.0-17.0 P 0.030 max S 0.030 max Si 0.08 max V 0.35 max W 3.0-4.5                                                                                                                  |
| N10665                                                     | Ni rem C 0.02 max Co 1.0 max Cr 1.0 max Fe 2.0 max Mn 1.0 max Mo 26.0-30.0 P 0.04 S 0.03 max Si 0.10 max                                                                                                                                               |
| N10675                                                     | Ni 65.0 min Al 0.50 max C 0.01 max Cb 0.20 max Co 3.0 max Cr 1.0-3.0 Cu 0.20 max Fe 1.0-3.0 Mn 3.0 max Mo 27.0-32.0 P 0.030 max S 0.010 max Si 0.10 max Ta 0.20 max Ti 0.20 max V 0.20 max W 3.0 max Zr 0.10 max Other Ni+Mo 94.0-98.0                 |
| N13009                                                     | Ni rem Al 4.75-5.25 B 0.010-0.020 Bi 0.00005 max C 0.12-0.17 Cb 0.75-1.25 Co 9.00-11.00 Cr 8.00-10.00 Cu 0.10 max Fe 1.50 max Mn 0.20 max Pb 0.0010 max S 0.015 max Si 0.20 max Ti 1.75-2.25 W 11.5-13.5 Zr 0.03-0.08                                  |
| N13010                                                     | Ni rem Al 5.75-6.25 B 0.010-0.020 Bi 0.00005 max C 0.08-0.13 Cb 0.10 max Co 9.50-10.50 Cr 7.50-8.50 Fe 0.35 max Mn 0.20 max Mo 5.75-6.25 P 0.015 max Pb 0.0005 max S 0.015 max Si 0.25 max Ta 4.00-4.50 Ti 0.80-1.20 W 0.10 max Zr 0.05-0.10           |
| N13017                                                     | Ni rem Al 3.85-4.15 B 0.020-0.030 Bi 0.00005 max C 0.02-0.06 Co 16.0-18.0 Cr 14.0-16.0 Cu 0.10 max Fe 0.50 max Mn 0.15 max Mo 4.50-5.50 N 0.0050 max O 0.010 max P 0.015 max Pb 0.0002 max S 0.015 max Si 0.20 max Ti 3.35-3.65 W 0.05 max Zr 0.06 max |
| N13020                                                     | Ni rem Al 3.75-4.75 B 0.025-0.035 Bi 0.00005 max C 0.03-0.10 Co 17.0-20.0 Cr 14.0-16.0 Cu 0.10 max Fe 2.00 max Mn 0.15 max Mo 4.50-5.50 Ti 2.75-3.75 Zr 0.06 max                                                                                       |
| N13021                                                     | Ni rem Ag 0.0005 max Al 4.5-4.9 B 0.003-0.010 Bi 0.0001 max C 0.12-0.17 Cr 14.0-15.7 Co 18.0-22.0 Cu 0.2 max Fe 1.0 max Mn 1.0 max Mo 4.5-5.5 Pb 0.0015 max S 0.015 max Si 1.0 max Ti 0.9-1.5                                                          |
| N13100                                                     | Ni rem Al 5.00-6.00 B 0.01-0.02 C 0.15-0.20 Co 13.0-17.0 Cr 8.0-11.0 Fe 1.0 max Mn 0.20 max Mo 2.0-4.0 S 0.015 max Si 0.20 max Ti 4.50-5.00 V 0.70-1.20 Zr 0.03-0.09                                                                                   |
| N13246                                                     | Ni rem Al 5.25-5.75 B 0.01-0.02 C 0.13-0.17 Cr 8.0-11.0 Co 9.0-10.0 Cu 0.10 max Hf 1.5-2.0 Fe 1.0 max Mn 0.20 max Mo 2.25-2.75 S 0.015 max Si 0.20 max Ta 1.25-1.75 Ti 1.25-1.75 W 9.0-11.0 Zr 0.03-0.08                                               |
| N14052                                                     | Ni 50.5 nom Al 0.10 max C 0.05 max Co 0.50 max Cr 0.25 max Fe rem Mn 0.60 max P 0.025 max S 0.025 max Si 0.30 max                                                                                                                                      |
| N19903                                                     | Ni 36.0-40.0 Al 0.30-1.15 B 0.012 max C 0.06 max Cb 2.40-3.50 Co 13.0-17.0 Cr 1.00 max Cu 0.50 max Fe rem Mn 1.00 max S 0.015 max Si 0.35 max Ti 1.00-1.25                                                                                             |
| N19907                                                     | Ni 35.0-40.0 Al 0.20 max B 0.012 max C 0.06 max Cb 4.3-5.2 Co 12.0-16.0 Cr 1.0 max Cu 0.5 max Fe rem Mn 1.0 max P 0.015 max S 0.015 max Si 0.35 max Ti 1.2-1.8                                                                                         |
| N19909                                                     | Ni 35.0-40.0 Al 0.15 max B 0.012 max C 0.06 max Cb 4.3-5.2 Co 12.0-16.0 Cr 1.0 max Cu 0.5 max Fe rem Mn 1.0 max P 0.015 max S 0.015 max Si 0.25-0.50 Ti 1.3-1.8                                                                                        |
| N24025                                                     | Ni rem C 0.25 max Cu 27.0-33.0 Fe 3.50 max Mn 1.50 max P 0.03 max S 0.03 max Si 3.5-4.5                                                                                                                                                                |

| CHEMICAL COMPOSITION OF NICKEL & NICKEL ALLOYS (Continued) |                                                                                                                                                                                     |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                        | Chemical Composition                                                                                                                                                                |
| N24030                                                     | Ni rem C 0.30 max Cu 27.0-33.0 Fe 3.50 max Mn 1.50 max P 0.03 max S 0.03 max Si 2.7-3.7                                                                                             |
| N24130                                                     | Ni rem C 0.30 max Cb 1.0-3.0 Cu 26.0-33.0 Fe 3.50 max Mn 1.50 max P 0.03 max S 0.03 max Si 1.0-2.0                                                                                  |
| N24135                                                     | Ni rem C 0.35 max Cb 0.5 max Cu 26.0-33.0 Fe 3.50 max Mn 1.50 max P 0.03 max S 0.03 max Si 1.25 max                                                                                 |
| N26022                                                     | Ni rem C 0.02 max Cr 20.0-22.5 Fe 2.0-6.0 Mn 1.00 max Mo 12.5-14.5 P 0.025 max S 0.025 max Si 0.80 max V 0.35 max W 2.5-3.5                                                         |
| N26055                                                     | Ni rem Bi 3.0-5.0 C 0.05 max Cr 11.0-14.0 Fe 2.0 max Mn 1.5 max Mo 2.0-3.5 P 0.03 max S 0.03 max Si 0.5 max Sn 3.0-5.0                                                              |
| N26455                                                     | Ni rem C 0.02 max Cr 15.0-17.5 Fe 2.0 max Mn 1.00 max Mo 15.0-17.5 P 0.03 max S 0.03 max Si 0.80 max W 1.0 max                                                                      |
| N26625                                                     | Ni rem C 0.06 max Cb 3.15-4.50 Cr 20.0-23.0 Fe 5.0 max Mn 1.00 max Mo 8.0-10.0 P 0.015 max S 0.015 max Si 1.00 max                                                                  |
| N30002                                                     | Ni rem C 0.12 max Cr 15.5-17.5 Fe 4.5-7.5 Mn 1.00 max Mo 16.0-18.0 P 0.040 max S 0.030 max Si 1.00 max V 0.20-0.40 W 3.75-5.25                                                      |
| N30007                                                     | Ni rem C 0.07 max Cr 1.0 max Fe 3.00 max Mn 1.00 max Mo 30.0-33.0 P 0.040 max S 0.030 max Si 1.00 max                                                                               |
| N30012                                                     | Ni rem C 0.12 max Cr 1.00 max Fe 4.0-6.0 Mn 1.00 max Mo 26.0-30.0 P 0.040 max S 0.030 max Si 1.00 max V 0.20-0.60                                                                   |
| N30107                                                     | Ni rem C 0.07 max Cr 17.0-20.0 Fe 3.0 max Mn 1.00 max Mo 17.0-20.0 P 0.040 max S 0.030 max Si 1.00 max                                                                              |
| N94620                                                     | Ni 27 nom Al 0.01 max C 0.02 max Cr 0.03 max Co 25 nom Cu 0.20 max Mg 0.01 max Mn 0.15 max Mo 0.06 max P 0.006 max S 0.006 max Si 0.15 max Ti 0.01 max Zr 0.01 max                  |
| N94630                                                     | Ni 29 nom Al 0.01 max C 0.02 max Cr 0.03 max Co 17 nom Cu 0.20 max Mg 0.01 max Mn 0.35 max Mo 0.06 max P 0.006 max S 0.006 max Si 0.15 max Ti 0.01 max Zr 0.01 max                  |
| N99600                                                     | Ni rem Al 0.05 max B 2.75-3.50 C 0.6-0.9 Co 0.10 max Cr 13.0-15.0 Fe 4.0-5.0 P 0.02 max S 0.02 max Se 0.005 max Si 4.0-5.0 Ti 0.05 max Zr 0.05 max Other 0.50 max                   |
| N99610                                                     | Ni rem Al 0.05 max B 2.75-3.50 C 0.06 Co 0.10 max Cr 13.0-15.0 Fe 4.0-5.0 P 0.02 max S 0.02 max Se 0.005 max Si 4.0-5.0 Ti 0.05 max Zr 0.05 max Other 0.50 max                      |
| N99612                                                     | Ni rem Al 0.05 max B 3.25-4.0 C 0.06 max Co 0.10 max Cr 13.5-16.5 Fe 1.5 max P 0.02 max S 0.02 max Se 0.005 max Ti 0.05 max Zr 0.05 max Other total 0.50 max                        |
| N99620                                                     | Ni rem Al 0.05 max B 2.75-3.50 C 0.06 max Co 0.10 max Cr 6.0-8.0 Fe 2.5-3.5 P 0.02 S 0.02 max Se 0.005 max Si 4.0-5.0 Ti 0.05 max Zr 0.05 max Other 0.50 max                        |
| N99622                                                     | Ni rem Al 0.05 max B 2.0-3.0 C 0.40-0.55 Co 0.10 max Cr 10.0-13.0 Fe 2.5-4.5 P 0.02 max S 0.02 max Se 0.005 max Si 3.0-4.0 Ti 0.05 max W 15.0-17.0 Zr 0.05 max Other total 0.50 max |
| N99624                                                     | Ni rem Al 0.05 max B 2.2-3.1 C 0.30-0.50 Co 0.10 max Cr 9.0-11.75 Fe 2.5-4.0 P 0.02 max S 0.02 max Se 0.005 Si 3.25-4.25 Ti 0.05 max W 11.50-12.75 Zr 0.05 max Other total 0.50 max |

| <b>CHEMICAL COMPOSITION OF NICKEL &amp; NICKEL ALLOYS (Continued)</b> |                                                                                                                                                                                |
|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                                                    |
| N99630                                                                | Ni rem Al 0.05 max B 2.75-3.50 C 0.06 max Co 0.10 max Fe 0.5 max P 0.02 max S 0.02 max Se 0.005 max Si 4.0-5.0 Ti 0.05 max Zr 0.05 max Other 0.50 max                          |
| N99640                                                                | Ni rem Al 0.05 max B 1.5-2.2 C 0.06 max Co 0.10 max Fe 1.5 max P 0.02 max S 0.02 max Se 0.005 max Si 3.0-4.0 Ti 0.05 max Zr 0.05 max Other 0.50 max                            |
| N99644                                                                | Ni rem B 2.00-3.00 C 0.30-0.60 Co 1.50 max Cr 8.0-14.0 Fe 1.25-3.25 Se 0.005 max Si 1.25-3.25                                                                                  |
| N99645                                                                | Ni rem B 2.00-4.00 C 0.40-0.80 Co 1.25 max Cr 10.0-16.0 Fe 3.00-5.00 Se 0.005 max Si 3.00-5.00                                                                                 |
| N99646                                                                | Ni rem B 2.50-4.50 C 0.50-1.00 Co 1.00 max Cr 12.0-18.0 Fe 3.50-5.50 Se 0.005 max Si 3.50-5.50                                                                                 |
| N99650                                                                | Ni rem Al 0.05 max B 0.03 max C 0.10 Co 0.10 max Cr 18.5-19.5 P 0.02 max S 0.02 max Se 0.005 max Si 9.75-10.50 Ti 0.05 max Zr 0.05 max Other 0.50 max                          |
| N99651                                                                | Ni rem Al 0.05 max B 1.0-1.5 C 0.10 max Co 0.10 max Cr 18.5-19.5 Fe 0.5 max P 0.02 max S 0.02 max Se 0.005 max Si 7.0-7.5 Ti 0.05 max Zr 0.05 max                              |
| N99700                                                                | Ni rem Al 0.05 max C 0.01 max Co 0.10 max P 10.0- 12.0 S 0.02 max Se 0.005 max Ti 0.05 max Zr 0.05 max Other 0.50 max                                                          |
| N99710                                                                | Ni rem Al 0.05 max B 0.01 max C 0.08 max Co 0.10 max Cr 13.0-15.0 Fe 0.2 max Mn 0.04 max P 9.7-10.5 S 0.02 max Se 0.005 max Si 0.10 max Ti 0.05 max Zr 0.05 max Other 0.50 max |
| N99800                                                                | Ni rem Al 0.05 max C 0.10 max Co 0.10 max Cu 4.0-5.0 Mn 21.5-24.5 P 0.02 max S 0.02 max Se 0.005 max Si 6.0-8.0 Ti 0.05 max Zr 0.05 max Other 0.50 max                         |

rem - remainder; nom - nominal

| <b>CHEMICAL COMPOSITION OF NICKEL &amp; NICKEL ALLOY CASTINGS</b> |            |                                                                                                                                   |
|-------------------------------------------------------------------|------------|-----------------------------------------------------------------------------------------------------------------------------------|
| <b>ASTM</b>                                                       |            |                                                                                                                                   |
| <b>A 494 Gr</b>                                                   | <b>UNS</b> | <b>Chemical Composition</b>                                                                                                       |
| CZ-100                                                            | N02100     | Ni rem C 1.00 max Cu 1.25 max Fe 3.00 max Mn 1.50 max Si 2.00 max                                                                 |
| M-35-1                                                            | N24135     | Ni rem C 0.35 max Cb 0.5 max Cu 26.0-33.0 Fe 3.50 max Mn 1.50 max P 0.03 max S 0.03 max Si 1.25 max                               |
| M-35-2                                                            | ---        | Ni rem C 0.35 max Cb 0.5 max Cu 26.0-33.0 Fe 3.50 max Mn 1.50 max P 0.03 max S 0.03 max Si 2.00 max                               |
| M-30H                                                             | N24030     | Ni rem C 0.30 max Cu 27.0-33.0 Fe 3.50 max Mn 1.50 max P 0.03 max S 0.03 max Si 2.7-3.7                                           |
| M-25S <sup>a</sup>                                                | N24025     | Ni rem C 0.25 max Cu 27.0-33.0 Fe 3.50 max Mn 1.50 max P 0.03 max S 0.03 max Si 3.5-4.5                                           |
| M-30C                                                             | N24130     | Ni rem C 0.30 max Cb 1.0-3.0 Cu 26.0-33.0 Fe 3.50 max Mn 1.50 max P 0.03 max S 0.03 max Si 1.0-2.0                                |
| N-12MV <sup>a</sup>                                               | N30012     | Ni rem C 0.12 max Cr 1.00 max Fe 4.0-6.0 Mn 1.00 max Mo 26.0-30.0 P 0.040 max S 0.030 max Si 1.00 max V 0.20-0.60                 |
| N-7M <sup>a</sup>                                                 | N30007     | Ni rem C 0.07 max Cr 1.0 max Fe 3.00 max Mn 1.00 max Mo 30.0-33.0 P 0.040 max S 0.030 max Si 1.00 max                             |
| CY-40 <sup>a</sup>                                                | N06040     | Ni rem C 0.40 max Cr 14.0-17.0 Fe 11.0 max Mn 1.50 max Si 3.00 max                                                                |
| CW-12MW <sup>a</sup>                                              | N30002     | Ni rem C 0.12 max Cr 15.5-17.5 Fe 4.5-7.5 Mn 1.00 max Mo 16.0-18.0 P 0.040 max S 0.030 max Si 1.00 max V 0.20-0.40<br>W 3.75-5.25 |
| CW-6M <sup>a</sup>                                                | N30107     | Ni rem C 0.07 max Cr 17.0-20.0 Fe 3.0 max Mn 1.00 max Mo 17.0-20.0 P 0.040 max S 0.030 max Si 1.00 max                            |
| CW-2M <sup>a</sup>                                                | N26455     | Ni rem C 0.02 max Cr 15.0-17.5 Fe 2.0 max Mn 1.00 max Mo 15.0-17.5 P 0.03 max S 0.03 max Si 0.80 max W 1.0 max                    |
| CW-6MC                                                            | N26625     | Ni rem C 0.06 max Cb 3.15-4.50 Cr 20.0-23.0 Fe 5.0 max Mn 1.00 max Mo 8.0-10.0 P 0.015 max S 0.015 max Si 1.00 max                |
| CY5SnBiM                                                          | N26055     | Ni rem Bi 3.0-5.0 C 0.05 max Cr 11.0-14.0 Fe 2.0 max Mn 1.5 max Mo 2.0-3.5 P 0.03 max S 0.03 max Si 0.5 max Sn 3.0-5.0            |
| CX2MW <sup>a</sup>                                                | N26022     | Ni rem C 0.02 max Cr 20.0-22.5 Fe 2.0-6.0 Mn 1.00 max Mo 12.5-14.5 P 0.025 max S 0.025 max Si 0.80 max V 0.35 max W 2.5-3.5       |

a. See ASTM A 494 for details regarding class designations and heat treat requirements. rem - remainder; nom - nominal

| <b>CHEMICAL COMPOSITION OF NICKEL &amp; NICKEL ALLOY - WELD FILLER METALS</b> |                                                                                                                                                 |
|-------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                                    | <b>Chemical Composition</b>                                                                                                                     |
| W80001                                                                        | Ni rem C 0.07 max Co 2.5 max Cr 1.0 max Cu 0.50 max Fe 4.0-7.0 Mn 1.0 max Mo 26.0-30.0 P 0.04 max S 0.03 max Si 1.0 max V 0.60 max<br>W 1.0 max |
| W80002                                                                        | Ni rem C 0.10 max Co 2.50 max Cr 14.50-16.50 Cu 0.50 max Fe 4.0-7.0 Mn 1.0 max Mo 15.0-17.0 P 0.040 max S 0.030 max Si 1.0 max<br>W 3.00-4.50   |



| CHEMICAL COMPOSITION OF NICKEL & NICKEL ALLOY - WELD FILLER METALS (Continued) |                                                                                                                                                  |
|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                                            | Chemical Composition                                                                                                                             |
| W80004                                                                         | Ni rem C 0.12 max Co 2.5 max Cr 2.5-5.5 Cu 0.50 max Fe 4.0-7.0 Mn 1.0 max Mo 23.0-27.0 P 0.04 max S 0.03 max Si 1.0 max V 0.60 max W 1.0 max     |
| W80276                                                                         | Ni rem C 0.02 max Co 2.5 max Cr 14.5-16.5 Cu 0.50 max Fe 4.0-7.0 Mn 1.0 max Mo 15.0-17.0 P 0.04 max S 0.03 max Si 0.2 max V 0.35 max W 3.0-4.5   |
| W80665                                                                         | Ni rem C 0.02 max Co 1.0 max Cr 1.0 max Cu 0.50 max Fe 2.0 max Mn 1.75 max Mo 26.0-30.0 P 0.04 max S 0.03 max Si 0.2 max W 1.0 max               |
| W82001                                                                         | Ni 85.00 min Al 1.0 max C 2.00 max Cu 2.50 max Fe 8.0 max Mn 2.5 max S 0.03 max Si 4.00 max Other 1.0 max total                                  |
| W82002                                                                         | Ni 45.0-60.0 Al 1.0 max C 2.00 max Cu 2.50 max Fe rem Mn 2.5 max S 0.03 max Si 4.00 max Other 1.0 max total                                      |
| W82003                                                                         | Ni 85.0 min Al 1.00-3.00 C 2.00 max Cu 2.50 max Fe 8.00 max Mn 2.5 max S 0.03 max Si 4.00 max Other 1.0 max total                                |
| W82004                                                                         | Ni 45.0-60.0 Al 1.00-3.00 C 2.00 max Cu 2.50 max Fe rem Mn 2.5 max S 0.03 max Si 4.0 max Other 1.0 max total                                     |
| W82006                                                                         | Ni 35.0-45.0 Al 1.0 max C 2.0 max Cu 2.5 max Fe rem Mn 10.0-14.0 S 0.03 max Si 1.0 max Other 1.0 max total                                       |
| W82032                                                                         | Ni 45.0-60.0 Al 1.0 max C 2.0 max Cu 2.5 max Fe rem Mn 3.0-5.0 S 0.03 max Si 1.0 max Other 1.0 max total                                         |
| W82141                                                                         | Ni 92.0 min Al 1.0 max C 0.10 max Cu 0.25 max Fe 0.75 max Mn 0.75 max P 0.03 max S 0.02 max Si 1.25 max Ti 1.0-4.0                               |
| W83002                                                                         | Ni rem C 2.2-3.0 Cr 25.0-30.0 Co 10.0-15.0 Fe 20.0-25.0 Mn 1.0 max Mo 7.0-10.0 Si 0.60-1.5 W 2.0-4.0                                             |
| W84001                                                                         | Ni 50.0-60.0 C 0.35-0.55 Cu 35.0-45.0 Fe 3.0-6.0 Mn 2.25 max S 0.025 max Si 0.75 max Other 1.0 max total                                         |
| W84002                                                                         | Ni 60.0-70.0 C 0.35-0.55 Cu 25.0-35.0 Fe 3.0-6.0 Mn 2.25 max S 0.025 max Si 0.75 max Other 1.0 max total                                         |
| W84190                                                                         | Ni 62.0-68.0 Al 0.50 max C 0.15 max Cu rem Fe 2.5 max Mn 4.0 max P 0.02 max S 0.015 max Si 1.5 max Ti 1.0 max                                    |
| W86002                                                                         | Ni rem C 0.05-0.15 Co 0.50-2.50 Cr 20.5-23.0 Cu 0.50 max Fe 17.0-20.0 Mn 1.0 max Mo 8.0-10.0 P 0.04 max S 0.03 max Si 1.0 max W 0.20-1.0         |
| W86003                                                                         | Ni 71.0 min C 0.15 max Cb 1.0-2.2 includes Ta, Co 1.0 max Cr 18.0-21.0 Fe 4.0 max Mn 1.50 max S 0.015 max Si 0.75 max                            |
| W86007                                                                         | Ni rem C 0.05 max Cb 1.75-2.50 Co 2.5 max Cr 21.0-23.5 Cu 1.5-2.5 Fe 18.0-21.0 Mn 1.0-2.0 Mo 5.5-7.5 P 0.04 max S 0.03 max Si 1.0 max W 1.0 max  |
| W86022                                                                         | Ni rem C 0.02 max Co 2.5 max Cr 20.0-22.5 Cu 0.50 max Fe 2.0-6.0 Mn 1.0 max Mo 12.5-14.5 P 0.03 max S 0.015 max Si 0.2 max V 0.35 W 2.5-3.5      |
| W86030                                                                         | Ni rem C 0.03 max Cb 0.30-1.50 Co 5.0 max Cr 28.0-31.5 Cu 1.0-2.4 Fe 13.0-17.0 Mn 1.5 max Mo 4.0-6.0 P 0.04 max S 0.02 max Si 1.0 max Ti 1.5-4.0 |
| W86040                                                                         | Ni rem C 0.03 max Cr 20.5-22.5 Cb 1.0-2.8 Cu 0.50 max Fe 5.0 max Mn 2.2 max Mo 8.8-10.0 P 0.03 max S 0.02 max Si 0.7 max Other 0.50 max total    |
| W86082                                                                         | Ni 67.0 min C 0.10 max Cr 18.0-22.0 Cb 2.0-3.0 Cu 0.50 max Fe 3.0 max Mn 2.5-3.5 P 0.03 max S 0.015 max Si 0.50 max Ti 0.75 max                  |

| CHEMICAL COMPOSITION OF NICKEL & NICKEL ALLOY - WELD FILLER METALS (Continued) |                                                                                                                                                                                 |
|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                                            | Chemical Composition                                                                                                                                                            |
| W86112                                                                         | Ni 55.0 min C 0.10 max Cb 3.15-4.15 includes Ta, Co 0.12 max Cr 20.0-23.0 Cu 0.50 max Fe 7.0 max Mn 1.0 max Mo 8.0-10.0 P 0.03 max S 0.02 max Si 0.75 max                       |
| W86117                                                                         | C 0.05-0.15 Cb+Ta 1.0 max Co 9.0-15.0 Cr 21.0-26.0 Cu 0.50 max Fe 5.0 max Mn 0.30-2.5 Mo 8.0-10.0 Ni rem P 0.03 max S 0.015 max Si 0.75 max                                     |
| W86130                                                                         | Ni 66.0 min Al 0.1-1.0 C 0.25 max Cb 4xSi min includes Ta, Co 1.0 max Cr 12.5-17.0 Fe 11.0 max Mn 1.0 max S 0.015 max Si 1.0 max Ti 1.0-2.75                                    |
| W86132                                                                         | Ni 62.0 min C 0.08 max Cb 1.5-4.0 includes Ta, Cr 13.0-17.0 Cu 0.50 max Fe 11.0 max Mn 3.5 max P 0.03 max S 0.02 max Si 0.75 max                                                |
| W86133                                                                         | Ni 62.0 min C 0.10 max Cb 0.5-3.0 includes Ta, Cr 13.0-17.0 Cu 0.50 max Fe 12.0 max Mn 1.0-3.5 Mo 0.50-2.50 P 0.03 max S 0.02 max Si 0.75 max                                   |
| W86134                                                                         | Ni 60.0 min C 0.20 max Cb 1.0-3.5 includes Ta, Cr 13.0-17.0 Cu 0.50 max Fe 12.0 max Mn 1.0-3.5 Mo 1.0-3.5 P 0.03 max S 0.02 max Si 1.0 max                                      |
| W86182                                                                         | Ni 59.0 min C 0.10 max Cb 1.0-2.5 includes Ta, Cr 13.0-17.0 Cu 0.50 Fe 10.0 Mn 5.0-9.5 P 0.03 max S 0.015 Si 1.0 max Ti 1.0 max                                                 |
| W86333                                                                         | Ni 44.0-47.0 C 0.08 max Co 2.50-4.00 Cr 24.0-27.0 Fe rem Mn 2.00 max Mo 2.50-4.00 P 0.030 max S 0.030 max Si 0.75-1.50 W 2.50-4.00                                              |
| W86455                                                                         | Ni rem C 0.015 max Co 2.0 max Cr 14.0-18.0 Cu 0.50 max Fe 3.0 max Mn 1.5 max Mo 14.0-17.0 P 0.04 max S 0.03 max Si 0.2 max Ti 0.7 max W 0.5 max                                 |
| W86620                                                                         | Ni 55.0 min C 0.10 max Cb 0.5-2.0 includes Ta, Cr 12.0-17.0 Cu 0.50 max Fe 10.0 max Mn 2.0-4.0 Mo 5.0-9.0 P 0.03 max S 0.02 max Si 1.0 max W 1.0-2.0                            |
| W86985                                                                         | Ni rem C 0.02 max Cb 0.5 max includes Ta, Co 5.0 max Cr 21.0-23.5 Cu 1.5-2.5 Fe 18.0-21.0 Mn 1.0 max Mo 6.0-8.0 P 0.04 max S 0.03 max Si 1.0 max W 1.5 max                      |
| W87718                                                                         | Ni 50.0-55.0 Al 0.20-0.80 B 0.006 max C 0.08 max Cr 17.0-21.0 Co 1.0 max Cb 4.75-5.5 Cu 0.30 max Fe rem Mn 0.50 max Mo 2.8-3.3 P 0.015 max S 0.015 max Si 0.75 max Ti 0.65-1.15 |
| W88021                                                                         | Ni 32.0-36.0 C 0.07 max Cb 8xC-1.00 includes Ta, Cr 19.0-21.0 Cu 3.0-4.0 Mn 0.5-2.5 Mo 2.0-3.0 P 0.04 S 0.03 Si 0.60                                                            |
| W88022                                                                         | Ni 32.0-36.0 C 0.03 max Cb 8xC-0.40 includes Ta, Cr 19.0-21.0 Cu 3.0-4.0 Mn 1.50-2.50 Mo 2.0-3.0 P 0.020 max S 0.015 max Si 0.30 max                                            |
| W88028                                                                         | Ni 30.0-33.0 C 0.03 max Cr 26.5-29.0 Cu 0.60-1.50 Mn 0.50-2.50 Mo 3.20-4.20 P 0.02 max S 0.02 max Si 0.90 max                                                                   |
| W88331                                                                         | Ni 33.0-37.0 C 0.18-0.25 Cr 14.0-17.0 Cu 0.75 max Mn 1.0-2.5 Mo 0.75 max P 0.04 max S 0.03 max Si 0.90 max                                                                      |
| W88334                                                                         | Ni 33.0-37.0 C 0.18-0.29 Cr 17.0-20.0 Cu 0.5 max Fe rem Mn 4.25-6.5 Mo 0.7 max P 0.03 max S 0.02 max Si 0.7-1.3                                                                 |
| W88335                                                                         | Ni 33.0-37.0 C 0.35-0.45 Cr 14.0-17.0 Cu 0.75 max Mn 1.0-2.5 Mo 0.50 max P 0.04 max S 0.03 max Si 0.90 max                                                                      |
| W88338                                                                         | Ni 33.0-37.0 C 0.75-0.95 Cr 17.0-20.0 Fe rem Mn 2.50 max P 0.03 max S 0.03 max Si 0.65-1.3 max                                                                                  |
| W88904                                                                         | Ni 24.0-26.0 C 0.03 Cr 19.0-21.5 Cu 1.2-2.0 Mn 1.0-2.5 Mo 4.0-5.2 P 0.03 S 0.02 Si 0.90                                                                                         |

| <b>CHEMICAL COMPOSITION OF NICKEL &amp; NICKEL ALLOY - WELD FILLER METALS (Continued)</b> |                                                                                   |
|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| <b>UNS</b>                                                                                | <b>Chemical Composition</b>                                                       |
| W89604                                                                                    | Ni rem B 2.00-3.00 C 0.30-0.60 Co 1.50 max Cr 8.0-14.0 Fe 1.25-3.25 Si 1.25-3.25  |
| W89605                                                                                    | Ni rem B 2.00-4.00 C 0.40-0.80 Co 1.25 max Cr 10.0-16.0 Fe 3.00-5.00 Si 3.00-5.00 |
| W89606                                                                                    | Ni rem B 2.50-4.50 C 0.50-1.00 Co 1.00 max Cr 12.0-18.0 Fe 3.50-5.50 Si 3.50-5.50 |

See Common Names & Cross Referenced Specifications - Nickel & Nickel Alloys - Weld Filler Metals (page 264) for UNS cross references to AWS and ASME specifications. rem - remainder; nom - nominal

| <b>MECHANICAL PROPERTIES OF NICKEL</b>       |            |                  |                              |                         |            |                       |            |             |
|----------------------------------------------|------------|------------------|------------------------------|-------------------------|------------|-----------------------|------------|-------------|
| <b>ASTM Spec.</b>                            | <b>UNS</b> | <b>Condition</b> | <b>Size OD</b>               | <b>Tensile Strength</b> |            | <b>Yield Strength</b> |            | <b>% El</b> |
|                                              |            |                  |                              | <b>ksi</b>              | <b>MPa</b> | <b>Ksi</b>            | <b>MPa</b> |             |
| B 161<br>Pipe                                | N02200     | Annealed         | ≤5 in (127 mm)               | 55                      | 380        | 15                    | 105        | 35          |
|                                              |            | Annealed         | >5 in (127 mm)               | 55                      | 380        | 12                    | 80         | 40          |
|                                              |            | Stress Relieved  | all sizes                    | 65                      | 450        | 40                    | 275        | 15          |
|                                              | N02201     | Annealed         | ≤5 in (127 mm)               | 50                      | 345        | 12                    | 80         | 35          |
|                                              |            | Annealed         | >5 in (127 mm)               | 50                      | 345        | 10                    | 70         | 40          |
|                                              |            | Stress Relieved  | all sizes                    | 60                      | 415        | 30                    | 205        | 15          |
| <b>ASTM Spec.</b>                            | <b>UNS</b> | <b>Condition</b> | <b>Thickness<sup>b</sup></b> | <b>ksi</b>              | <b>MPa</b> | <b>Ksi</b>            | <b>MPa</b> | <b>% El</b> |
| B 162<br>Plate, Sheet,<br>Strip <sup>a</sup> | N02200     | Annealed         | over 0.109                   | 55                      | 380        | 15                    | 100        | 40          |
|                                              |            | Annealed         | 0.010-0.049                  | 55                      | 380        | 15                    | 100        | 30          |
|                                              |            | Annealed         | 0.050-0.109                  | 55                      | 380        | 15                    | 100        | 35          |
|                                              | N02201     | Annealed         | over 0.109                   | 50                      | 345        | 12                    | 80         | 40          |
|                                              |            | Annealed         | 0.010-0.049                  | 50                      | 345        | 12                    | 80         | 30          |
|                                              |            | Annealed         | 0.050-0.109                  | 50                      | 345        | 12                    | 80         | 35          |

a. Plate - hot-rolled; sheet - hot and cold-rolled; strip - cold-rolled. b. Applies to sheet and strip only, no thickness limitations on plate. Single values are minimum specified.

| MECHANICAL PROPERTIES OF NICKEL & NICKEL ALLOYS - TUBING & PIPING |        |        |                        |                  |     |                |     |      |                  |
|-------------------------------------------------------------------|--------|--------|------------------------|------------------|-----|----------------|-----|------|------------------|
| ASTM Spec.                                                        | Form   | UNS    | Condition <sup>a</sup> | Tensile Strength |     | Yield Strength |     | % El | Hardness HRB max |
|                                                                   |        |        |                        | ksi              | MPa | Ksi            | MPa |      |                  |
| B 163                                                             | ST     | N02200 | Annealed               | 55               | 379 | 15             | 103 | 40   | ---              |
|                                                                   |        | N02200 | Stress relieved        | 65               | 448 | 40             | 276 | 15   | 65               |
|                                                                   |        | N02201 | Annealed               | 50               | 345 | 12             | 83  | 40   | ---              |
|                                                                   |        | N02201 | Stress relieved        | 60               | 414 | 30             | 207 | 15   | 62               |
|                                                                   |        | N04400 | Annealed               | 70               | 483 | 28             | 193 | 35   | ---              |
|                                                                   |        | N04400 | Stress relieved        | 85               | 586 | 55             | 379 | 15   | 75               |
|                                                                   |        | N06600 | Annealed               | 80               | 552 | 35             | 241 | 30   | ---              |
|                                                                   |        | N06690 | Annealed               | 85               | 586 | 35             | 241 | 30   | ---              |
|                                                                   |        | N08800 | Annealed               | 75               | 517 | 30             | 207 | 30   | ---              |
|                                                                   |        | N08801 | Annealed               | 65               | 448 | 25             | 172 | 30   | ---              |
|                                                                   |        | N08800 | Annealed               | 83               | 572 | 47             | 324 | 30   | ---              |
|                                                                   |        | N08810 | Annealed               | 65               | 448 | 25             | 172 | 30   | ---              |
|                                                                   |        | N08825 | Annealed               | 85               | 586 | 35             | 241 | 30   | ---              |
| B 167                                                             | SP, ST | N06601 | Annealed               | 80               | 550 | 30             | 205 | 30   | ---              |
| B 444                                                             | P, T   | N06625 | gr 1 Annealed          | 120              | 827 | 60             | 414 | 30   | ---              |
|                                                                   |        | N06625 | gr 2 Solution-annealed | 100              | 690 | 40             | 276 | 30   | ---              |
| B 464                                                             | WP     | N08020 | Stabilized-annealed    | 80               | 551 | 35             | 241 | 30   | ---              |
|                                                                   |        | N08024 | Annealed               | 80               | 551 | 35             | 241 | 30   | ---              |
|                                                                   |        | N08026 | Solution-annealed      | 80               | 551 | 35             | 241 | 30   | ---              |
| B 517                                                             | WP     | N06600 | ---                    | 80               | 550 | 35             | 240 | 30   | ---              |
| B 535                                                             | SP     | N08330 | Annealed               | 70               | 483 | 30             | 207 | 30   | 70-90            |
|                                                                   |        | N08332 | Annealed               | 67               | 462 | 27             | 186 | 30   | 65-88            |
| B 619                                                             | WP,    | N10001 | ---                    | 100              | 690 | 45             | 310 | 40   | ---              |
| B 626                                                             | WT     | N06002 | ---                    | 100              | 690 | 40             | 276 | 35   | ---              |

| MECHANICAL PROPERTIES OF NICKEL & NICKEL ALLOYS - TUBING & PIPING (Continued) |      |        |                        |                  |     |                |     |      |                  |
|-------------------------------------------------------------------------------|------|--------|------------------------|------------------|-----|----------------|-----|------|------------------|
| ASTM Spec.                                                                    | Form | UNS    | Condition <sup>a</sup> | Tensile Strength |     | Yield Strength |     | % El | Hardness HRB max |
|                                                                               |      |        |                        | ksi              | MPa | Ksi            | MPa |      |                  |
| B 626<br>(con't)                                                              | WT   | N06007 | ---                    | 90               | 621 | 35             | 241 | 35   | ---              |
|                                                                               |      | N06022 | ---                    | 100              | 690 | 45             | 310 | 45   | ---              |
|                                                                               |      | N06030 | ---                    | 85               | 586 | 35             | 241 | 30   | ---              |
|                                                                               |      | N06059 | ---                    | 100              | 690 | 45             | 310 | 45   | ---              |
|                                                                               |      | N06230 | ---                    | 110              | 760 | 45             | 310 | 40   | ---              |
|                                                                               |      | N06455 | ---                    | 100              | 690 | 40             | 276 | 40   | ---              |
|                                                                               |      | N06975 | ---                    | 85               | 586 | 32             | 221 | 40   | ---              |
|                                                                               |      | N06985 | ---                    | 90               | 621 | 35             | 241 | 45   | ---              |
|                                                                               |      | N08031 | ---                    | 94               | 650 | 40             | 276 | 40   | ---              |
|                                                                               |      | N08320 | ---                    | 75               | 517 | 28             | 193 | 35   | ---              |
|                                                                               |      | N10276 | ---                    | 100              | 690 | 41             | 283 | 40   | ---              |
| B 622                                                                         | SP   | N10665 | ---                    | 110              | 760 | 51             | 352 | 40   | ---              |
|                                                                               |      | N06002 | ---                    | 100              | 690 | 40             | 276 | 35   | ---              |
|                                                                               |      | N06007 | ---                    | 90               | 621 | 35             | 241 | 35   | ---              |
|                                                                               |      | N06022 | ---                    | 100              | 690 | 45             | 310 | 45   | ---              |
|                                                                               |      | N06030 | ---                    | 85               | 586 | 35             | 241 | 30   | ---              |
|                                                                               |      | N06059 | ---                    | 100              | 690 | 45             | 310 | 45   | ---              |
|                                                                               |      | N06060 | ---                    | 90               | 621 | 35             | 241 | 40   | ---              |
|                                                                               |      | N06230 | ---                    | 110              | 760 | 45             | 310 | 40   | ---              |
|                                                                               |      | N06250 | ---                    | 90               | 621 | 35             | 241 | 40   | ---              |
|                                                                               |      | N06255 | ---                    | 85               | 586 | 32             | 221 | 40   | ---              |
|                                                                               |      | N06455 | ---                    | 100              | 690 | 40             | 276 | 40   | ---              |
|                                                                               |      | N06975 | ---                    | 85               | 586 | 32             | 221 | 40   | ---              |
|                                                                               |      | N06985 | ---                    | 90               | 621 | 35             | 241 | 40   | ---              |
|                                                                               |      | N08031 | ---                    | 94               | 650 | 40             | 276 | 40   | ---              |

| MECHANICAL PROPERTIES OF NICKEL & NICKEL ALLOYS - TUBING & PIPING (Continued) |      |        |                        |                  |     |                |     |      |                  |
|-------------------------------------------------------------------------------|------|--------|------------------------|------------------|-----|----------------|-----|------|------------------|
| ASTM Spec.                                                                    | Form | UNS    | Condition <sup>a</sup> | Tensile Strength |     | Yield Strength |     | % El | Hardness HRB max |
|                                                                               |      |        |                        | ksi              | MPa | Ksi            | MPa |      |                  |
| B 622<br>(con't)                                                              | SP   | N08135 | ---                    | 73               | 503 | 31             | 214 | 40   | ---              |
|                                                                               |      | N08320 | ---                    | 75               | 517 | 28             | 193 | 35   | ---              |
|                                                                               |      | N08535 | ---                    | 73               | 503 | 31             | 214 | 40   | ---              |
|                                                                               |      | N10001 | ---                    | 100              | 690 | 45             | 310 | 40   | ---              |
|                                                                               |      | N10276 | ---                    | 100              | 690 | 41             | 283 | 40   | ---              |
|                                                                               |      | N10665 | ---                    | 110              | 760 | 51             | 352 | 40   | ---              |

a. See specific ASTM Standard for specific details of heat treat condition. P - pipe, T - tube, SP- seamless pipe, ST - seamless tube, WP - welded pipe, WT - welded tube. Single values are minimum specified.

| MECHANICAL PROPERTIES OF NICKEL & NICKEL ALLOYS - PLATE SHEET & STRIP |            |        |                        |                  |     |                |     |                 |                  |
|-----------------------------------------------------------------------|------------|--------|------------------------|------------------|-----|----------------|-----|-----------------|------------------|
| ASTM Spec.                                                            | Form       | UNS    | Condition <sup>a</sup> | Tensile Strength |     | Yield Strength |     | % El            | Hardness HRB max |
|                                                                       |            |        |                        | ksi              | MPa | ksi            | MPa |                 |                  |
| B 127                                                                 | Pl, Sh, St | N04400 | Annealed               | 70               | 485 | 28             | 195 | 35              | ---              |
| B 162                                                                 | Pl, Sh, St | N02200 | Annealed               | 55               | 380 | 15             | 100 | 40 <sup>b</sup> | ---              |
|                                                                       |            | N02201 | Annealed               | 50               | 345 | 12             | 80  | 40 <sup>b</sup> | ---              |
| B 168                                                                 | Pl, Sh, St | N06600 | Annealed               | 80               | 550 | 35             | 240 | 30              | ---              |
|                                                                       |            | N06601 | Annealed               | 80               | 550 | 30             | 205 | 30              | ---              |
|                                                                       |            | N06617 | Annealed               | 95               | 655 | 35             | 240 | 30              | ---              |
|                                                                       |            | N06690 | Annealed               | 85               | 586 | 35             | 240 | 30              | ---              |
| B 333                                                                 | Sh, St     | N10001 | ---                    | 115              | 795 | 50             | 345 | 45              | 100 <sup>g</sup> |
|                                                                       |            | N10665 | ---                    | 110              | 758 | 51             | 352 | 40              | 100 <sup>g</sup> |
|                                                                       | Pl         | N10001 | ---                    | 100              | 690 | 45             | 310 | 40              | 100 <sup>g</sup> |
|                                                                       |            | N10665 | ---                    | 110              | 758 | 51             | 352 | 40              | 100 <sup>g</sup> |
| B 409                                                                 | Pl, Sh, St | N08800 | Annealed               | 75               | 520 | 30             | 205 | 30              | ---              |

| MECHANICAL PROPERTIES OF NICKEL & NICKEL ALLOYS - PLATE SHEET & STRIP (Continued) |                     |        |                        |                  |     |                |     |      |                  |
|-----------------------------------------------------------------------------------|---------------------|--------|------------------------|------------------|-----|----------------|-----|------|------------------|
| ASTM Spec.                                                                        | Form                | UNS    | Condition <sup>a</sup> | Tensile Strength |     | Yield Strength |     | % El | Hardness HRB max |
|                                                                                   |                     |        |                        | ksi              | MPa | ksi            | MPa |      |                  |
| B 409                                                                             | Pl, Sh, St          | N08810 | Annealed               | 65               | 450 | 25             | 170 | 30   | ---              |
|                                                                                   |                     | N08811 | Annealed               | 65               | 450 | 25             | 170 | 30   | ---              |
| B 424                                                                             | Pl, Sh, St          | N08825 | Annealed               | 85               | 586 | 35             | 241 | 30   | ---              |
|                                                                                   |                     | N08221 | Annealed               | 79               | 544 | 34             | 235 | 30   | ---              |
| B 434                                                                             | Pl, Sh, St          | N10003 | ---                    | 100              | 690 | 40             | 280 | 40   | ---              |
| B 435                                                                             | Pl, Sh, St          | N06002 | ---                    | 95               | 655 | 35             | 240 | 35   | ---              |
|                                                                                   |                     | N06230 | ---                    | 110              | 760 | 45             | 310 | 40   | ---              |
| B 443                                                                             | Sh, St              | N06625 | gr 1 Annealed - CR     | 120              | 827 | 60             | 414 | 30   | ---              |
|                                                                                   | Pl, Sh              | N06625 | gr 1 Annealed - HR     | 110              | 758 | 55             | 379 | 30   | ---              |
|                                                                                   | Pl                  | N06625 | gr 1 Annealed - CR     | 110              | 758 | 55             | 379 | 30   | ---              |
|                                                                                   | Pl, Sh, St          | N06625 | gr 2 Annealed          | 100              | 690 | 40             | 276 | 30   | ---              |
| B 463                                                                             | Pl, Sh, St          | N08020 | Stabilize-annealed     | 80               | 551 | 35             | 241 | 30   | 95 (217 HB)      |
|                                                                                   |                     | N08024 | Annealed               | 80               | 551 | 35             | 241 | 30   | 95 (217 HB)      |
|                                                                                   |                     | N08026 | Solution-annealed      | 80               | 551 | 35             | 241 | 30   | 95 (217 HB)      |
| B 575                                                                             | Pl, Sh, St          | N10276 | ---                    | 100              | 690 | 41             | 283 | 40   | 100 <sup>g</sup> |
|                                                                                   |                     | N06022 | ---                    | 100              | 690 | 45             | 310 | 45   | 100 <sup>g</sup> |
|                                                                                   |                     | N06455 | ---                    | 100              | 690 | 40             | 276 | 40   | 100 <sup>g</sup> |
|                                                                                   |                     | N06059 | ---                    | 100              | 690 | 45             | 310 | 45   | 100 <sup>g</sup> |
| B 582                                                                             | Pl <sup>c</sup>     | N06007 | Annealed               | 90               | 621 | 35             | 241 | 35   | 100 <sup>g</sup> |
|                                                                                   | Pl <sup>d</sup>     | N06007 | Annealed               | 85               | 586 | 30             | 207 | 30   | 100 <sup>g</sup> |
|                                                                                   | Sh, St <sup>e</sup> | N06007 | Annealed               | 90               | 621 | 35             | 241 | 40   | 100 <sup>g</sup> |
|                                                                                   | Pl, <sup>f</sup>    | N06975 | Annealed               | 85               | 586 | 32             | 221 | 40   | 100 <sup>g</sup> |
|                                                                                   | Sh, St <sup>e</sup> | N06975 | Annealed               | 85               | 586 | 32             | 221 | 40   | 100 <sup>g</sup> |
|                                                                                   | Pl <sup>c</sup>     | N06985 | Annealed               | 90               | 621 | 35             | 241 | 45   | 100 <sup>g</sup> |

| MECHANICAL PROPERTIES OF NICKEL & NICKEL ALLOYS - PLATE SHEET & STRIP (Continued) |                 |        |                        |                  |     |                |     |      |                  |
|-----------------------------------------------------------------------------------|-----------------|--------|------------------------|------------------|-----|----------------|-----|------|------------------|
| ASTM Spec.                                                                        | Form            | UNS    | Condition <sup>a</sup> | Tensile Strength |     | Yield Strength |     | % El | Hardness HRB max |
|                                                                                   |                 |        |                        | ksi              | MPa | ksi            | MPa |      |                  |
| B 582<br>(con't)                                                                  | Pl <sup>d</sup> | N06985 | Annealed               | 85               | 586 | 30             | 207 | 30   | ---              |
|                                                                                   | Sh <sup>e</sup> | N06985 | Annealed               | 90               | 621 | 35             | 241 | 45   | 100 <sup>g</sup> |
|                                                                                   | Pl, Sh, St      | N06030 | Annealed               | 85               | 586 | 35             | 241 | 30   | ---              |
| B 620                                                                             | Pl, Sh, St      | N08320 | ---                    | 75               | 517 | 28             | 193 | 35   | 95 <sup>g</sup>  |

a. See specific ASTM Standard for specific details of heat treat condition. CR - cold-rolled; HR - hot-rolled.

b. Sheet and strip 0.010 to 0.49 in (0.25 to 1.2 mm), inclusive, in thickness requires an elongation of 30% minimum; and thicknesses from 0.050 to 0.109 in (1.3 to 2.7 mm), inclusive, requires an elongation of 35% minimum.

c. Thickness from  $\frac{3}{16}$  to  $\frac{3}{4}$  in (4.76 to 19.05 mm) inclusive.

d. Thickness over  $\frac{3}{4}$  to 2  $\frac{1}{2}$  in (19.05 to 63.5 mm) inclusive.

e. Thickness over 0.020 in (0.51 mm).

f. Thickness  $\frac{3}{16}$  to 2  $\frac{1}{2}$  in (4.76 to 63.5 mm) inclusive.

g. For information purpose only, not to be used as a basis for rejection or acceptance.

Pl - plate, Sh - sheet, St - strip. Single values are minimum specified.

| MECHANICAL PROPERTIES OF NICKEL ALLOYS - FLANGES, FORGED FITTINGS & VALVE PARTS |            |        |                        |                  |     |                |     |      |      |
|---------------------------------------------------------------------------------|------------|--------|------------------------|------------------|-----|----------------|-----|------|------|
| ASTM Spec.                                                                      | Form       | UNS    | Condition <sup>a</sup> | Tensile Strength |     | Yield Strength |     | % El | % RA |
|                                                                                 |            |        |                        | ksi              | MPa | ksi            | MPa |      |      |
| B 462                                                                           | Fl, FFt, V | N08020 | Stabilized-annealed    | 80               | 551 | 35             | 214 | 30.0 | 50.0 |
|                                                                                 |            | N08024 | Annealed               | 80               | 551 | 35             | 214 | 30.0 | 50.0 |
|                                                                                 |            | N08026 | Solution-annealed      | 80               | 551 | 35             | 214 | 30.0 | 50.0 |
|                                                                                 |            | N08367 | Solution-annealed      | 95               | 655 | 45             | 310 | 30.0 | 50.0 |

a. See specific ASTM Standard for specific details of heat treat condition.

Fl - flange, FFt - forged fitting, V - valve.

Single values are minimum specified.



| MECHANICAL PROPERTIES OF NICKEL ALLOYS - FORGINGS |        |                                         |                  |     |                |     |      |
|---------------------------------------------------|--------|-----------------------------------------|------------------|-----|----------------|-----|------|
| ASTM Spec.                                        | UNS    | Section Thickness max                   | Tensile Strength |     | Yield Strength |     | % El |
|                                                   |        |                                         | ksi              | MPa | ksi            | MPa |      |
| B 564                                             | N04400 | ---                                     | 70               | 483 | 25             | 172 | 35   |
|                                                   | N06022 | ---                                     | 100              | 690 | 45             | 310 | 45   |
|                                                   | N06059 | ---                                     | 100              | 690 | 45             | 310 | 45   |
|                                                   | N06110 | ≤ 4 in (102 mm)                         | 95               | 655 | 45             | 310 | 60   |
|                                                   | N06110 | > 4 - 10 in (102 - 254 mm) <sup>a</sup> | 90               | 621 | 40             | 276 | 50   |
|                                                   | N06230 | ---                                     | 110              | 758 | 45             | 310 | 40   |
|                                                   | N06600 | ---                                     | 80               | 552 | 35             | 241 | 30   |
|                                                   | N06617 | ---                                     | 95               | 655 | 35             | 241 | 35   |
|                                                   | N06625 | ≤ 4 in (102 mm)                         | 120              | 827 | 60             | 414 | 30   |
|                                                   | N06625 | > 4 - 10 in (102 - 254 mm) <sup>a</sup> | 110              | 758 | 50             | 345 | 25   |
|                                                   | N08031 | ---                                     | 94               | 650 | 40             | 276 | 40   |
|                                                   | N08367 | ---                                     | 95               | 655 | 45             | 310 | 30   |
|                                                   | N08800 | ---                                     | 75               | 517 | 30             | 207 | 30   |
|                                                   | N08810 | ---                                     | 65               | 448 | 25             | 172 | 30   |
|                                                   | N08825 | ---                                     | 85               | 586 | 35             | 241 | 30   |
|                                                   | N10276 | ---                                     | 100              | 690 | 41             | 283 | 40   |

a. Over 4 to 10 in (102 to 254 mm) diameter for parts machined from forged bar.  
Single values are minimum specified.

| MECHANICAL PROPERTIES OF NICKEL & NICKEL ALLOYS - RODS & BARS |        |           |                                                           |                  |     |                |     |                 |
|---------------------------------------------------------------|--------|-----------|-----------------------------------------------------------|------------------|-----|----------------|-----|-----------------|
| ASTM Spec.                                                    | UNS    | Condition | Thickness or Diameter                                     | Tensile Strength |     | Yield Strength |     | % El            |
|                                                               |        |           |                                                           | ksi              | MPa | ksi            | MPa |                 |
| B 160                                                         | N02200 | Annealed  | All sizes                                                 | 55               | 380 | 15             | 105 | 40 <sup>a</sup> |
|                                                               | N02201 | Annealed  | All sizes                                                 | 55               | 345 | 10             | 70  | 40 <sup>a</sup> |
| B 164                                                         | N04400 | Annealed  | All sizes                                                 | 70               | 480 | 25             | 170 | 35              |
|                                                               | N04405 | Annealed  | All sizes                                                 | 70               | 480 | 25             | 170 | 35              |
| B 166                                                         | N06600 | Annealed  | All sizes                                                 | 80               | 550 | 35             | 240 | 30 <sup>a</sup> |
|                                                               | N06601 | Annealed  | All sizes                                                 | 80               | 550 | 30             | 205 | 30              |
|                                                               | N06617 | Annealed  | All sizes                                                 | 95               | 655 | 35             | 240 | 30              |
|                                                               | N06690 | Annealed  | All sizes                                                 | 85               | 586 | 35             | 240 | 30 <sup>a</sup> |
| B 335                                                         | N10001 | n/s       | $\frac{5}{16}$ -1 $\frac{1}{2}$ in (7.94-38.1 mm) incl    | 115              | 795 | 46             | 315 | 35              |
|                                                               | N10001 | n/s       | > 1 $\frac{1}{2}$ -3 $\frac{1}{2}$ in (38.1-88.9 mm) incl | 100              | 690 | 46             | 315 | 30              |
|                                                               | N10665 | n/s       | $\frac{5}{16}$ -3 $\frac{1}{2}$ in (7.94-88.9 mm) incl    | 110              | 758 | 51             | 352 | 40              |
| B 408                                                         | N08800 | Annealed  | All sizes                                                 | 75               | 515 | 30             | 205 | 30              |
|                                                               | N08810 | Annealed  | All sizes                                                 | 65               | 450 | 25             | 170 | 30              |
|                                                               | N08811 | Annealed  | All sizes                                                 | 65               | 450 | 25             | 170 | 30              |
| B 425                                                         | N08825 | Annealed  | All sizes                                                 | 85               | 586 | 35             | 241 | 30 <sup>a</sup> |
|                                                               | N08221 | Annealed  | All sizes                                                 | 79               | 544 | 34             | 235 | 30              |
| B 446                                                         | N06625 | Annealed  | Grade 1, $\leq$ 4 in (102 mm)                             | 120              | --- | 60             | --- | 30              |
|                                                               | N06625 | Annealed  | Grade 1, > 4 - 10 in (102 - 254 mm)                       | 110              | --- | 50             | --- | 25              |
|                                                               | N06625 | SA        | Grade 2, All sizes                                        | 100              | --- | 40             | --- | 30              |
| B 511                                                         | N08330 | Annealed  | All sizes                                                 | 70               | 483 | 30             | 207 | 30              |
|                                                               | N08332 | Annealed  | All sizes                                                 | 67               | 462 | 27             | 186 | 30              |
| B 573                                                         | N10003 | n/s       | All sizes                                                 | 100              | 689 | 40             | 276 | 35              |
| B 574                                                         | N10276 | n/s       | All sizes                                                 | 100              | 690 | 41             | 283 | 40              |
|                                                               | N06022 | n/s       | All sizes                                                 | 100              | 690 | 45             | 310 | 45              |

| MECHANICAL PROPERTIES OF NICKEL & NICKEL ALLOYS - RODS & BARS (Continued) |        |           |                                                           |                  |     |                |     |                 |
|---------------------------------------------------------------------------|--------|-----------|-----------------------------------------------------------|------------------|-----|----------------|-----|-----------------|
| ASTM Spec.                                                                | UNS    | Condition | Thickness or Diameter                                     | Tensile Strength |     | Yield Strength |     | % El            |
|                                                                           |        |           |                                                           | ksi              | MPa | ksi            | MPa |                 |
| B574                                                                      | N06455 | n/s       | All sizes                                                 | 100              | 690 | 40             | 276 | 40              |
|                                                                           | N06059 | n/s       | All sizes                                                 | 100              | 690 | 45             | 310 | 45              |
| B581                                                                      | N06007 | n/s       | $\frac{5}{16}$ - $\frac{3}{4}$ in (7.94-19.05 mm) incl    | 90               | 621 | 35             | 241 | 35              |
|                                                                           | N06007 | n/s       | $> \frac{3}{4}$ - $3 \frac{1}{2}$ in (19.05-88.9 mm) incl | 85               | 586 | 30             | 207 | 30              |
|                                                                           | N06975 | n/s       | $\frac{5}{16}$ - $3 \frac{1}{2}$ in (7.94-88.9 mm) incl   | 85               | 586 | 32             | 221 | 40              |
|                                                                           | N06985 | n/s       | $\frac{5}{16}$ - $\frac{3}{4}$ (7.9-19.05 mm) incl        | 90               | 621 | 35             | 241 | 45              |
|                                                                           | N06985 | n/s       | $> \frac{3}{4}$ - $3 \frac{1}{2}$ in (19.05-88.9 mm) incl | 85               | 586 | 30             | 207 | 35              |
|                                                                           | N06030 | n/s       | All sizes                                                 | 85               | 586 | 35             | 241 | 30              |
| B 621                                                                     | N08320 | n/s       | All sizes                                                 | 75               | 517 | 28             | 193 | 35              |
| B 672                                                                     | N08700 | Annealed  | All sizes                                                 | 80               | 551 | 35             | 241 | 30 <sup>b</sup> |

a. Not applicable to diameters or cross sections under 3/32 in (2.4 mm). b. Also includes reduction of area 50.0% minimum.

n/s - not specified. SA - Solution Annealed, see ASTM B 446 for heat treatment details.

| MECHANICAL PROPERTIES OF NICKEL ALLOYS - WIRES <sup>a</sup> |        |                |                                 |                  |     |                |     |      |
|-------------------------------------------------------------|--------|----------------|---------------------------------|------------------|-----|----------------|-----|------|
| ASTM Spec.                                                  | UNS    | Condition      | Size                            | Tensile Strength |     | Yield Strength |     | % El |
|                                                             |        |                |                                 | ksi              | MPa | ksi            | MPa |      |
| B 164                                                       | N04400 | Annealed       | All sizes                       | 70               | 483 | 85             | 586 | ---  |
|                                                             | N04405 | Annealed       | All sizes                       | 70               | 483 | 85             | 586 | ---  |
|                                                             | N04400 | Regular temper | $< \frac{1}{2}$ in (12.7 mm)    | 110              | 758 | 140            | 965 | ---  |
|                                                             | N04400 | Regular temper | $\geq \frac{1}{2}$ in (12.7 mm) | 90               | 621 | 130            | 896 | ---  |
| B 166                                                       | N06600 | Annealed       | $< 0.032$ in (0.81 mm)          | 80               | 552 | 115            | 793 | ---  |
|                                                             | N06600 | Annealed       | $\geq 0.032$ (0.81 mm)          | 80               | 552 | 105            | 724 | ---  |
|                                                             | N06690 | Annealed       | $< 0.032$ in (0.81 mm)          | 80               | 552 | 115            | 793 | ---  |
|                                                             | N06690 | Annealed       | $\geq 0.032$ (0.81 mm)          | 80               | 552 | 105            | 724 | ---  |

| MECHANICAL PROPERTIES OF NICKEL ALLOYS - WIRES <sup>a</sup> (Continued) |        |           |           |                  |     |                |     |                   |
|-------------------------------------------------------------------------|--------|-----------|-----------|------------------|-----|----------------|-----|-------------------|
| ASTM                                                                    |        |           |           | Tensile Strength |     | Yield Strength |     |                   |
| Spec.                                                                   | UNS    | Condition | Size      | ksi              | MPa | ksi            | MPa | % El              |
| B 672                                                                   | N08700 | Annealed  | All sizes | 80               | 551 | 35             | 241 | 30.0 <sup>b</sup> |

a. Also includes a wrapping test. b. Also includes reduction of area 50.0% minimum.

| MECHANICAL PROPERTIES OF NICKEL & NICKEL ALLOYS - CASTINGS |                      |        |                        |                  |     |                |     |      |                      |
|------------------------------------------------------------|----------------------|--------|------------------------|------------------|-----|----------------|-----|------|----------------------|
| ASTM Spec.                                                 | Grade                | UNS    | Condition <sup>a</sup> | Tensile Strength |     | Yield Strength |     | % El | Hardness HB          |
|                                                            |                      |        |                        | ksi              | MPa | ksi            | MPa |      |                      |
| B 494                                                      | CZ-100               | N02100 | As cast                | 50               | 345 | 18             | 125 | 10.0 | ---                  |
|                                                            | M-35-1               | N24135 | As cast                | 65               | 450 | 25             | 170 | 25.0 | ---                  |
|                                                            | M-35-2               | ---    | As cast                | 65               | 450 | 30             | 205 | 25.0 | ---                  |
|                                                            | M-30H                | N24030 | As cast                | 100              | 690 | 60             | 415 | 10.0 | 243-294 <sup>d</sup> |
|                                                            | M-25S <sup>a</sup>   | N24025 | As cast <sup>b</sup>   | ---              | --- | ---            | --- | ---  | 300 min <sup>e</sup> |
|                                                            | M-30C                | N24130 | As cast                | 65               | 450 | 35.5           | 225 | 25.0 | 125-150 <sup>d</sup> |
|                                                            | N-12MV <sup>a</sup>  | N30012 | Solution-annealed      | 76               | 525 | 40             | 275 | 6.0  | ---                  |
|                                                            | N-7M <sup>a</sup>    | N30007 | Solution-annealed      | 76               | 525 | 40             | 275 | 20.0 | ---                  |
|                                                            | CY-40 <sup>a</sup>   | N06040 | As cast <sup>c</sup>   | 70               | 485 | 28             | 195 | 30.0 | ---                  |
|                                                            | CW-12MW <sup>a</sup> | N30002 | Solution-annealed      | 72               | 495 | 40             | 275 | 4.0  | ---                  |
|                                                            | CW-6M <sup>a</sup>   | N30107 | Solution-annealed      | 72               | 495 | 40             | 275 | 25.0 | ---                  |
|                                                            | CW-2M <sup>a</sup>   | N26455 | Solution-annealed      | 72               | 495 | 40             | 275 | 20.0 | ---                  |
|                                                            | CW-6MC               | N26625 | Solution-annealed      | 70               | 485 | 40             | 275 | 25.0 | ---                  |
|                                                            | CY5SnBiM             | N26055 | As cast                | ---              | --- | ---            | --- | ---  | ---                  |
|                                                            | CX2MW <sup>a</sup>   | N26022 | Solution-annealed      | 80               | 550 | 45             | 280 | 30.0 | ---                  |

a. See ASTM A 494 for details regarding class designation and heat treat requirements. b. M-25S class 1 - as cast; class 2 and class 3 see ASTM A494 for more details. c. CY-40 class 1 - as cast; CY-40 class 2 - solution-annealed, see ASTM A494 for more details. d. For information only, see ASTM A 494 for more details. e. Hardness of 300 HB minimum for the age hardened condition.

| ASME P-No. - BASE METAL NICKEL & NICKEL ALLOYS |                        |                        |                      |        |                     |                     |
|------------------------------------------------|------------------------|------------------------|----------------------|--------|---------------------|---------------------|
| ASME Spec.                                     | Condition <sup>a</sup> | Size or Thickness (in) | UTS ksi <sup>c</sup> | UNS    | Nominal Composition | Product Form        |
| <b>P No. 41</b>                                |                        |                        |                      |        |                     |                     |
| SB-160                                         | A                      | ---                    | 55                   | N02200 | 99.0Ni              | Rod, Bar            |
|                                                | HR                     | ---                    | 60                   | N02200 | 99.0Ni              | Rod, Bar            |
|                                                | CD                     | 1 and under            | 80                   | N02200 | 99.0Ni              | Rod, Bar            |
|                                                |                        | > 1-4                  | 75                   | N02200 | 99.0Ni              | Rod, Bar            |
|                                                |                        | All                    | 65                   | N02200 | 99.0Ni              | Square, etc.        |
|                                                | A                      | All                    | 50                   | N02201 | Low C-99.0Ni        | Rod, Bar            |
| SB-161                                         | HR                     | All                    | 50                   | N02201 | Low C-99.0Ni        | Rod, Bar            |
|                                                | A                      | ---                    | 55                   | N02200 | 99.0Ni              | Pipe, Tube          |
|                                                | SR                     | ---                    | 65                   | N02200 | 99.0Ni              | Pipe, Tube          |
|                                                | A                      | ---                    | 50                   | N02201 | Low C-99.0Ni        | Smls. Pipe & Tube   |
| SB-162                                         | SR                     | ---                    | 60                   | N02201 | Low C-99.0Ni        | Smls. Pipe & Tube   |
|                                                | A                      | ---                    | 55                   | N02200 | 99.0Ni              | Plate, Sheet, Strip |
|                                                | HR                     | ---                    | 55                   | N02200 | 99.0Ni              | Plate, Sheet, Strip |
|                                                | A                      | ---                    | 50                   | N02201 | Low C-99.0Ni        | Plate, Sheet, Strip |
| SB-163                                         | HR                     | ---                    | 50                   | N02201 | Low C-99.0Ni        | Plate, Sheet, Strip |
|                                                | A                      | ---                    | 55                   | N02200 | 99.0Ni              | Smls. Tube          |
|                                                | SR                     | ---                    | 65                   | N02200 | 99.0Ni              | Smls. Tube          |
|                                                | A                      | ---                    | 50                   | N02201 | Low C-99.0Ni        | Smls. Tube          |
| SB-163                                         | SR                     | ---                    | 60                   | N02201 | Low C-99.0Ni        | Smls. Tube          |
| <b>P No. 42</b>                                |                        |                        |                      |        |                     |                     |
| SB-127                                         | A                      | ---                    | 70                   | N04400 | 67Ni-30Cu           | Plate, Sheet, Strip |
|                                                | HR                     | ---                    | 75                   | N04400 | 67Ni-30Cu           | Plate, Sheet, Strip |
| SB-163                                         | A                      | ---                    | 70                   | N04400 | 67Ni-30Cu           | Smls. Tube          |
|                                                | SR                     | ---                    | 85                   | N04400 | 67Ni-30Cu           | Smls. Tube          |

| ASME P-No. - BASE METAL NICKEL & NICKEL ALLOYS (Continued) |                        |                        |                      |        |                     |                   |
|------------------------------------------------------------|------------------------|------------------------|----------------------|--------|---------------------|-------------------|
| ASME Spec.                                                 | Condition <sup>a</sup> | Size or Thickness (in) | UTS ksi <sup>c</sup> | UNS    | Nominal Composition | Product Form      |
| <b>P No. 42 (Continued)</b>                                |                        |                        |                      |        |                     |                   |
| SB-164                                                     | A                      | ---                    | 70                   | N04400 | 67Ni-30Cu           | Rod, Bar          |
|                                                            | HF                     | b                      | 80                   | N04400 | 67Ni-30Cu           | Rod, Bar          |
|                                                            | SR                     | Hex. over 2 1/8        | 75                   | N04400 | 67Ni-30Cu           | Rod, Bar          |
|                                                            |                        | 4-12 dia., incl.       | 80                   | N04400 | 67Ni-30Cu           | Rod, Bar          |
|                                                            |                        | > 12 dia.              | 75                   | N04400 | 67Ni-30Cu           | Rod, Bar          |
|                                                            | CD                     | < 1/2                  | 110                  | N04400 | 67Ni-30Cu           | Round             |
|                                                            |                        | < 1/2                  | 85                   | N04400 | 67Ni-30Cu           | Square, etc.      |
|                                                            | SR                     | < 1/2                  | 84                   | N04400 | 67Ni-30Cu           | Round             |
|                                                            |                        | 1/2-3 1/2, incl.       | 87                   | N04400 | 67Ni-30Cu           | Round             |
|                                                            |                        | > 3 1/2-4, incl.       | 84                   | N04400 | 67Ni-30Cu           | Round             |
|                                                            |                        | All                    | 84                   | N04400 | 67Ni-30Cu           | Square, etc.      |
| SB-165                                                     | A                      | ---                    | 70                   | N04400 | 67Ni-30Cu           | Smls. Pipe & Tube |
|                                                            | SR                     | ---                    | 85                   | N04400 | 67Ni-30Cu           | Smls. Pipe & Tube |
| SB-564                                                     | A                      | ---                    | 70                   | N04400 | 67Ni-30Cu           | Forging           |
| <b>P No. 43</b>                                            |                        |                        |                      |        |                     |                   |
| SB-163                                                     | A                      | ---                    | 80                   | N06600 | 72Ni-15Cr-8Fe       | Smls. Tube        |
|                                                            | A                      | ---                    | 85                   | N06690 | 58Ni-29Cr-9Fe       | Smls. Tube        |
| SB-166                                                     | A                      | ---                    | 80                   | N06600 | 72Ni-15Cr-8Fe       | Rod, Bar          |
|                                                            | HF                     | 1/4-3, incl.           | 90                   | N06600 | 72Ni-15Cr-8Fe       | Rod, Bar          |
|                                                            |                        | > 3 and hex.           | 85                   | N06600 | 72Ni-15Cr-8Fe       | Rod, Bar          |
|                                                            | A                      | ---                    | 85                   | N06690 | 58Ni-29Cr-9Fe       | Rod, Bar          |
|                                                            | HF                     | 1/4-3, incl.           | 90                   | N06690 | 58Ni-29Cr-9Fe       | Rod, Bar          |
|                                                            |                        | > 3 and hex.           | 85                   | N06690 | 58Ni-29Cr-9Fe       | Rod, Bar          |
|                                                            | CD/A                   | ---                    | 80                   | N06600 | 72Ni-15Cr-8Fe       | Smls. Pipe & Tube |

| ASME P-No. - BASE METAL NICKEL & NICKEL ALLOYS (Continued) |                        |                        |                      |        |                     |                     |
|------------------------------------------------------------|------------------------|------------------------|----------------------|--------|---------------------|---------------------|
| ASME Spec.                                                 | Condition <sup>a</sup> | Size or Thickness (in) | UTS ksi <sup>c</sup> | UNS    | Nominal Composition | Product Form        |
| <b>P No. 43 (Continued)</b>                                |                        |                        |                      |        |                     |                     |
| SB-167                                                     | HF                     | 5 and under            | 80                   | N06600 | 72Ni-15Cr-8Fe       | Smls. Pipe & Tube   |
|                                                            |                        | > 5 dia.               | 75                   | N06600 | 72Ni-15Cr-8Fe       | Smls. Pipe & Tube   |
|                                                            | HF/A                   | 5 dia. and under       | 80                   | N06600 | 72Ni-15Cr-8Fe       | Smls. Pipe & Tube   |
|                                                            |                        | > 5 dia.               | 75                   | N06600 | 72Ni-15Cr-8Fe       | Smls. Pipe & Tube   |
|                                                            | CD/A                   | ---                    | 85                   | N06690 | 58Ni-29Cr-9Fe       | Smls. Pipe & Tube   |
|                                                            | HF                     | ---                    | 85                   | N06690 | 58Ni-29Cr-9Fe       | Smls. Pipe & Tube   |
| SB-168                                                     | HF/A                   | ---                    | 85                   | N06690 | 58Ni-29Cr-9Fe       | Smls. Pipe & Tube   |
|                                                            | A                      | ---                    | 80                   | N06600 | 72Ni-15Cr-8Fe       | Plate, Sheet, Strip |
|                                                            | HR                     | ---                    | 85                   | N06600 | 72Ni-15Cr-8Fe       | Plate, Sheet, Strip |
|                                                            | A                      | ---                    | 85                   | N06690 | 58Ni-29Cr-9Fe       | Plate, Sheet, Strip |
| SB-435                                                     | A                      | ---                    | 85                   | N06690 | 58Ni-29Cr-9Fe       | Plate, Sheet, Strip |
|                                                            |                        | ---                    | 100                  | N06002 | 47Ni-22Cr-9Mo-18Fe  | Sheet, Strip        |
| SB-443                                                     | A                      | ---                    | 95                   | N06002 | 47Ni-22Cr-9Mo-18Fe  | Plate               |
|                                                            |                        | ---                    | 120                  | N06625 | 60Ni-22Cr-9Mo-3.5Cb | Plate, Sheet, Strip |
| SB-444                                                     | A                      | ---                    | 120                  | N06625 | 60Ni-22Cr-9Mo-3.5Cb | Smls. Pipe & Tube   |
| SB-446                                                     | A                      | ---                    | 120                  | N06625 | 60Ni-22Cr-9Mo-3.5Cb | Rod, Bar            |
| SB-516                                                     | A                      | ---                    | 80                   | N06600 | 72Ni-15Cr-8Fe       | Welded Tube         |
| SB-517                                                     | A                      | ---                    | 80                   | N06600 | 72Ni-15Cr-8Fe       | Welded Pipe         |
| SB-564                                                     | A                      | ---                    | 80                   | N06600 | 72Ni-15Cr-8Fe       | Forging             |
|                                                            | A                      | Up to 4, incl.         | 120                  | N06625 | 60Ni-22Cr-9Mo-3.5Cb | Forging             |
|                                                            | A                      | > 4-10, incl.          | 110                  | N06625 | 60Ni-22Cr-9Mo-3.5Cb | Forging             |
| SB-572                                                     | A                      | ---                    | 95                   | N06002 | 47Ni-22Cr-9Mo-18Fe  | Rod                 |
| SB-619                                                     | A                      | ---                    | 100                  | N06002 | 47Ni-22Cr-9Mo-18Fe  | Welded Pipe         |
| SB-622                                                     | A                      | ---                    | 100                  | N06002 | 47Ni-22Cr-9Mo-18Fe  | Smls. Pipe & Tube   |

| ASME P-No. - BASE METAL NICKEL & NICKEL ALLOYS (Continued) |                        |                        |                      |        |                            |                     |
|------------------------------------------------------------|------------------------|------------------------|----------------------|--------|----------------------------|---------------------|
| ASME Spec.                                                 | Condition <sup>a</sup> | Size or Thickness (in) | UTS ksi <sup>c</sup> | UNS    | Nominal Composition        | Product Form        |
| <b>P No. 43 (Continued)</b>                                |                        |                        |                      |        |                            |                     |
| SB-626                                                     | A                      | ---                    | 100                  | N06002 | 47Ni-22Cr-9Mo-18Fe         | Welded Tube         |
| SB-704                                                     | CW/A                   | ---                    | 120                  | N06625 | 60Ni-22Cr-9Mo-3.5Cb        | Welded Tube         |
| SB-705                                                     | CW/A                   | ---                    | 120                  | N06625 | 60Ni-22Cr-9Mo-3.5Cb        | Welded Pipe         |
| <b>P No. 44</b>                                            |                        |                        |                      |        |                            |                     |
| SB-333                                                     | A                      | < 3/16                 | 115                  | N10001 | 28Mo-5Fe                   | Sheet, Strip        |
|                                                            |                        | 3/4-2 1/2, incl.       | 100                  | N10001 | 28Mo-5Fe                   | Plate               |
|                                                            |                        | < 3/16                 | 110                  | N10665 | 28Mo                       | Sheet, Strip        |
|                                                            |                        | 3/16 -2 1/2, incl.     | 110                  | N10665 | 28Mo                       | Plate               |
| SB-335                                                     | A                      | 5/16-1 1/2, incl.      | 115                  | N10001 | 28Mo-5Fe                   | Rod                 |
|                                                            |                        | 1 1/2-3 1/2, incl.     | 100                  | N10001 | 28Mo-5Fe                   | Rod                 |
|                                                            | A                      | 5/16 -3 1/2, incl.     | 110                  | N10665 | 28Mo                       | Rod                 |
| SB-434                                                     | A                      | ---                    | 100                  | N10003 | 70Ni-16Mo-7Cr-5Fe          | Plate, Sheet, Strip |
| SB-564                                                     | ---                    | ---                    | 100                  | N10276 | Low C-16Mo-16Cr-5 1/2Fe    | Forging             |
| SB-573                                                     | A                      | ---                    | 100                  | N10003 | 70Ni-16Mo-7Cr-5Fe          | Rod                 |
| SB-574                                                     | A                      | ---                    | 100                  | N06455 | Low C-15.5Mo-16Cr          | Rod                 |
|                                                            | A                      | ---                    | 100                  | N10276 | Low C-16Mo-16Cr-5.5Fe      | Rod                 |
|                                                            | SA                     | ---                    | 100                  | N06022 | Low C-13.5Mo-21.5Cr-4Fe-3W | Rod                 |
| SB-575                                                     | A                      | ---                    | 100                  | N06455 | Low C-15.5Mo-16Cr          | Plate, Sheet, Strip |
|                                                            | A                      | ---                    | 100                  | N10276 | Low C-16Mo-16Cr-5.5Fe      | Plate, Sheet, Strip |
|                                                            | SA                     | ---                    | 100                  | N06022 | Low C-13.5Mo-21.5Cr-4Fe-3W | Plate, Sheet, Strip |
| SB-619                                                     | A                      | ---                    | 100                  | N06455 | Low C-15.5Mo-16Cr          | Welded Pipe         |
|                                                            | A                      | ---                    | 100                  | N10001 | 28Mo-5Fe                   | Welded Pipe         |
|                                                            | A                      | ---                    | 100                  | N10276 | Low C-16Mo-16Cr-5.5 Fe     | Welded Pipe         |
|                                                            | A                      | ---                    | 110                  | N10665 | 28Mo                       | Welded Pipe         |



| ASME P-No. - BASE METAL NICKEL & NICKEL ALLOYS (Continued) |                        |                        |                      |        |                            |                   |
|------------------------------------------------------------|------------------------|------------------------|----------------------|--------|----------------------------|-------------------|
| ASME Spec.                                                 | Condition <sup>a</sup> | Size or Thickness (in) | UTS ksi <sup>c</sup> | UNS    | Nominal Composition        | Product Form      |
| <b>P No. 44 (Continued)</b>                                |                        |                        |                      |        |                            |                   |
| SB-619                                                     | SA                     | ---                    | 100                  | N06022 | Low C-13.5Mo-21.5Cr-4Fe-3W | Welded Pipe       |
| SB-622                                                     | A                      | ---                    | 100                  | N06455 | Low C-15.5Mo-16Cr          | Smls. Pipe & Tube |
|                                                            | A                      | ---                    | 100                  | N10001 | 28Mo-5Fe                   | Smls. Pipe & Tube |
|                                                            | A                      | ---                    | 100                  | N10276 | Low C-16Mo-16Cr-5.5Fe      | Smls. Pipe & Tube |
|                                                            | A                      | ---                    | 110                  | N10665 | 28Mo                       | Smls. Pipe & Tube |
|                                                            | SA                     | ---                    | 100                  | N06022 | Low C-13.5Mo-21.5Cr-4Fe-3W | Smls. Pipe & Tube |
| SB-626                                                     | SA                     | ---                    | 100                  | N06455 | Low C-15.5Mo-16Cr          | Welded Tube       |
|                                                            | SA                     | ---                    | 100                  | N10001 | 28Mo-5Fe                   | Welded Tube       |
|                                                            | SA                     | ---                    | 100                  | N10276 | Low C-16Mo-16Cr-5.5Fe      | Welded Tube       |
|                                                            | SA                     | ---                    | 110                  | N10665 | 28Mo                       | Welded Tube       |
|                                                            | SA                     | ---                    | 100                  | N06022 | Low C-13.5Mo-21.5Cr-4Fe-3W | Welded Tube       |
| SB-710                                                     | A                      | ---                    | 70                   | N08330 | 35Ni-19Cr-1.25Si           | Welded Pipe       |
| <b>P No 45</b>                                             |                        |                        |                      |        |                            |                   |
| SB-163                                                     | A                      | ---                    | 75                   | N08800 | 33Ni-21Cr                  | Smls. Tube        |
|                                                            | A                      | ---                    | 65                   | N08810 | 33Ni-21Cr                  | Smls. Tube        |
|                                                            | A                      | ---                    | 85                   | N08825 | 42Ni-21.5Cr-3Mo-2.3Cu      | Smls. Tube        |
| SA-351                                                     |                        |                        |                      |        |                            |                   |
| Gr CN7M                                                    | ---                    | ---                    | 62                   | J95150 | 28Ni-19Cr-3Cu-2Mo          | Casting           |
| Gr CT15C                                                   | ---                    | ---                    | 63                   | ---    | 20Cr-32 ½Ni-Cb             | Casting           |
| SB-407                                                     | A                      | ---                    | 75                   | N08800 | 33Ni-21Cr                  | Smls. Pipe & Tube |
|                                                            | A                      | ---                    | 65                   | N08810 | 33Ni-21Cr                  | Smls. Pipe & Tube |
|                                                            | A                      | ---                    | 65                   | N08811 | 33Ni-21Cr-1Al+Ti           | Smls. Pipe & Tube |
| SB-408                                                     | A                      | ---                    | 75                   | N08800 | 33Ni-21Cr                  | Rod, Bar          |
|                                                            | A                      | ---                    | 65                   | N08810 | 33Ni-21Cr                  | Rod, Bar          |

| ASME P-No. - BASE METAL NICKEL & NICKEL ALLOYS (Continued) |                        |                        |                      |        |                                         |                     |
|------------------------------------------------------------|------------------------|------------------------|----------------------|--------|-----------------------------------------|---------------------|
| ASME Spec.                                                 | Condition <sup>a</sup> | Size or Thickness (in) | UTS ksi <sup>c</sup> | UNS    | Nominal Composition                     | Product Form        |
| <b>P No. 45 (Continued)</b>                                |                        |                        |                      |        |                                         |                     |
| SB-408                                                     | A                      | ---                    | 65                   | N08811 | 33Ni-21Cr-Al+Ti                         | Rod, Bar            |
| SB-409                                                     | A                      | ---                    | 75                   | N08800 | 33Ni-21Cr                               | Plate, Sheet, Strip |
|                                                            | A                      | ---                    | 65                   | N08810 | 33Ni-21Cr                               | Plate, Sheet, Strip |
|                                                            | A                      | ---                    | 65                   | N08811 | 33Ni-21Cr-Al+Ti                         | Plate, Sheet, Strip |
| SB 423                                                     | CD/A                   | ---                    | 85                   | N08825 | 42Ni-21.5Cr-3Mo-2.3Cu                   | Smls. Pipe & tube   |
|                                                            | HF/A                   | ---                    | 75                   | N08825 | 42Ni-21.5Cr-3Mo-2.3Cu                   | Smls. Pipe & tube   |
| SB-424                                                     | A                      | ---                    | 85                   | N08825 | 42Ni-21.5Cr-3Mo-2.3Cu                   | Plate, Sheet, Strip |
| SB-425                                                     | A                      | ---                    | 85                   | N08825 | 42Ni-21.5Cr-3Mo-2.3Cu                   | Rod, Bar            |
| SB-435                                                     | ---                    | ---                    | 100                  | R30556 | 22Cr-20.75Ni-18.5Co-3.25 Mo-2.75W-FeRem | Plate, Sheet, Strip |
| SB-462                                                     | A                      | ---                    | 80                   | N08020 | 35Ni-35Fe-20Cr-Cb                       | Forging             |
| SB-463                                                     | A                      | ---                    | 80                   | N08020 | 35Ni-35Fe-20Cr-Cb                       | Plate, Sheet, Strip |
|                                                            | A                      | ---                    | 80                   | N08026 | 35Ni-24Cr-5Mo-2Cu                       | Plate, Sheet, Strip |
| SB-464                                                     | A                      | ---                    | 80                   | N08020 | 35Ni-35Fe-20Cr-Cb                       | Smls. & Welded Pipe |
|                                                            | A                      | ---                    | 80                   | N08026 | 35Ni-24Cr-5Mo-2Cu                       | Welded Pipe         |
| SB-468                                                     | A                      | ---                    | 80                   | N08020 | 35Ni-35Fe-20Cr-Cb                       | Smls. & Welded Tube |
|                                                            | A                      | ---                    | 80                   | N08026 | 35Ni-24Cr-5Mo-2Cu                       | Welded Tube         |
| SB-473                                                     | A                      | ---                    | 80                   | N08020 | 35Ni-35Fe-20Cr-Cb                       | Bar                 |
| SB-514                                                     | A                      | ---                    | 75                   | N08800 | 33Ni-21Cr                               | Welded Pipe         |
|                                                            | A                      | ---                    | 65                   | N08810 | 33Ni-21Cr                               | Welded Pipe         |
| SB-515                                                     | A                      | ---                    | 75                   | N08800 | 33Ni-21Cr                               | Welded Pipe         |
|                                                            | A                      | ---                    | 65                   | N08810 | 33Ni-21Cr                               | Welded Pipe         |
| SB-564                                                     | A                      | ---                    | 75                   | N08800 | 33Ni-21Cr                               | Forging             |
|                                                            | A                      | ---                    | 65                   | N08810 | 33Ni-21Cr                               | Forging             |

| ASME P-No. - BASE METAL NICKEL & NICKEL ALLOYS (Continued) |                        |                                          |                      |        |                                        |                       |
|------------------------------------------------------------|------------------------|------------------------------------------|----------------------|--------|----------------------------------------|-----------------------|
| ASME Spec.                                                 | Condition <sup>a</sup> | Size or Thickness (in)                   | UTS ksi <sup>c</sup> | UNS    | Nominal Composition                    | Product Form          |
| <b>P No. 45 (Continued)</b>                                |                        |                                          |                      |        |                                        |                       |
| SB-572                                                     | ---                    | ---                                      | 100                  | R30556 | 22Cr-20.75Ni-18.5Co-3.25Mo-2.75W-FeRem | Rod                   |
| SB-581                                                     | A                      | $\frac{5}{16}$ - $\frac{3}{4}$ , incl.   | 90                   | N06007 | 22.3Cr-19.5Fe-6.5Mo-2Cu-2Cb            | Rod                   |
|                                                            |                        | > $\frac{3}{4}$ - $3\frac{1}{2}$         | 85                   | N06007 | 22.3Cr-19.5Fe-6.5Mo-2Cu-2Cb            | Rod                   |
|                                                            | A                      | $\frac{5}{16}$ - $3\frac{1}{2}$          | 85                   | N06975 | 49.5Ni-24.5Cr-6Mo-1Cu-1Ti              | Rod                   |
|                                                            |                        | $\frac{5}{16}$ - $\frac{3}{4}$ , incl.   | 90                   | N06985 | 22Cr-20Fe-7Mo-2Cu                      | Rod                   |
|                                                            | A                      | > $\frac{3}{4}$ - $3\frac{1}{2}$ , incl. | 85                   | N06985 | 22Cr-20Fe-7Mo-2Cu                      | Rod                   |
|                                                            | SA                     | ---                                      | 85                   | N06030 | 30Cr-15Fe-5Mo-2Cu                      | Rod                   |
| SB-582                                                     | A                      | > 0.020                                  | 90                   | N06007 | 22.3Cr-19.5Fe-6.5Mo-2Cu-2Cb            | Sheet & Strip         |
|                                                            |                        | $\frac{3}{16}$ - $\frac{3}{4}$ , incl.   | 90                   | N06007 | 22.3Cr-19.5Fe-6.5Mo-2Cu-2Cb            | Plate                 |
|                                                            |                        | > $\frac{3}{4}$ - $2\frac{1}{2}$ , incl. | 85                   | N06007 | 22.3Cr-19.5Fe-6.5Mo-2Cu-2Cb            | Plate                 |
|                                                            | A                      | $\frac{3}{16}$ - $2\frac{1}{2}$ , incl.  | 85                   | N06975 | 49.5Ni-24.5Cr-6Mo-1Cu-1Ti              | Plate                 |
|                                                            |                        | > 0.020                                  | 85                   | N06975 | 49.5Ni-24.5Cr-6Mo-1Cu-1Ti              | Sheet, Strip          |
|                                                            | A                      | $\frac{5}{16}$ - $\frac{3}{4}$ , incl.   | 90                   | N06985 | 22Cr-20Fe-7Mo-2Cu                      | Plate                 |
|                                                            |                        | > $\frac{3}{4}$ - $2\frac{1}{2}$ , incl. | 85                   | N06985 | 22Cr-20Fe-7Mo-2Cu                      | Plate                 |
|                                                            |                        | > 0.020                                  | 90                   | N06985 | 22Cr-20Fe-7Mo-2Cu                      | Sheet, Strip          |
|                                                            | SA                     | ---                                      | 85                   | N06030 | 30Cr-15Fe-5Mo-2Cu                      | Plate, Sheet, & Strip |
| SB-599                                                     | A                      | ---                                      | 80                   | N08700 | 25Ni-21Cr-4.5Mo-Cb                     | Plate, Sheet, & Strip |
| SB-619                                                     | A                      | ---                                      | 90                   | N06007 | 22.3Cr-19.5Fe-6.5Mo-2Cu-2Cb            | Welded Pipe           |
|                                                            |                        | ---                                      | 85                   | N06975 | 49.5Ni-24.5Cr-6Mo-1Cu-1Ti              | Welded Pipe           |
|                                                            |                        | ---                                      | 90                   | N06985 | 22Cr-20Fe-7Mo-2Cu                      | Welded Pipe           |
|                                                            |                        | ---                                      | 75                   | N08320 | 26Ni-22Cr-5Mo-Ti                       | Welded Pipe           |
|                                                            | SA                     | ---                                      | 85                   | N06030 | 30Cr-15Fe-5Mo-2Cu                      | Welded Pipe           |

| ASME P-No. - BASE METAL NICKEL & NICKEL ALLOYS (Continued) |                        |                        |                      |        |                                        |                       |
|------------------------------------------------------------|------------------------|------------------------|----------------------|--------|----------------------------------------|-----------------------|
| ASME Spec.                                                 | Condition <sup>a</sup> | Size or Thickness (in) | UTS ksi <sup>c</sup> | UNS    | Nominal Composition                    | Product Form          |
| <b>P No. 45 (Continued)</b>                                |                        |                        |                      |        |                                        |                       |
| SB-619<br>(continued)                                      | ---                    | ---                    | 100                  | R30556 | 22Cr-20.75Ni-18.5Co-3.25Mo-2.75W-FeRem | Welded Pipe           |
| SB-620                                                     | A                      | ---                    | 75                   | N08320 | 26Ni-22Cr-5Mo-Ti                       | Plate, Sheet, & Strip |
| SB-621                                                     | A                      | ---                    | 75                   | N08320 | 26Ni-22Cr-5Mo-Ti                       | Rod                   |
| SB-622                                                     | A                      | ---                    | 90                   | N06007 | 22.3Cr-19.5Fe-6.5Mo-2Cu-2Cb            | Smls. Pipe & Tube     |
|                                                            | ---                    | ---                    | 85                   | N06975 | 49.5Ni-24.5Cr-6Mo-1Cu-1Ti              | Smls. Pipe & Tube     |
|                                                            | ---                    | ---                    | 90                   | N06985 | 22Cr-20Fe-7Mo                          | Smls. Pipe & Tube     |
|                                                            | ---                    | ---                    | 75                   | N08320 | 26Ni-22Cr-5Mo-Ti                       | Smls. Pipe & Tube     |
|                                                            | SA                     | ---                    | 85                   | N06030 | 30Cr-15Fe-5Mo-2Cu                      | Smls. Pipe & Tube     |
|                                                            | ---                    | ---                    | 100                  | R30556 | 22Cr-20.75Ni-18.5Co-3.25Mo-2.75W-FeRem | Smls. Pipe & Tube     |
| SB-625                                                     | A                      | ---                    | 71                   | N08904 | 25.5Ni-21Cr-4.5Mo-1.5Cu                | Plate, Sheet, & Strip |
| SB-626                                                     | SA                     | ---                    | 90                   | N06007 | 22.3Cr-19.5Fe-6.5Mo-2Cu-2Cb            | Welded Tube           |
|                                                            | SA                     | ---                    | 85                   | N06975 | 49.5Ni-24.5Cr-6Mo-1Cu-1Ti              | Welded Tube           |
|                                                            | SA                     | ---                    | 90                   | N06985 | 22Cr-20Fe-7Mo-2Cu                      | Welded Tube           |
|                                                            | SA                     | ---                    | 75                   | N08320 | 26Ni-22Cr-5Mo-Ti                       | Welded Tube           |
|                                                            | SA                     | ---                    | 85                   | N06030 | 30Cr-15Fe-5Mo-2Cu                      | Welded Tube           |
|                                                            | ---                    | ---                    | 100                  | R30556 | 22Cr-20.75Ni-18.5Co-3.25Mo-2.75W-FeRem | Welded Tube           |
| SB-668                                                     | A                      | ---                    | 73                   | N08028 | Low C-31Ni-27Cr-35Mo-1Cu               | Smls. Tube            |
| SB-672                                                     | A                      | All                    | 80                   | N08700 | 25Ni-21Cr-4.5Mo-Cb                     | Bar, Wire             |
| SB-673                                                     | ST                     | All                    | 71                   | N08904 | 25.5Ni-21Cr-4.5Mo-1.5Cu                | Welded Pipe           |
| SB-674                                                     | ST                     | All                    | 71                   | N08904 | 25.5Ni-21Cr-4.5Mo-1.5Cu                | Welded Tube           |
| SB-675                                                     | ST                     | All                    | 75                   | N08366 | 24.5Ni-21Cr-6.5Mo                      | Welded Pipe           |
|                                                            | ---                    | ---                    | 104                  | N08367 | Low C-24 ½Ni-21Cr-6 ½Mo-N              | Welded Pipe           |

| ASME P-No. - BASE METAL NICKEL & NICKEL ALLOYS (Continued) |                        |                        |                      |        |                           |                       |
|------------------------------------------------------------|------------------------|------------------------|----------------------|--------|---------------------------|-----------------------|
| ASME Spec.                                                 | Condition <sup>a</sup> | Size or Thickness (in) | UTS ksi <sup>c</sup> | UNS    | Nominal Composition       | Product Form          |
| <b>P No. 45 (Continued)</b>                                |                        |                        |                      |        |                           |                       |
| SB-676                                                     | ST                     | All                    | 75                   | N08366 | 24.5Ni-21Cr-6.5Mo         | Welded Tube           |
|                                                            | ---                    | ---                    | 104                  | N08367 | Low C-24 ½Ni-21Cr-6 ½Mo-N | Welded Tube           |
| SB-677                                                     | ST                     | All                    | 71                   | N08904 | 25.5Ni-21Cr-4.5Mo-1.5Cu   | Smls. Pipe & Tube     |
| SB-688                                                     | A                      | All                    | 75                   | N08366 | 25Ni-21Cr-6Mo             | Plate, Sheet, & Strip |
|                                                            | ---                    | ---                    | 104                  | N08367 | Low C-24 ½Ni-21Cr-6 ½Mo-N | Plate, Sheet, & Strip |
| SB-690                                                     | A                      | All                    | 75                   | N08366 | 25Ni-21Cr-6Mo             | Smls. Pipe & Tube     |
|                                                            | ---                    | ---                    | 104                  | N08367 | Low C-24 ½Ni-21Cr-6 ½Mo-N | Smls. Pipe & Tube     |
| SB-691                                                     | A                      | All                    | 75                   | N08366 | 25Ni-21Cr-6Mo             | Rod, Bar, & Wire      |
|                                                            | ---                    | ---                    | 104                  | N08367 | Low C-24 ½Ni-21Cr-6 ½Mo-N | Rod & Bar             |
| SB-704                                                     | CW/A                   | ---                    | 85                   | N08825 | 42Ni-21 ½Cr-3Mo-2.3Cu     | Welded Tube           |
| SB-705                                                     | CW/A                   | ---                    | 85                   | N08825 | 42Ni-21 ½Cr-3Mo-23Cu      | Welded Pipe           |
| <b>P No. 46</b>                                            |                        |                        |                      |        |                           |                       |
| SB-511                                                     | A                      | ---                    | 70                   | N08330 | 35Ni-19Cr-1.25Si          | Bar                   |
| SB-535                                                     | A                      | ---                    | 70                   | N08330 | 35Ni-19Cr-1.25Si          | Smls. & Welded Pipe   |
| SB-536                                                     | A                      | ---                    | 70                   | N08330 | 35Ni-19Cr-1.25Si          | Plate, Sheet, Strip   |
| <b>P No. 47</b>                                            |                        |                        |                      |        |                           |                       |
| SB-435                                                     | ---                    | ---                    | 110                  | N06230 | 22Cr-14W-2Mo-Al-La        | Plate, Sheet, Strip   |
| SB-572                                                     | ---                    | ---                    | 110                  | N06230 | 22Cr-14W-2Mo-Al-La        | Rod                   |
| SB-619                                                     | ---                    | ---                    | 110                  | N06230 | 22Cr-14W-2Mo-Al-La        | Welded Pipe           |
| SB-622                                                     | ---                    | ---                    | 110                  | N06230 | 22Cr-14W-2Mo-Al-La        | Smls Pipe & Tube      |
| SB-626                                                     | ---                    | ---                    | 110                  | N06230 | 22Cr-14W-2Mo-Al-La        | Welded Tube           |
| SB-710                                                     | A                      | ---                    | 70                   | N08330 | 35Ni-19Cr-1.25Si          | Welded Pipe           |

a. A - annealed; HR - hot rolled; SR - Stress Relieved; HF - hot finished; CD - Cold Drawn; SA - solution annealed; CW - cold worked; ST - solution treated; CW/A - cold worked/annealed; CD/A - cold drawn/annealed; HF/A - hot finished/annealed.

b. Except hex. over 2 ½. c. Minimum value.

| ASME F No. - WELDING FILLER METAL NICKEL & NICKEL ALLOYS |                |                    |       |                |                           |
|----------------------------------------------------------|----------------|--------------------|-------|----------------|---------------------------|
| F No.                                                    | ASME Spec. No. | AWS Classification | F No. | ASME Spec. No. | AWS Classification        |
| 41                                                       | SFA-5.11       | E Ni-1             | 44    | SFA-5.11       | E NiMo-3                  |
| 41                                                       | SFA-5.14       | ER Ni-1            | 44    | SFA-5.11       | E NiMo-7                  |
| 41                                                       | SFA-5.30       | IN 61              | 44    | SFA-5.11       | E NiCrMo-4                |
| 42                                                       | SFA-5.11       | E NiCu-7           | 44    | SFA-5.11       | E NiCrMo-5                |
| 42                                                       | SFA-5.14       | ER NiCu-7          | 44    | SFA-5.11       | E NiCrMo-7                |
| 42                                                       | SFA-5.30       | IN 60              | 44    | SFA-5.11       | E NiCrMo-10 (C-22 alloy)  |
| 43                                                       | SFA-5.11       | E NiCrFe-1         | 44    | SFA-5.14       | ER NiMo-1                 |
| 43                                                       | SFA-5.11       | E NiCrFe-2         | 44    | SFA-5.14       | ER NiMo-2                 |
| 43                                                       | SFA-5.11       | E NiCrFe-3         | 44    | SFA-5.14       | ER NiMo-7 (B-2 alloy)     |
| 43                                                       | SFA-5.11       | E NiCrFe-4         | 44    | SFA-5.14       | ER NiCrMo-4               |
| 43                                                       | SFA-5.11       | E NiCrMo-2         | 44    | SFA-5.14       | ER NiCrMo-5               |
| 43                                                       | SFA-5.11       | E NiCrMo-3         | 44    | SFA-5.14       | ER NiCrMo-7 (C-4 alloy)   |
| 43                                                       | SFA-5.11       | E NiCrMo-b         | 44    | SFA-5.14       | ER NiCrMo-10 (C-22 alloy) |
| 43                                                       | SFA-5.14       | ER NiCr-3          | 45    | SFA-5.11       | E NiCrMo-1                |
| 43                                                       | SFA-5.14       | ER NiCrFe-5        | 45    | SFA-5.11       | E NiCrMo-9                |
| 43                                                       | SFA-5.14       | ER NiCrFe-6        | 45    | SFA-5.11       | E NiCrMo-11 (G-30 alloy)  |
| 43                                                       | SFA-5.14       | ER NiCrMo-2        | 45    | SFA-5.14       | ER NiCrMo-1               |
| 43                                                       | SFA-5.14       | ER NiCrMo-3        | 45    | SFA-5.14       | ER NiFeCr-1               |
| 43                                                       | SFA-5.30       | IN 82              | 45    | SFA-5.14       | ER NiCrMo-8               |
| 43                                                       | SFA-5.30       | IN 62              | 45    | SFA-5.14       | ER NiCrMo-9               |
| 43                                                       | SFA-5.30       | IN 6A              | 45    | SFA-5.14       | ER NiCrMo-11 (G-30 alloy) |
| 44                                                       | SFA-5.11       | E NiMo-1           |       |                |                           |

| COMMON NAMES & CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS - WELD FILLER METALS |        |                         |                      |                      |
|----------------------------------------------------------------------------------------------|--------|-------------------------|----------------------|----------------------|
| Common Name                                                                                  | UNS    | ASME                    | AWS                  | MIL-SPEC             |
| 75Ni-25Cr <sup>a</sup>                                                                       | W86003 | ---                     | ---                  | ---                  |
| 904L Electrode                                                                               | W88904 | SFA-5.4 (E385)          | A5.4 (E385)          | ---                  |
| Avesta PE 12                                                                                 | W86040 | ---                     | A5.11 (ENiCrMo-12)   | ---                  |
| Carpenter 20Cb-3                                                                             | W88022 | SFA-5.4 (E320)          | A5.4 (E320)          | ---                  |
|                                                                                              |        | SFA-5.9 (EC320)         | A5.9 (EC320)         | ---                  |
| Carpenter 20Cb3L.R.                                                                          | W88022 | SFA-5.4 (E320LR)        | A5.4 (E320LR)        | ---                  |
|                                                                                              |        | SFA-5.9 (EC320LR)       | A5.9 (EC320LR)       | ---                  |
| Cast Iron Electrode ENi-CI                                                                   | W82001 | ---                     | A5.15 (ENi-CI)       | ---                  |
| Cast Iron Electrode ENi-CI-A                                                                 | W82003 | SFA-5.15 (ENi-CI-A)     | A5.15 (ENi-CI-A)     | ---                  |
| Cast Iron Electrode ENiCu-A                                                                  | W84001 | ---                     | A5.15 (ENiCu-A)      | ---                  |
| Cast Iron Electrode ENiCu-B                                                                  | W84002 | ---                     | A5.15 (ENiCu-B)      | ---                  |
| Cast Iron Electrode ENiFe-CI                                                                 | W82002 | ---                     | A5.15 (ENiFe-CI)     | ---                  |
| Cast Iron Electrode ENiFe-CI-A                                                               | W82004 | SFA-5.15 (ENiFe-CI-A)   | A5.15 (ENiFe-CI-A)   | ---                  |
| Cast Iron Electrode ENiFeMn-CI-A                                                             | W82006 | SFA-5.15 (ENiFeMn-CI-A) | A5.15 (ENiFeMn-CI-A) | ---                  |
| Cast Iron Fux Cored Wire                                                                     | W82032 | SFA-5.15 (ENiFeT3-CI)   | A5.15 (ENiFeT3-CI)   | ---                  |
| E383 Electrode                                                                               | W88028 | SFA-5.4 (E383)          | A5.4 (E383)          | ---                  |
| E330 Electrode                                                                               | W88331 | SFA-5.4 (E330)          | A5.4 (E330)          | E-22200/3 (MIL-330)  |
| E330H high carbon                                                                            | W88335 | SFA-5.4 (E330H)         | A5.4 (E330H)         | ---                  |
| Hard Surfacing Electrode                                                                     | W83002 | SFA-5.13 (ENiCrFeCo)    | A5.11 (ENiCrFeCo)    | ---                  |
| Hard Surfacing Electrode                                                                     | W89604 | ---                     | A5.13 (ENiCr-A)      | ---                  |
| Hard Surfacing Electrode                                                                     | W89605 | ---                     | A5.13 (ENiCr-B)      | ---                  |
| Hard Surfacing Electrode                                                                     | W89606 | ---                     | A5.13 (ENiCr-C)      | ---                  |
| Hastelloy B                                                                                  | W80001 | SFA-5.11 (ENiMo-1)      | A5.11 (ENiMo-1)      | E-22200/3 (MIL-3N1B) |
| Hastelloy B-2                                                                                | W80665 | SFA-5.11 (ENiMo-7)      | A5.11 (ENiMo-7)      | ---                  |
| Hastelloy C                                                                                  | W80002 | SFA-5.11 (ENiCrMo-5)    | A5.11 (ENiCrMo-5)    | E-22200/3 (MIL-3N1C) |
|                                                                                              |        | SFA-5.13 (ENiCrMo-5A)   | A5.13 (ENiCrMo-5A)   |                      |

| COMMON NAMES & CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS - WELD FILLER METALS (Continued) |        |                         |                      |                       |
|----------------------------------------------------------------------------------------------------------|--------|-------------------------|----------------------|-----------------------|
| Common Name                                                                                              | UNS    | ASME                    | AWS                  | MIL-SPEC              |
| Hastelloy C-22                                                                                           | W86022 | SFA-5.11 (ENiCrMo-10)   | A5.11 (ENiCrMo-10)   | ---                   |
| Hastelloy C-276                                                                                          | W80276 | SFA-5.11 (ENiCrMo-4)    | A5.11 (ENiCrMo-4)    | E-22200/3 (MIL-3N1C)  |
| Hastelloy G                                                                                              | W86007 | SFA-5.11 (ENiCrMo-1)    | A5.11 (ENiCrMo-1)    | ---                   |
| Hastelloy G-30                                                                                           | W86030 | SFA-5.11 (ENiCrMo-11)   | A5.11 (ENiCrMo-11)   | ---                   |
| Hastelloy W <sup>b</sup>                                                                                 | W80004 | SFA-5.11 (ENiMo-3)      | A5.11 (ENiMo-3)      | E-22200/3 (MIL-4N1W)  |
|                                                                                                          |        | SFA-5.34 (ENiCrMo-4T-X) | A5.34 (ENiCrMo-4T-X) | ---                   |
| Hastelloy X <sup>c</sup>                                                                                 | W86002 | SFA-5.11 (ENiCrMo-2)    | A5.11 (ENiCrMo-2)    | ---                   |
| Inconel 112 Electrode                                                                                    | W86112 | SFA-5.11 (ENiCrMo-3)    | A5.11 (ENiCrMo-3)    | E-22200/3 (MIL-1N12)  |
| Inconel 112 Electrode                                                                                    |        | SFA-5.34 (ENiCrMo-3T-X) | A5.34 (ENiCrMo-3T-X) | ---                   |
| Inconel 117 Electrode                                                                                    | W86117 | SFA-5.11 (ENiCrCoMo-1)  | A5.11 (ENiCrCoMo-1)  | ---                   |
| Inconel 132 <sup>d</sup>                                                                                 | W86132 | SFA-5.11 (ENiCrFe-1)    | A5.11 (ENiCrFe-1)    | E-22200/3 (MIL-3N12)  |
|                                                                                                          |        | SFA-5.34 (ENiCrFe-1T-X) | A5.34 (ENiCrFe-1T-X) | E-22200/3 (MIL-3N12H) |
| Inconel 152 Electrode <sup>f</sup>                                                                       | W86152 | SFA-5.11 (ENiCrFe-7)    | A5.11 (ENiCrFe-7)    | ---                   |
| Inconel 182 Electrode                                                                                    | W86182 | SFA-5.11 (ENiCrFe-3)    | A5.11 (ENiCrFe-3)    | E-22200/3 (MIL-8N12)  |
| INCO-Weld A                                                                                              | W86133 | SFA-5.11 (ENiCrFe-2)    | A5.11 (ENiCrFe-2)    | E-22200/3 (MIL-4N1A)  |
|                                                                                                          |        | SFA-5.34 (ENiCrFe-2T-X) | A5.34 (ENiCrFe-2T-X) | E-22200/3 (MIL-4N1AH) |
| INCO-Weld B                                                                                              | W86134 | SFA-5.11 (ENiCrFe-4)    | A5.11 (ENiCrFe-4)    | ---                   |
| Monel 190 Electrode                                                                                      | W84190 | SFA-5.11 (ENiCu-7)      | A5.11 (ENiCu-7)      | E-22200/3 (MIL-9N10)  |
| Nickel 141 Electrode                                                                                     | W82141 | SFA-5.11 (ENi-1)        | A5.11 (ENi-1)        | E-22200/3 (MIL-4N11)  |
| Ni-Cr Electrode <sup>e</sup>                                                                             | W86130 | ---                     | ---                  | ---                   |
| Ni-Cr Electrode <sup>e</sup>                                                                             | W86182 | SFA-5.34 (ENiCrFe-3T-X) | A5.34 (ENiCrFe-3T-X) | E-22200/3 (MIL-8N12H) |
| Ni-Cr Flux Cored Electrode                                                                               | W86082 | SFA-5.34 (ENiCr-3T-X)   | A5.34 (ENiCr-3T-X)   | ---                   |
| RA 330-04 Electrode                                                                                      | W88334 | ---                     | ---                  | ---                   |
| RA 330-80                                                                                                | W88338 | ---                     | ---                  | ---                   |
| RA 333 Electrode                                                                                         | W86333 | ---                     | ---                  | ---                   |
| ---                                                                                                      | W86455 | SFA-5.11 (ENiCrMo-7)    | A5.11 (ENiCrMo-7)    | ---                   |



| COMMON NAMES & CROSS REFERENCED SPECIFICATIONS - NICKEL & NICKEL ALLOYS - WELD FILLER METALS (Continued) |        |                         |                      |          |
|----------------------------------------------------------------------------------------------------------|--------|-------------------------|----------------------|----------|
| Common Name                                                                                              | UNS    | ASME                    | AWS                  | MIL-SPEC |
| ---                                                                                                      | W86620 | SFA-5.11 (ENiCrMo-6)    | A5.11 (ENiCrMo-6)    | ---      |
| ---                                                                                                      | W86985 | SFA-5.11 (ENiCrMo-9)    | A5.11 (ENiCrMo-9)    | ---      |
| ---                                                                                                      | W87718 | SFA-5.34 (ENiFeCr-2T-X) | A5.34 (ENiFeCr-2T-X) | ---      |

- a. Includes AMS specification 5677.
- b. Includes AMS specification 5787.
- c. Includes AMS specification 5677.
- d. Includes AMS specification 5684.
- e. Includes AMS specification 5779.
- f. Obsolete, no longer active and are retained for reference purposes only.

| INTERNATIONAL CROSS REFERENCES - NICKEL & NICKEL ALLOYS <sup>a</sup> |         |               |              |         |       |                |        |
|----------------------------------------------------------------------|---------|---------------|--------------|---------|-------|----------------|--------|
| Common Name                                                          | USA UNS | Product Form  | USA ASTM/AWS | BRITAIN |       | GERMANY        |        |
|                                                                      |         |               |              | BS      | Alloy | DIN            | W. Nr. |
| Nickel 200                                                           | N02200  | Plate, Sheet  | B 162        | 3072    | NA11  | 17750 Ni99.0   | 2.4066 |
|                                                                      |         | Strip         | B 162        | 3073    | NA11  | 17750 Ni99.0   | 2.4066 |
|                                                                      |         | Rod           | B 160        | 3075    | NA11  | 17152Ni99.0    | 2.4066 |
|                                                                      |         | Bar           | B 160        | 3076    | NA11  | 17152 Ni99.0   | 2.4066 |
|                                                                      |         | Seamless Pipe | B 161        | ---     | ---   | 17751 Ni99.0   | 2.4066 |
|                                                                      |         | Seamless Tube | B 161        | 3074    | NA11  | 17751 Ni99.0   | 2.4066 |
|                                                                      |         | Welded Pipe   | B 725        | ---     | ---   | ---            | ---    |
|                                                                      |         | Welded Tube   | B 730        | ---     | ---   | ---            | ---    |
|                                                                      |         | Fittings      | B 366        | ---     | ---   | ---            | ---    |
| Nickel 201                                                           | N02201  | Forgings      | ---          | ---     | ---   | 17754 LCNi99.0 | 2.4068 |
|                                                                      |         | Plate, Sheet  | B 162        | 3072    | NA12  | 17750 LCNi99.0 | 2.4068 |
|                                                                      |         | Strip         | B 162        | 3073    | NA12  | 17750 LCNi99.0 | 2.4068 |
|                                                                      |         | Rod           | B 160        | 3075    | NA12  | 17152 LCNi99.0 | 2.4068 |
|                                                                      |         | Bar           | B 160        | 3076    | NA12  | 17152 LCNi99.0 | 2.4068 |

| INTERNATIONAL CROSS REFERENCES - NICKEL & NICKEL ALLOYS <sup>a</sup> (Continued) |         |                     |              |         |       |                |        |
|----------------------------------------------------------------------------------|---------|---------------------|--------------|---------|-------|----------------|--------|
| Common Name                                                                      | USA UNS | Product Form        | USA ASTM/AWS | BRITAIN |       | GERMANY        |        |
|                                                                                  |         |                     |              | BS      | Alloy | DIN            | W. Nr. |
| Nickel 201                                                                       | N02201  | Seamless Pipe       | B 161        | ---     | ---   | 17751 LCNi99.0 | 2.4068 |
|                                                                                  |         | Seamless Tube       | B 161        | 3074    | NA12  | 17751 LCNi99.0 | 2.4068 |
|                                                                                  |         | Welded Pipe         | B 725        | ---     | ---   | ---            | ---    |
|                                                                                  |         | Welded Tube         | B 730        | ---     | ---   | ---            | ---    |
|                                                                                  |         | Fittings            | B 366        | ---     | ---   | ---            | ---    |
|                                                                                  |         | Forgings            | ---          | ---     | ---   | 17754 LCNi99.0 | 2.4068 |
| Alloy 20Cb-3                                                                     | N08020  | Plate               | B 463        | ---     | ---   | NiCr20CuMo     | 2.4660 |
|                                                                                  |         | Fittings            | B 366        | ---     | ---   | NiCr20CuMo     | 2.4660 |
|                                                                                  |         | Welded Pipe         | B 464        | ---     | ---   | NiCr20CuMo     | 2.4660 |
|                                                                                  |         | Welded Tube         | B 468        | ---     | ---   | NiCr20CuMo     | 2.4660 |
| Alloy 400                                                                        | N04400  | Plate, Sheet        | B 127        | 3072    | NA13  | 17750 NiCu30Fe | 2.4360 |
|                                                                                  |         | Strip               | B 127        | 3073    | NA13  | 17750 NiCu30Fe | 2.4360 |
|                                                                                  |         | Rod                 | B 164        | 3075    | NA13  | 17752 NiCu30Fe | 2.4360 |
|                                                                                  |         | Bar                 | B 164        | 3076    | NA13  | 17752 NiCu30Fe | 2.4360 |
|                                                                                  |         | Seamless Tubing     | B 165        | 3074    | NA13  | 17751 NiCu30Fe | 2.4360 |
|                                                                                  |         | Seamless Pipe       | B 165        | ---     | ---   | 17751 NiCu30Fe | 2.4360 |
|                                                                                  |         | Forgings            | B 564        | ---     | ---   | ---            | ---    |
| Alloy 600                                                                        | N06600  | Sheet, Plate        | B 168        | 3072    | NA14  | 17750 NiCr15Fe | 2.4816 |
|                                                                                  |         | Strip               | B 168        | 3073    | NA14  | 17750 NiCr15Fe | 2.4816 |
|                                                                                  |         | Welded Tube         | B 516        | 3074    | NA14  | 17751 NiCr15Fe | 2.4816 |
|                                                                                  |         | Bar                 | B 166        | 3076    | NA14  | ---            | 2.4816 |
| Alloy 601                                                                        | N06601  | Sheet, Plate, Strip | B 168        | ---     | ---   | 17750          | 2.4851 |
|                                                                                  |         | Seamless Tube       | B 167        | ---     | ---   | 17751          | 2.4851 |
|                                                                                  |         | Seamless Pipe       | B 167        | ---     | ---   | 17751          | 2.4851 |

| INTERNATIONAL CROSS REFERENCES - NICKEL & NICKEL ALLOYS <sup>a</sup> (Continued) |         |                     |                           |         |       |                   |        |
|----------------------------------------------------------------------------------|---------|---------------------|---------------------------|---------|-------|-------------------|--------|
| Common Name                                                                      | USA UNS | Product Form        | USA ASTM/AWS              | BRITAIN |       | GERMANY           |        |
|                                                                                  |         |                     |                           | BS      | Alloy | DIN               | W. Nr. |
| Alloy 601                                                                        | N06601  | Bar                 | B 166                     | ---     | ---   | ---               | 2.4851 |
| Alloy 617                                                                        | N06617  | Weld Filler Metal   | AWS A5.14<br>ERNiCrCoMo-1 | ---     | ---   | ---               | 2.4663 |
| Alloy 625                                                                        | N06625  | Sheet, Plate        | B 443                     | 3072    | NA21  | 17750 NiCr22Mo9Nb | 2.4856 |
|                                                                                  |         | Strip               | B 443                     | 3073    | NA21  | 17750 NiCr22Mo9Nb | 2.4856 |
|                                                                                  |         | Seamless Tube       | B 444                     | 3074    | NA21  | 17751 NiCr22Mo9Nb | 2.4856 |
|                                                                                  |         | Bar                 | B 446                     | 3076    | NA21  | 17752 NiCr22Mo9Nb | 2.4856 |
| Alloy 690                                                                        | N06690  | Sheet, Plate, Strip | B 168                     | ---     | ---   | 17750             | 2.4642 |
|                                                                                  |         | Seamless Tube       | B 167                     | ---     | ---   | 17751             | 2.4642 |
|                                                                                  |         | Seamless Pipe       | B 167                     | ---     | ---   | 17751             | 2.4642 |
|                                                                                  |         | HE Tubes            | B 163                     | ---     | ---   | 17751             | 2.4642 |
|                                                                                  |         | Bar                 | B 166                     | ---     | ---   | ---               | 2.4642 |
| Alloy 718                                                                        | N07718  | Plate, Sheet, Strip | B 670                     | ---     | ---   | NiCr19NbMo        | 2.4668 |
|                                                                                  |         | Forgings            | B 637                     | ---     | ---   | NiCr19NbMo        | 2.4668 |
|                                                                                  |         | Weld Filler Metal   | AWS A5.14<br>ERNiFeCr-2   | ---     | ---   | ---               | 2.4668 |
| Alloy 800                                                                        | N08800  | Sheet, Plate        | B 409                     | 3072    | NA15  | X10NiCrAlTi       | 1.4876 |
|                                                                                  |         | Strip               | B 409                     | 3073    | NA15  | X10NiCrAlTi       | 1.4876 |
|                                                                                  |         | Welded Tube         | B 515                     | 3074    | NA15  | X10NiCrAlTi       | 1.4876 |
|                                                                                  |         | Bar                 | B 408                     | 3076    | NA15  | X10NiCrAlTi       | 1.4876 |
| Alloy 800H                                                                       | N08810  | Sheet, Plate        | B 409                     | 3072    | NA15H | X10NiCrAlTi       | 1.4876 |
|                                                                                  |         | Strip               | B 409                     | 3073    | NA15H | X10NiCrAlTi       | 1.4876 |
|                                                                                  |         | Welded Tube         | B 407                     | 3074    | NA15H | X10NiCrAlTi       | 1.4876 |
|                                                                                  |         | Bar                 | B 408                     | 3076    | NA15H | X10NiCrAlTi       | 1.4876 |

| INTERNATIONAL CROSS REFERENCES - NICKEL & NICKEL ALLOYS <sup>a</sup> (Continued) |         |                     |              |         |       |                    |        |
|----------------------------------------------------------------------------------|---------|---------------------|--------------|---------|-------|--------------------|--------|
| Common Name                                                                      | USA UNS | Product Form        | USA ASTM/AWS | BRITAIN |       | GERMANY            |        |
|                                                                                  |         |                     |              | BS      | Alloy | DIN                | W. Nr. |
| Alloy 825                                                                        | N08825  | Sheet, Plate        | B 424        | 3072    | NA16  | 17750              | 2.4858 |
|                                                                                  |         | Strip               | B 424        | 3073    | NA16  | 17750              | 2.4858 |
|                                                                                  |         | Seamless Tube       | B 423        | 3074    | NA16  | 17751              | 2.4858 |
|                                                                                  |         | Bar                 | B 425        | 3076    | NA16  | ---                | 2.4858 |
| Alloy B-2                                                                        | N10665  | Plate, sheet, strip | B 333        | ---     | ---   | 17750 NiMo28       | 2.4617 |
|                                                                                  |         | Welded Pipe         | B 622        | ---     | ---   | 17751 NiMo28       | 2.4617 |
|                                                                                  |         | Welded Tube         | B 622        | ---     | ---   | 17751 NiMo28       | 2.4617 |
| Alloy C-4                                                                        | N06455  | Plate, Sheet, Strip | B 575        | ---     | NA45  | 17750 NiMo16Cr16Ti | 2.4610 |
|                                                                                  |         | Welded Tube         | B 626        | ---     | NA45  | 17751 NiMo16Cr16Ti | 2.4610 |
|                                                                                  |         | Welded Pipe         | B 619        | ---     | NA45  | 17751 NiMo16Cr16Ti | 2.4610 |
|                                                                                  |         | Seamless Tube       | B 622        | ---     | NA45  | 17751 NiMo16Cr16Ti | 2.4610 |
|                                                                                  |         | Seamless Pipe       | B 622        | ---     | NA45  | 17751 NiMo16Cr16Ti | 2.4610 |
| Alloy C-276                                                                      | N010276 | Plate, Sheet, Strip | B 575        | ---     | ---   | 17750 NiMo16Cr5W   | 2.4819 |
|                                                                                  |         | Welded Tube         | B 626        | ---     | ---   | 17751 NiMo16Cr5W   | 2.4819 |
|                                                                                  |         | Welded Pipe         | B 619        | ---     | ---   | 17751 NiMo16Cr5W   | 2.4819 |
|                                                                                  |         | Seamless Tube       | B 622        | ---     | ---   | 17751 NiMo16Cr5W   | 2.4819 |
|                                                                                  |         | Seamless Pipe       | B 622        | ---     | ---   | 17751 NiMo16Cr5W   | 2.4819 |
| Alloy G                                                                          | N06007  | Plate, Sheet, Strip | B 582        | ---     | ---   | 17750 NiCr22Mo6Cu  | 2.4618 |
|                                                                                  |         | Welded Tube         | B 626        | ---     | ---   | 17751 NiCr22Mo6Cu  | 2.4618 |
|                                                                                  |         | Welded Pipe         | B 619        | ---     | ---   | 17751 NiCr22Mo6Cu  | 2.4618 |
|                                                                                  |         | Seamless Tube       | B 622        | ---     | ---   | 17751 NiCr22Mo6Cu  | 2.4618 |
|                                                                                  |         | Seamless Pipe       | B 622        | ---     | ---   | 17751 NiCr22Mo6Cu  | 2.4618 |

| INTERNATIONAL CROSS REFERENCES - NICKEL & NICKEL ALLOYS <sup>a</sup> (Continued) |         |                     |              |         |       |                  |        |
|----------------------------------------------------------------------------------|---------|---------------------|--------------|---------|-------|------------------|--------|
| Common Name                                                                      | USA UNS | Product Form        | USA ASTM/AWS | BRITAIN |       | GERMANY          |        |
|                                                                                  |         |                     |              | BS      | Alloy | DIN              | W. Nr. |
| Alloy G-3                                                                        | N06985  | Plate, Sheet, Strip | B 582        | ---     | ---   | 17750 NiCr22MoCu | 2.4619 |
|                                                                                  |         | Welded Tube         | B 626        | ---     | ---   | 17751 NiCr22MoCu | 2.4619 |
|                                                                                  |         | Welded Pipe         | B 619        | ---     | ---   | 17751 NiCr22MoCu | 2.4619 |
| Alloy G-30                                                                       | N06030  | Plate, Sheet, Strip | B 582        | ---     | ---   | 17744            | 2.4603 |
|                                                                                  |         | Welded Tube         | B 626        | ---     | ---   | 17744            | 2.4603 |
|                                                                                  |         | Welded Pipe         | B 619        | ---     | ---   | 17744            | 2.4603 |
|                                                                                  |         | Seamless Tube       | B 622        | ---     | ---   | 17744            | 2.4603 |
|                                                                                  |         | Seamless Pipe       | B 622        | ---     | ---   | 17744            | 2.4603 |
| Alloy X-750                                                                      | N07750  | Forgings            | B 637        | ---     | HR505 | ---              | 2.4669 |
| Monel 400                                                                        | N04400  | Plate, Sheet, Strip | B 127        | ---     | ---   | ---              | 2.4360 |
|                                                                                  |         | HE Tubes            | B 163        | ---     | ---   | ---              | 2.4360 |
|                                                                                  |         | Rod, Bar, Wire      | B 164        | ---     | ---   | ---              | 2.4360 |
|                                                                                  |         | Seamless Tube       | B 165        | ---     | ---   | ---              | 2.4360 |
|                                                                                  |         | Seamless Pipe       | B 165        | ---     | ---   | ---              | 2.4360 |
| Monel K-500                                                                      | N05500  | Nuts                | F 467 (500)  | ---     | ---   | ---              | 2.4375 |

a. It is not practical to directly correlate the various metal designations from country to country, let alone comparing several countries and their metal designations; from the view that chemical composition may be similar, but not identical, and that manufacturing technologies may differ greatly. Consequently, the cross references made in this table are, at best, only listed as a guide to assist in finding comparable metal designations, rather than equivalent metal designations.

UNS - Unified Numbering System; ASTM - American Society for Testing Materials; BS - British Standards; DIN - Deutsches Institut für Normung; W-Nr. - Werkstoffe Number.

# Chapter

# 3

## ***TITANIUM & TITANIUM ALLOYS***

Metallic titanium was first isolated in impure form in 1887 and with higher purity in 1910; however, it was not until the 1950s that it began to come into use as a structural material. This was initially stimulated by aircraft applications. Although the aerospace industry still provides the major market, titanium and titanium alloys are finding increasingly widespread use in other industries due to their many desirable properties. Notable among these is their low densities, which fall between those of aluminum and iron and give very attractive strength to weight ratios. In addition, titanium and titanium alloys readily form stable protective surface layers which give them excellent corrosion resistance in many environments, including oxidizing acids and chlorides, and good elevated temperature properties up to about 550°C (1022°F) in some cases.

Titanium metal is abundant in the earth's crust and is extracted commercially from the ore minerals rutile (titanium dioxide) and ilmenite (iron-titanium oxide). The commercial extraction process involves treatment of the ore with chlorine gas to produce titanium tetrachloride, which is purified and reduced to a metallic titanium sponge by reaction with magnesium or sodium. The sponge, blended with alloying elements (and reclaimed scrap) as desired, is then vacuum melted. Several meltings may be necessary to achieve a homogeneous ingot which is ready for processing into useful shapes, typically by forging followed by rolling. For many applications the cost of titanium alloys can be justified on the basis of desirable properties.

Pure titanium, like iron, is allotropic. At ambient temperature it has a hexagonal close packed (hcp) crystal structure which is stable during heating up to 883°C (1621°F) where it transforms to the body centered cubic (bcc) crystal structure. It remains bcc at higher temperatures until it melts at 1668°C (3034°F). On cooling, the transformation from bcc to hcp in pure titanium cannot be suppressed by rapid cooling, the transformation occurring by a martensitic type reaction. This is not, however, the case with titanium alloys, in which the transformation can

be suppressed or modified. Thus the microstructures of titanium alloys frequently contain particles of the bcc phase at ambient temperatures.

Different alloying elements have different effects. Some stabilize the hcp "alpha" structure by allowing it to exist at temperatures above 883°C (1621°F) while others stabilize the bcc "beta" structure by allowing it to remain stable below this temperature. Particular combinations of alloy composition and heat treatment can thus be used to obtain a wide range of possible microstructures, and hence a wide range of useful combinations of properties. The most important of the alpha stabilizers are aluminium, tin, and oxygen, while the important beta stabilizers include molybdenum, vanadium, manganese, chromium, and iron.

The spectrum of titanium-based materials can be divided into four classes depending their constituent phases; this in turn depends on their relative contents of alpha-stabilizing and beta-stabilizing alloying elements. The four basic classes are: (1) unalloyed or commercially pure titanium; (2) alpha and near-alpha alloys; (3) alpha-plus-beta alloys; and, (4) beta alloys. These four classes will be considered further in the sections that follow.

### **Unalloyed (Commercial Purity) Titanium**

Unalloyed titanium typically contains between 99% and 99.5% titanium with the balance being made up of iron and the interstitial impurity elements hydrogen, nitrogen, carbon and, most importantly, oxygen. Titanium has a strong affinity for the interstitial elements, so much so that commercial purity titanium is sometimes referred to as an alpha phase titanium-oxygen alloy. The properties of titanium and its alloys are quite sensitive to the amounts of these elements present. For example, an oxygen content of only 0.1% is sufficient to raise the hardness of pure titanium by a factor of about three. At the same time the ductility and impact toughness are adversely affected, with excessive quantities causing embrittlement. Maximum contents of iron and the four interstitial impurity elements are therefore specified. For example, there are four ASTM grades of unalloyed titanium (grades 1 to 4, corresponding to UNS R50250, R50400, R50500 and R50700), differing primarily in their specified maximum oxygen contents (between about 0.1 and 0.4%). Unalloyed titanium also has a specified maximum hydrogen content, typically about 0.01%, because the presence of small amounts of hydrogen can lead to the precipitation of embrittling hydride particles, even at ambient temperature. Small amounts of iron cause the formation of microscopic particles of beta phase which act to strengthen the material. Typically a maximum of 0.2 to 0.5% is specified. Nitrogen and carbon also cause strengthening. The ASTM standards deal with the

adverse effects of these residual impurities by specifying, in most grades, a maximum of 0.4% total residual content.

In addition to the four grades described above, there are several other grades of unalloyed titanium. For example there are grades (ASTM grades 7 and 11 corresponding to UNS R52400 and R52250) which contain 0.2% palladium for improved corrosion resistance especially in applications where operating conditions vary between oxidizing and mildly reducing. Another grade (ASTM grade 12, UNS R53400) of unalloyed titanium contains 0.3% molybdenum and 0.8% nickel, giving improved strength plus somewhat improved corrosion resistance. Unalloyed titanium is also produced with extra low interstitial content, as "ELI" alloys for applications requiring high ductility and/or toughness.

The microstructure of unalloyed titanium consists of grains of the alpha phase, with the possibility of small amounts of beta phase as a result of the presence of the iron impurity as mentioned above. The alpha grains in the annealed condition are either equiaxed or acicular, the former when worked alpha is recrystallized in the alpha region, and the latter when the material is cooled from above the beta transus (the temperature above which only the beta phase is present).

Unalloyed titanium is less expensive, generally more corrosion resistant, and lower in strength than the titanium alloys discussed below. Its impact toughness is comparable to that of quenched and tempered low alloy steel, and its toughness at low temperatures can be high with appropriate levels of interstitial impurity content. Although titanium has a low thermal conductivity, its heat transfer rate is high because of the characteristics of its surface oxide film and its resistance to corrosion. Unalloyed titanium is weldable and formable and finds uses in applications requiring corrosion resistance and high ductility for fabrication where strength is not of primary importance. It is not heat treatable. Typical applications include heat exchangers, chemical process piping, valves and tanks, as well as airframe sheet components.

### **Alpha and Near-Alpha Alloys**

Titanium alloys have a fully alpha (hcp) structure only if they contain alpha stabilizers such as aluminum, tin, and oxygen. These elements also act as solid solution strengtheners; however, their total amounts must be restricted to avoid the formation of an embrittling "alpha-2" phase, which is the intermetallic compound  $Ti_3Al$ . Aluminum is particularly potent in this respect, so in some alloys aluminum is partially replaced by zirconium to add strength while avoiding this embrittlement. The oxygen lowers the ductility and thus low oxygen or



extra low interstitial (ELI) alloys are available. The typical all-alpha alloy is Ti-5%Al-2.5%Sn (ASTM grade 6, UNS R54520, the ELI equivalent is UNS R54521).

In reality, small particles of beta phase can occur in the microstructures of all-alpha alloys as a result of the presence of iron impurity. In the near-alpha alloys, small amounts (1 to 2%) of beta stabilizers such as molybdenum and vanadium are added to retain some beta phase at ambient temperature. However the microstructures of these alloys are primarily alpha, and their responses to thermal and mechanical treatments are closer to those of the all-alpha alloys than to the alpha-plus-beta alloys discussed below.

Near-alpha titanium alloys include Ti-8%Al-1%Mo-1%V (UNS R54810), Ti-6%Al-2%Nb-1%Ta-0.8%Mo (UNS R56210), Ti-6%Al-2%Sn-4%Zr-2%Mo (Ti-6242 or UNS R54620), Timetal-1100 (a high temperature creep resistant alloy) and Ti-3%Al-2.5%V (UNS R56320). Several of these alloys including Ti-6-2-4-2 and Ti-3Al-2.5V are sometimes considered near-alpha alloys and sometimes alpha-beta alloys.

All-alpha alloys are not heat treatable and can be strengthened only by cold working or by cold working and annealing to control the grain size. On the other hand, some control over microstructure and properties is possible in near-alpha alloys by varying the processing conditions. This gives alpha grains with different sizes and morphologies, ranging from equiaxed to acicular (martensitic), depending on the annealing temperature and cooling rate. A common treatment for Ti-8Al-1Mo-1V is "mill annealing" which consists of annealing in a region where both alpha and beta phases are stable, e.g. 790°C (1454°F), and then furnace cooling. Improved notch sensitivity, at the expense of lower strength, can be obtained by "duplex annealing" (e.g. 1010°C (1850°F) for 15 minutes, air cool, then reheat for 15 minutes at 750°C (1382°F), then air cool). This minimizes the amount of embrittling alpha-2 phase. The alpha-2 phase is also responsible for decreased resistance to stress corrosion cracking in this alloy.

All-alpha and near-alpha alloys are slightly less corrosion resistant than unalloyed titanium, but they are higher in strength and retain high ductility. They have good toughness properties even at cryogenic temperatures, especially the ELI alloys. They are weldable and in many cases have excellent resistance to creep and oxidation and are therefore preferred for high temperature applications. All-alpha titanium alloys are employed as forgings such as gas turbine engine casings and rings. ELI alloys are useful for high pressure cryogenic applications. Typical uses of near-alpha alloys include airframe skin and structural

components such as seamless tubing and honeycomb panels (foil) as well as moderately high temperature applications such as blades in the compressor sections of jet engines. The Ti-3%Al-2.5%V alloy is also used for a range of industrial applications (it is boiler code approved) as well as for golf club shafts and bicycle frames.

### **Alpha-Plus-Beta Alloys**

This class of titanium alloy contains both alpha stabilizers and beta stabilizers, the latter in sufficient quantity to permit the development of microstructures containing appreciable amounts of beta phase, typically 10 to 50%, at ambient temperature. These alloys can thus be heat treated to develop a range of microstructures, with control over the distribution and morphology of the alpha and beta phases. There are two classes of alpha-beta alloys, as determined by the amount of beta stabilizer. The "lean" alpha-beta alloys are moderately heat treatable (i.e. have low hardenability) and are weldable, while the "rich" alpha-beta alloys have greater hardenability, and can thus be through-hardened in thicker sections by heat treatment, but are more difficult to weld. The most important of these alpha-beta alloys is Ti-6%Al-4%V (UNS R56400), a "lean" alloy which is also the most important of all the titanium alloys. Other "lean" alpha-beta alloys include Ti-6%Al-2%Sn-4%Zr-2%Mo (Ti-6-2-4-2 or UNS R54620), while the "rich" alloys include Ti-6%Al-6%V-2%Sn (UNS R56620) and Ti-6%Al-2%Sn-4%Zr-6%Mo (Ti-6-2-4-6 or UNS R56260). Ti-6Al-4V is also available in an ELI grade (UNS R56401).

The microstructures and microstructural transformations in these alloys, as developed by appropriate thermal and mechanical processing, are complex. The following examples apply to Ti-6Al-4V. Quenching from above the beta transus gives a martensitic alpha prime structure, although this does not have the extreme hardness of ferrous martensite. Slower cooling gives acicular or coarser plate-like alpha phase, with some intergranular beta phase present. If the material is annealed slightly below the beta transus and water quenched, other microstructures are developed, consisting of mixtures of primary alpha with martensitic, acicular or equiaxed alpha, in some cases with intergranular beta phase as well. High temperature processing, for example by forging, produces a range of microstructures, depending on the forging temperature and cooling rate. Alternatively, the alloy can be solution treated, quenched and aged to control the quantity and dispersion of the beta phase which precipitates from martensitic alpha formed during the quench. This latter treatment gives the highest strengths of the Ti-6Al-4V alloys, with tensile strength as high as 185,000 psi, as compared to annealed Ti-6Al-4V at 145,000 psi. In general, the wide range of microstructures possible

as a result of heat treatment and thermomechanical processing gives rise to a wide range of properties.

Alpha-beta alloys are capable of excellent combinations of strength, toughness and corrosion resistance. They have acceptable forming properties and are generally weldable. Their creep resistance at elevated temperatures is poorer than that of the alpha or near alpha alloys. Typical applications include rocket motor cases, blades, and discs for aircraft turbines and compressors, structural aircraft components including fasteners and landing gear, chemical process equipment, marine components, and surgical implant materials. The ELI alloys have cryogenic applications.

### **Beta Alloys**

These alloys contain a balance of beta stabilizers to alpha stabilizers which is sufficiently high that a fully beta phase microstructure can be retained on cooling. In this condition, the alloys are generally thermodynamically unstable, and this can be used to advantage by allowing some decomposition reactions (alpha precipitation) during an aging treatment in order to provide strengthening. Their generally high strength, high toughness, and improved formability as compared to alpha-beta alloys provides an attractiveness, although processing is sometimes critical. Furthermore, the beta alloys are more readily heat treated in thick sections.

Typical beta alloys include Ti-10%V-2%Fe-3%Al, Ti-15%V-3%Cr-3%Sn-3%Al (Ti-15-3), Ti-13%V-11%Cr-3%Al (UNS R58010), Ti-3%Al-8%V-6%Cr-4%Zr-4%Mo (Beta C or Ti-3-8-6-4-4 or UNS R58640), and Ti-15%Mo-2.7%Nb-3%Al (Timetal•21S). The beta alloys are becoming more widely used, notably Ti-15-3, Beta C and Timetal•21S.

Beta alloys are heat treatable to very high strengths, especially when they are cold worked in the solution treated and quenched condition and subsequently aged. The solution treatment plus quenching provides a metastable beta microstructure which decomposes on subsequent aging to a mixture of alpha and beta (the "near-beta" alloys) depending on the precise thermal treatment.

The cold formability of most beta alloys is generally high and their fracture toughness is generally superior to that of the alpha-beta alloys, although in the high strength condition they can have low ductility. In addition, they have relatively high density. Typical applications include high strength airframe components, fasteners, springs, pipe, and commercial consumer products.

## **Products**

Available mill products vary by alloy but bar, billet, extrusions, strip, sheet, plate, wire, pipe and tubing are available for unalloyed titanium, while some or all of these products are available for titanium alloys. Many grades of titanium and its alloys are also available as castings and most can be forged. Some beta alloys have superior forgeability; sheet can be cold-formed in the solution-treated condition. Ti-6Al-4V is relatively difficult to cold form but is readily hot formed or even superplastically formed.

## **Weldability**

In general, welding of titanium and its alloys can be readily performed but it is necessary to exclude reactive gases, including oxygen and nitrogen from the air, and to maintain cleanliness. Thus weld properties are heavily influenced by welding procedures, especially by the adequacy of inert gas shielding. The GTAW (gas tungsten arc welding) process is common, although GMAW (gas metal arc welding), friction welding, laser welding, resistance welding, plasma arc welding, electron beam welding, and diffusion bonding are all used in some cases. Both alloy composition and microstructure are important in determining weldability, with the presence of beta phase having a deleterious effect. Thus unalloyed titanium and alpha alloys are generally weldable and welded joints generally have acceptable strength and ductility; postweld stress-relief annealing of weldments is recommended. Some alpha-beta alloys, specifically Ti-6Al-4V, are weldable in the annealed condition as well as in the solution treated and partially aged condition (aging can be completed during the post-weld heat treatment). Strongly stabilized alpha-beta alloys can be embrittled by welding, the result of phase transformations occurring in the weld metal or the heat affected zone. Some beta alloys are weldable in the annealed or the solution treated condition.

## **Corrosion Resistance**

Unalloyed titanium, the most corrosion-resistant of the titanium-based materials, is resistant to nitric acid and many different chlorine-bearing environments, including hot chloride solutions. It is also resistant to sulphides. The Pd-bearing unalloyed grades have improved resistance to corrosion in reducing media, so that it can be applied in hydrochloric, phosphoric, and sulphuric acid solutions. Since the corrosion resistance is based on the formation of a stable adherent protective surface oxide

film, corrosion susceptibility can arise if the environment is such that the film cannot regenerate itself when damaged; such a situation can arise for example in the case of crevice corrosion, where oxygen depletion and acidic conditions can occur in confined spaces.

Although titanium and its alloys are generally resistant to stress-corrosion cracking (SCC), problems can arise under some specific service conditions, i.e. particular combinations of material (alloy composition and heat treatment), loading parameters (stress, stress concentrations, loading rate, etc.) and environment (including temperature). Although SCC can be a potential problem in other environments, the following generalizations apply to behaviour in salt solutions. Alloys containing high aluminum and oxygen levels are particularly susceptible to SCC. In near-alpha alloys, treatments which lead to the formation of alpha-2 render the alloy susceptible, for example mill annealed alloys in neutral salt solutions. In alpha-beta alloys, the alpha phase is susceptible so the above factors apply; however, the distribution of beta phase also plays a role in determining susceptibility. Some beta alloys, particularly those in which the beta phase is stabilized by manganese or chromium, are susceptible. Different concentration levels of species in the salt solutions can aggravate or ameliorate SCC susceptibility. Hot salt environments, 220 to 510°C (428 to 950°F), can also give rise to cracking problems in some highly stressed titanium alloys. Beta alloys are much more tolerant of hydrogen.

Hydrogen can have adverse effects on alpha and alpha-beta alloys in situations where brittle titanium hydride forms within the alpha phase under stress. This is a potential problem over a range of temperatures above ambient, and particularly for material in contact with high pressures of gaseous hydrogen.

### **Creep And Oxidation Resistance**

Unalloyed titanium has good creep resistance below 315°C (599°F). Alpha alloys are generally stable for periods of 1000 hours up to 540°C (1004°F), alpha-beta alloys up to about 370°C (698°F) in the mill annealed condition and as high as 425°C (797°F) after heat treatment.

| <b>SAE/AMS SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                                  |
|----------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                     | <b>Title</b>                                                                                     |
| 2249                                                           | Chemical check analysis limits titanium and titanium alloys                                      |
| 2380                                                           | Approval and control of premium-quality titanium alloys                                          |
| 2419                                                           | Cadmium-Titanium plating                                                                         |
| 2444                                                           | Coating, titanium nitride physical vapor deposition                                              |
| 2486                                                           | Conversion coating of titanium alloys fluoride-phosphate type                                    |
| 2488                                                           | Anodic treatment of titanium and titanium alloys                                                 |
| 2631                                                           | Ultrasonic inspection titanium and titanium alloy bar and billet                                 |
| 2642                                                           | Structural examination of titanium alloys etch- anodize inspection procedure                     |
| 2643                                                           | Structural examination of titanium alloys chemical etch inspection procedure                     |
| 2689                                                           | Fusion welding titanium and titanium alloys                                                      |
| 2775                                                           | Case hardening of titanium and titanium alloys                                                   |
| 2801                                                           | Heat treatment of titanium alloy parts                                                           |
| 2809                                                           | Identification titanium and titanium alloy wrought products                                      |
| 4900                                                           | Titanium sheet, strip, and plate commercially pure annealed, 55.0 ksi (379 MPa) yield strength   |
| 4901                                                           | Titanium sheet, strip, and plate commercially pure annealed, 70.0 ksi (485 MPa)                  |
| 4902                                                           | Titanium sheet, strip, and plate commercially pure annealed, 40.0 ksi (276 MPa) yield strength   |
| 4905                                                           | Titanium alloy plate, damage-tolerant grade 6Al-4V, beta annealed                                |
| 4906                                                           | Titanium alloy sheet and strip 6Al-4V, continuously rolled, annealed, noncurrent April 1982      |
| 4907                                                           | Titanium alloy sheet, strip, and plate 6.0Al-4.0V, extra low interstitial annealed               |
| 4908                                                           | Titanium alloy sheet and strip 8Mn annealed, 110,000 psi (760 MPa) yield strength                |
| 4909                                                           | Titanium alloy sheet, strip, and plate 5Al-2.5Sn, extra low interstitial annealed                |
| 4910                                                           | Titanium alloy sheet, strip, and plate 5Al-2.5Sn annealed                                        |
| 4911                                                           | Titanium alloy sheet, strip, and plate 6Al-4V annealed                                           |
| 4912                                                           | Titanium alloy sheet and strip 4Al-3Mo-1V solution heat treated, noncurrent July 81              |
| 4913                                                           | Titanium alloy sheet and strip 4Al-3Mo-1V solution and precipitation treated, noncurrent July 81 |
| 4914                                                           | Titanium alloy cold rolled sheet and strip 15V-3Al-3Cr-3Sn solution heat treated                 |
| 4915                                                           | Titanium alloy sheet, strip, and plate 8Al-1V-1Mo single annealed                                |

| <b>SAE/AMS SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                                                       |
|----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                          |
| 4916                                                                       | Titanium alloy sheet, strip, and plate 8Al-1Mo-1V duplex annealed                                                                     |
| 4917                                                                       | Titanium alloy sheet, strip, and plate 13.5V-11Cr-3.0Al solution heat treated                                                         |
| 4918                                                                       | Titanium alloy sheet, strip, and plate 6Al-6V-2Sn annealed                                                                            |
| 4919                                                                       | Titanium alloy sheet, strip, and plate 6Al-2Sn-4Zr-2Mo-0.08Si duplex annealed                                                         |
| 4920                                                                       | Titanium alloy forgings 6Al-4V alpha-beta or beta processed, annealed                                                                 |
| 4921                                                                       | Titanium bars, wire, forgings, and rings commercially pure 70.0 ksi (483 MPa) yield strength                                          |
| 4922                                                                       | Tubing, seamless, hydraulic, titanium alloy 15V-3.0Cr-3.0Al-3.0 Sn cold worked and precipitation heat treated                         |
| 4924                                                                       | Titanium alloy bars, forgings, and rings 5Al-2.5Sn, extra low interstitial annealed                                                   |
| 4926                                                                       | Titanium alloy bars and rings 5Al-2.5Sn annealed, 110,000 psi (760 MPa) yield strength                                                |
| 4928                                                                       | Titanium alloy bars, wire, forgings, and rings 6Al-4V annealed                                                                        |
| 4930                                                                       | Titanium alloy bars, wire, forgings, and rings 6Al-4V, extra low interstitial annealed                                                |
| 4931                                                                       | Titanium alloy bars, forgings, and rings 6Al-4V extra low interstitial (ELI) duplex annealed, fracture toughness                      |
| 4932                                                                       | Titanium alloy sheet 6Al-4V driver sheet                                                                                              |
| 4933                                                                       | Titanium alloy extrusions and flash welded rings 8Al-1Mo-1V solution heat treated and stabilized                                      |
| 4934                                                                       | Titanium alloy extrusions and flash welded rings 6Al-4V solution heat treated and aged                                                |
| 4935                                                                       | Titanium alloy extrusions and flash welded rings 6Al-4V annealed beta processed                                                       |
| 4936                                                                       | Titanium alloy extrusions and flash welded rings 6Al-6V-2Sn beta extruded plus annealed, heat treatable                               |
| 4937                                                                       | Titanium alloy extrusions and flash welded rings 6Al-6V-2Sn beta extruded plus annealed, heat treatable                               |
| 4941                                                                       | Titanium tubing, welded annealed, 40,000 psi (276 MPa) yield strength                                                                 |
| 4942                                                                       | Titanium tubing, seamless annealed, 40,000 psi (275 MPa) yield strength                                                               |
| 4943                                                                       | Titanium alloy tubing, seamless, hydraulic 3.0Al-2.5V annealed                                                                        |
| 4944                                                                       | Titanium alloy tubing, seamless, hydraulic 3.0Al-2.5V cold worked, stress relieved                                                    |
| 4945                                                                       | Titanium alloy tubing, seamless, hydraulic 3Al-2.5V, texture controlled 105 ksi (724 MPa) yield strength cold worked, stress relieved |
| 4951                                                                       | Titanium welding wire commercially pure environment controlled packaging                                                              |
| 4952                                                                       | Titanium alloy welding wire 6Al-2Sn-4Zr-2Mo                                                                                           |
| 4953                                                                       | Titanium alloy welding wire 5Al-2.5Sn                                                                                                 |
| 4954                                                                       | Titanium alloy welding wire 6Al-4V                                                                                                    |

| <b>SAE/AMS SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                                                                    |
|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                                                       |
| 4955                                                                       | Titanium alloy welding wire 8Al-1Mo-1V                                                                                                             |
| 4956                                                                       | Titanium alloy welding wire 6Al-4V, extra low interstitial environment controlled packaging                                                        |
| 4957                                                                       | Titanium alloy bars and wire 3Al-8V-6Cr-4Mo-4Zr consumable electrode melted cold drawn                                                             |
| 4958                                                                       | Titanium alloy bars and rods 3Al-8V-6Cr-4Mo-4Zr consumable electrode melted solution heat treated and centerless ground                            |
| 4959                                                                       | Titanium alloy wire 13.5V-11Cr-3Al spring temper                                                                                                   |
| 4965                                                                       | Titanium alloy bars, wire, forgings, and rings 6.0Al-4.0V solution and precipitation heat treated                                                  |
| 4966                                                                       | Titanium alloy forgings 5Al-2.5Sn annealed, 110,000 psi (758 MPa) yield strength                                                                   |
| 4967                                                                       | Titanium alloy bars, forgings, and rings 6.0Al-4.0V annealed, heat treatable                                                                       |
| 4970                                                                       | Titanium alloy bars, wire, and forgings 7Al-4Mo solution and precipitation heat treated                                                            |
| 4971                                                                       | Titanium alloy bars, wire, forgings, and rings 6Al-6V-2Sn annealed, heat treatable                                                                 |
| 4972                                                                       | Titanium alloy bars, wire, and rings 8Al-1Mo-1V solution heat treated and stabilized                                                               |
| 4973                                                                       | Titanium alloy forgings 8Al-1Mo-1V solution heat treated and stabilized                                                                            |
| 4974                                                                       | Titanium alloy bars and forgings 11Sn-5.0Zr-2.3Al-1.0Mo-0.21Si solution and precipitation heat treated                                             |
| 4975                                                                       | Titanium alloy bars and rings 6.0Al-2.0Sn-4.0Zr-2.0Mo-0.08Si solution and precipitation heat treated                                               |
| 4976                                                                       | Titanium alloy forgings 6.0Al-2.0Sn-4.0Zr-2.0Mo solution and precipitation heat treated                                                            |
| 4977                                                                       | Titanium alloy bars 11.5Mo-6.0Zr-4.5Sn 1275°-1350°F (690°-730°C) solution heat treated, noncurrent April 1987                                      |
| 4978                                                                       | Titanium alloy bars, wire, forgings, and rings 6Al-6V-2Sn annealed                                                                                 |
| 4979                                                                       | Titanium alloy bars, wire, forgings, and rings 6Al-6V-2Sn solution and precipitation heat treated                                                  |
| 4980                                                                       | Titanium alloy bars 11.5Mo-6.0Zr-4.5Sn 1375°F (745°C) solution heat treated, noncurrent April 1987                                                 |
| 4981                                                                       | Titanium alloy bars, wire, and forgings 6.0Al-2.0Sn-4.0Zr-6.0Mo solution and precipitation heat treated                                            |
| 4982                                                                       | Titanium alloy wire 44.5Cb                                                                                                                         |
| 4983                                                                       | Titanium alloy forgings 10V-2Fe-3Al consumable electrode melted, single solution heat treated and aged 180,000 psi (1240 MPa) tensile strength     |
| 4984                                                                       | Titanium alloy forgings 10V-2Fe-3Al consumable electrode melted, solution heat treated and aged 173,000psi (1195 MPa) tensile strength             |
| 4985                                                                       | Titanium alloy castings, investment or rammed graphite 6Al-4V annealed                                                                             |
| 4986                                                                       | Titanium alloy forgings 10V-2Fe-3Al consumable electrode melted, single solution heat treated and overaged 160,000 psi (1105 MPa) tensile strength |
| 4987                                                                       | Titanium alloy forgings 10V-2Fe-3Al consumable electrode melted, single solution heat treated and overaged 140,000 psi (965 MPa) tensile strength  |
| 4991                                                                       | Titanium alloy castings, investment 6Al-4V annealed                                                                                                |



| <b>SAE/AMS SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                                |
|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                 | <b>Title</b>                                                                                                   |
| 4993                                                                       | Titanium alloy compacts for B-Nuts 6Al-4V blended powder product                                               |
| 4994                                                                       | Titanium alloy powdered metal products 6Al-4V hot isostatically pressed, annealed                              |
| 4995                                                                       | Billets and preforms 5Al-2Sn-2Zr-4Cr-4Mo-0.10O premium quality, powder-metallurgy product, noncurrent Oct 1989 |
| 4996                                                                       | Billets and preforms 6Al-4V premium quality, powder- metallurgy product, noncurrent Oct 1989                   |
| 4997                                                                       | Titanium alloy powder 5Al-2Sn-2Zr-4Cr-4Mo-0.10O premium quality, noncurrent Jan 1992                           |
| 4998                                                                       | Powder 6Al-4V premium quality, noncurrent Oct 1989                                                             |
| 7498                                                                       | Rings, flash welded titanium and titanium alloys                                                               |

| <b>SAE AEROSPACE STANDARDS (AS) - TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                                                                             |
|----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AS</b>                                                            | <b>Title</b>                                                                                                                                |
| 1576B                                                                | Fittings, Welded, Hydraulic, Titanium and Corrosion Resistant Steel, 3000 psi Hydraulic                                                     |
| 1580A                                                                | Ring, Tube Weld, 3000 psi Hydraulic, Titanium                                                                                               |
| 1814B                                                                | Terminology for Titanium Microstructures                                                                                                    |
| 4076                                                                 | Contractile Strain Ratio Testing of Titanium Hydraulic Tubing                                                                               |
| 4194                                                                 | Sheet and Strip Surface Finish Nomenclature                                                                                                 |
| 4568                                                                 | Hose Assembly, PTFE, Aramid Reinforced Standard Duty, 4000/3000 psi, 275°F, Titanium Fittings, Flareless, Straight to Straight              |
| 4569                                                                 | Hose Assembly, PTFE, Aramid Reinforced, Standard Duty, 4000/3000 psi, 275°F, Titanium Fittings, Flareless, Straight to 45°                  |
| 4570                                                                 | Hose Assembly, PTFE, Aramid Reinforced, Standard Duty, 4000/3000 psi, 275°F, Titanium Fittings, Flareless, Straight to 90°                  |
| 4571                                                                 | Hose Assembly, PTFE, Aramid Reinforced, Standard Duty, 4000/3000 psi, 275°F, Titanium Fittings, Flareless, 45° to 90°                       |
| 4572                                                                 | Hose Assembly, PTFE, Aramid Reinforced, Standard Duty, 4000/3000 psi, 275°F, Titanium Fittings, Flareless, 45° to 45°                       |
| 4573                                                                 | Hose Assembly, PTFE, Aramid Reinforced, Standard Duty, 4000/3000 Flareless, 90° to 90°                                                      |
| 4624                                                                 | Hose Assembly, Polytetrafluoroethylene, Aramid Reinforced, Heavy -Duty, 275°F, 3000 psi, Flareless, Titanium Fittings, Straight to Straight |
| 4625                                                                 | Hose Assembly, Polytetrafluoroethylene, Aramid Reinforced, Heavy -Duty, 275°F, 3000 psi, Flareless, Titanium Fittings, Straight to 45°      |
| 4626                                                                 | Hose Assembly, Polytetrafluoroethylene, Aramid Reinforced, Heavy -Duty, 275°F, 3000 psi, Flareless, Titanium Fittings, Straight to 90°      |
| 4627                                                                 | Hose Assembly, Polytetrafluoroethylene, Aramid Reinforced, Heavy -Duty, 275°F, 3000 psi, Flareless, Titanium Fittings, 45° to 45°           |

| <b>SAE AEROSPACE STANDARDS (AS) - TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                                                   |
|----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| <b>AS</b>                                                                        | <b>Title</b>                                                                                                                      |
| 4628                                                                             | Hose Assembly, Polytetrafluoroethylene, Aramid Reinforced, Heavy -Duty, 275°F, 3000 psi, Flareless, Titanium Fittings, 45° to 90° |
| 4629                                                                             | Hose Assembly, Polytetrafluoroethylene, Aramid Reinforced, Heavy -Duty, 275°F, 3000 psi, Flareless, Titanium Fittings, 90° to 90° |
| 7460                                                                             | Bolts and Screws, Titanium Alloy 6Al - 4V Procurement Specification for (Superseding AMS 7460D)                                   |
| 7461                                                                             | Bolts and Screws, Titanium Alloy 6Al - 4V Fatigue-Rated, Procurement Specification for (Superseding AMS 7461C)                    |

| <b>SAE AEROSPACE RECOMMENDED PRACTICES (ARP) - TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                            |
|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| <b>ARP</b>                                                                        | <b>Title</b>                                                                               |
| 1333                                                                              | Nondestructive Testing of Electron Beam Welded Joints in Titanium-Base Alloys              |
| 1795                                                                              | Stress-Corrosion of Titanium Alloys Effect of Cleaning Agents on Aircraft Engine Materials |
| 1843                                                                              | Surface Preparation for Structural Adhesive Bonding Titanium Alloy Parts                   |
| 1932                                                                              | Anodize Treatment of Titanium and Titanium Alloys pH 12.4 Maximum                          |
| 4146                                                                              | Coiled Tubing - Titanium Alloy, Hydraulic Applications                                     |
| 982B                                                                              | Minimizing Stress- Corrosion Cracking in Wrought Titanium Alloy Products                   |

| <b>SAE AEROSPACE TOLERANCE SPECIFICATIONS FOR TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                                                  |
|----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                                       | <b>Title</b>                                                                                                     |
| 2241                                                                             | Tolerances, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire           |
| 2242                                                                             | Tolerances, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Sheet, Strip, and Plate |
| 2244                                                                             | Tolerances, Titanium and Titanium Alloy Tubing                                                                   |
| 2245                                                                             | Tolerances, Titanium and Titanium Alloy Extruded Bars, Rods, and Shapes                                          |

| <b>ASTM SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                                                     |
|-------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| <b>ASTM</b>                                                 | <b>Title</b>                                                                                                        |
| B 265                                                       | Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate                                      |
| B 299                                                       | Standard Specification for Titanium Sponge                                                                          |
| B 337                                                       | Standard Specification for Seamless and Welded Titanium and Titanium Alloy Pipe                                     |
| B 338                                                       | Standard Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers |
| B 348                                                       | Standard Specification for Titanium and Titanium Alloy Bars and Billets                                             |
| B 363                                                       | Standard Specification for Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings               |
| B 367                                                       | Standard Specification for Titanium and Titanium Alloy Castings                                                     |
| B 381                                                       | Standard Specification for Titanium and Titanium Alloy Forgings                                                     |
| B 481                                                       | Standard Practice for Preparation of Titanium and Titanium Alloys for Electroplating                                |
| B 600                                                       | Standard Guide for Descaling and Cleaning Titanium and Titanium Alloy Surfaces                                      |
| B 817                                                       | Standard Specification for Powder Metallurgy (P/M) Titanium Alloy Structural Components                             |

| <b>ASTM TESTING STANDARDS - TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                                                           |
|----------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| <b>ASTM</b>                                                    | <b>Title</b>                                                                                                              |
| E 120                                                          | Standard Test Methods for Chemical Analysis of Titanium and Titanium Alloys                                               |
| E 539                                                          | Standard Test Method for X-Ray Emission Spectrometric Analysis of 6Al-4V Titanium Alloy                                   |
| E 1320                                                         | Standard Reference Radiographs for Titanium Castings                                                                      |
| E 1409                                                         | Standard Test Method for Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique        |
| E 1447                                                         | Standard Test Method for Determination of Hydrogen in Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method |
| F 945                                                          | Standard Test Method for Stress-Corrosion of Titanium Alloys by Aircraft Engine Cleaning Materials                        |
| G 41                                                           | Standard Practice for Determining Cracking Susceptibility of Metals Exposed Under Stress to a Hot Salt Environment        |

| <b>SURGICAL IMPLANT INTERNATIONAL SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                                          |
|---------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| <b>Standard</b>                                                                       | <b>Title</b>                                                                                             |
| ASTM F 67                                                                             | Standard Specification for Unalloyed Titanium for Surgical Implant Applications                          |
| ASTM F 136                                                                            | Standard Specification for Wrought Titanium 6Al-4V ELI Alloy for Surgical Implant Applications           |
| ASTM F 620                                                                            | Standard Specification for Titanium 6Al-4V ELI Alloy Forgings for Surgical Implants                      |
| ASTM F 1295                                                                           | Standard Specification for Wrought Titanium-6 Aluminum-7 Niobium Alloy for Surgical Implant Applications |
| AS 2320.2                                                                             | Metals for the Manufacture of Surgical Implants - Part 2: Unalloyed Titanium                             |
| AS 2320.3                                                                             | Metals for the Manufacture of Surgical Implants - Part 3: Wrought Titanium 6-Aluminium 4-Vanadium Alloy  |
| CAN3-Z310.1 -78                                                                       | Titanium Alloy (6% Aluminum and 4% Vanadium) for Surgical Implants                                       |
| CAN/CSA-Z310.7                                                                        | Orthopaedic Implant Standards                                                                            |
| BS 7252: Part 2                                                                       | Metallic Materials for Surgical Implants Part 2: Unalloyed Titanium                                      |
| BS 7252: Part 3                                                                       | Metallic Materials for Surgical Implants Part 3: Wrought Titanium 6 - Aluminium 4-Vanadium Alloy         |
| BS 7254: Section 6.2                                                                  | Orthopaedic Implants Part 6: Forgings Section 6.2: Method for Specifying Forgings                        |
| DIN 5832 Part 2                                                                       | Implants for Surgery - Metallic Materials - Part II: Unalloyed Titanium                                  |
| DIN 5832 Part 3                                                                       | Implants for Surgery - Metallic Materials - Part 3: Wrought Titanium 6-Aluminium 4-Vanadium Alloy        |

| <b>ASME SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                                            |
|-------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| <b>ASME</b>                                                 | <b>Title</b>                                                                                               |
| SB-265                                                      | Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate                                      |
| SB-337                                                      | Specification for Seamless and Welded Titanium and Titanium Alloy Pipe                                     |
| SB-338                                                      | Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers |
| SB-348                                                      | Specification for Titanium and Titanium Alloy Bars and Billets                                             |
| SB-363                                                      | Specification for Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings               |
| SB-367                                                      | Specification for Titanium and Titanium Alloy Castings                                                     |
| SB-381                                                      | Specification for Titanium and Titanium Alloy Forgings                                                     |

| AWS SPECIFICATIONS - TITANIUM & TITANIUM ALLOYS |                                                                                |
|-------------------------------------------------|--------------------------------------------------------------------------------|
| AWS                                             | Title                                                                          |
| A5.16                                           | Specification for Titanium and Titanium Alloy Welding Electrodes and Rods      |
| D10.6                                           | Recommended Practices for Gas Tungsten Arc Welding of Titanium Pipe and Tubing |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - TITANIUM & TITANIUM ALLOYS |                     |                            |                                                                                                                                                            |                                                                                        |                |
|-----------------------------------------------------------------------|---------------------|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------|
| UNS                                                                   | SAE/AMS             | MILITARY                   | ASTM                                                                                                                                                       | ASME                                                                                   | AWS            |
| R50100                                                                | ---                 | ---                        | ---                                                                                                                                                        | SFA-5.16 (ERTi-1)                                                                      | A5.16 (ERTi-1) |
| R50120                                                                | ---                 | ---                        | ---                                                                                                                                                        | SFA-5.16 (ERTi-2)                                                                      | A5.16 (ERTi-2) |
| R50125                                                                | 4951                | ---                        | ---                                                                                                                                                        | SFA-5.16 (ERTi-3)                                                                      | A5.16 (ERTi-3) |
| R50130                                                                | ---                 | ---                        | ---                                                                                                                                                        | SFA-5.16 (ERTi-4)                                                                      | A5.16 (ERTi-4) |
| R50250                                                                | ---                 | T-81556, T-81915           | B 265 grade 1, B 337 grade 1,<br>B 338 grade 1, B 348 grade 1,<br>B 381 grade F-1, F 67 grade 1,<br>F 467 alloy Ti 1, F 468 alloy Ti 1                     | SB-265 grade 1, SB-337 grade 1,<br>SB-338 grade 1, SB-348 grade 1,<br>SB-381 grade F-1 | ---            |
| R50400                                                                | 4902, 4941,<br>4942 | T-9046, T-81556            | B 265 grade 2, B 337 grade 2,<br>B 338 grade 2, B 348 grade 2,<br>B 367 grade C-2,<br>B 381 grade F-2, F 67 grade 2,<br>F 467 alloy Ti 2, F 468 alloy Ti 2 | SB-265 grade 2, SB-337 grade 2,<br>SB-338 grade 2, SB-348 grade 2,<br>SB-381 grade F-2 | ---            |
| R50550                                                                | 4900                | T-9046, T-81556            | B 265 grade 3, B 337 grade 3,<br>B 338 grade 3, B 348 grade 3,<br>B 367 grade C-3,<br>B 381 grade F-3, F 67 grade 3                                        | SB-265 grade 3, SB-337 grade 3,<br>SB-338 grade 3, SB-348 grade 3,<br>SB-381 grade F-3 | ---            |
| R50700                                                                | 4901                | T-9046, T-9047,<br>F-83142 | B 265 grade 4, B 348 grade 4,<br>B 381 grade F-4, F 67 grade 4,<br>F 467 alloy Ti 4, F 468 alloy Ti 4                                                      | ---                                                                                    | ---            |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - TITANIUM & TITANIUM ALLOYS (Continued) |                     |                                                  |                                                                                                                                                          |                                                                                             |                   |
|-----------------------------------------------------------------------------------|---------------------|--------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-------------------|
| UNS                                                                               | SAE/AMS             | MILITARY                                         | ASTM                                                                                                                                                     | ASME                                                                                        | AWS               |
| R52250                                                                            | ---                 | ---                                              | B 265 grade 11, B 337 grade 11,<br>B 338 grade 11, B 348 grade 11,<br>B 381 grade F-11                                                                   | SB-265 grade 11                                                                             | ---               |
| R52400                                                                            | ---                 | ---                                              | B 265 grade 7, B 337 grade 7,<br>B 338 grade 7, B 348 grade 7,<br>B 381 grade F-7, F 467 alloy Ti 7,<br>F 468 alloy Ti 7                                 | SB-265 grade 7, SB-337 grade 7,<br>SB-338 grade 7, SB-348 grade 7,<br>SB-381 grade F-7      | ---               |
| R52401                                                                            | ---                 | ---                                              | B 265 grades 7, 11, B 337 grades 7, 11,<br>B 338 grades 7, 11, B 348 grades 7, 11,<br>B 367 grade Ti-Pd7B,<br>B 367 grade Ti-Pd8A,<br>B 381 grades 7, 11 | SFA-5.16 (ERTi-7)                                                                           | A5.16 (ERTi-7)    |
| R52550                                                                            | ---                 | ---                                              | B 367 grade C-2, B 367 grade C-3                                                                                                                         | ---                                                                                         | ---               |
| R52700                                                                            | ---                 | ---                                              | ---                                                                                                                                                      | ---                                                                                         | ---               |
| R53400                                                                            | ---                 | ---                                              | B 265 grade 12, B 337 grade 12,<br>B 338 grade 12, B 348 grade 12,<br>B 381 grade F-12                                                                   | SB-265 grade 12, SB-337 grade 12,<br>SB-338 grade 12, SB-348 grade 12,<br>SB-381 grade F-12 | ---               |
| R53401                                                                            | ---                 | ---                                              | B 265 grade 12, B 337 grade 12,<br>B 338 grade 12, B 348 grade 12,<br>B 381 grade 12                                                                     | SFA-5.16 (ERTi-12)                                                                          | A5.16 (ERTi-12)   |
| R54520                                                                            | 4910, 4926,<br>4966 | T-9046, T-9047,<br>T-81556, T-81915,<br>F-83142, | B 265 grade 6, B 348 grade 6,<br>B 367 grade C-6, B 381 grade F-6                                                                                        | ---                                                                                         | ---               |
| R54521                                                                            | 4909, 4924          | T-9046, T-9047,<br>T-81556, F-83142              | ---                                                                                                                                                      | ---                                                                                         | ---               |
| R54522                                                                            | 4953                | ---                                              | ---                                                                                                                                                      | SFA-5.16 (ERTi-6)                                                                           | A5.16 (ERTi-6)    |
| R54523                                                                            | ---                 | ---                                              | ---                                                                                                                                                      | SFA-5.16 (ERTi-6ELI)                                                                        | A5.16 (ERTi-6ELI) |
| R54550                                                                            | ---                 | F-83142                                          | ---                                                                                                                                                      | ---                                                                                         | ---               |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - TITANIUM & TITANIUM ALLOYS (Continued) |                                                                                                |                                                 |                                                                   |                                            |                                      |
|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|-------------------------------------------------|-------------------------------------------------------------------|--------------------------------------------|--------------------------------------|
| UNS                                                                               | SAE/AMS                                                                                        | MILITARY                                        | ASTM                                                              | ASME                                       | AWS                                  |
| R54560                                                                            | ---                                                                                            | T-9046, T-9047                                  | ---                                                               | ---                                        | ---                                  |
| R54620                                                                            | 4919, 4952,<br>4975, 4976                                                                      | T-9046, T-9047,<br>T-81915, F-83142             | ---                                                               | ---                                        | ---                                  |
| R54621                                                                            | ---                                                                                            | ---                                             | ---                                                               | ---                                        | ---                                  |
| R54624                                                                            | ---                                                                                            | ---                                             | B 265, B 337, B 338                                               | ---                                        | ---                                  |
| R54790                                                                            | 4974                                                                                           | T-9047, F-83142                                 | ---                                                               | ---                                        | ---                                  |
| R54810                                                                            | 4915, 4916,<br>4933, 4955                                                                      | T-9046, T-9047,<br>T-81556, F-83142             | ---                                                               | ---                                        | ---                                  |
| R56080                                                                            | 4908                                                                                           | T-9046                                          | ---                                                               | ---                                        | ---                                  |
| R56210                                                                            | ---                                                                                            | T-9046, T-9047                                  | ---                                                               | SFA-5.16 (ERTi-15)                         | A5.16 (ERTi-15)                      |
| R56260                                                                            | 4981                                                                                           | T-9047                                          | ---                                                               | ---                                        | ---                                  |
| R56320                                                                            | 4943, 4944                                                                                     | T-9046, T-9047                                  | B 265 grade 9, B 337 grade 9,<br>B 338 grade 9, B 348 grade 9     | SFA-5.16 (ERTi-9)                          | A5.16 (ERTi-9)                       |
| R56320                                                                            | ---                                                                                            | ---                                             | B 381 grade F-9                                                   | ---                                        | --                                   |
| R56321                                                                            | ---                                                                                            | ---                                             | ---                                                               | SFA-5.16 (ERTi-9ELI),<br>SFA-5.16 (ERTi-5) | A5.16 (ERTi-9ELI),<br>A5.16 (ERTi-5) |
| R56400                                                                            | 4905, 4906,<br>4911, 4931,<br>4934, 4935,<br>4954, 4965,<br>4967, 4920,<br>4928, 4930,<br>4993 | T-9046, T-9047,<br>T-81556, T-81915,<br>F-83142 | B 265 grade 5, B 348 grade 5,<br>B 367 grade C-5, B 381 grade F-5 |                                            |                                      |
| R56401 <sup>a</sup>                                                               | 4907, 4985,<br>4991, 4996,<br>4998                                                             | T-9046, T-9047,<br>T-81556, F-83142             | ---                                                               | ---                                        | ---                                  |
| R56402                                                                            | 4956                                                                                           | ---                                             | ---                                                               | SFA-5.16 (ERTi-5ELI)                       | A5.16 (ERTi-5ELI)                    |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                           |                                      |                                                                     |             |            |
|----------------------------------------------------------------------------------------------|---------------------------|--------------------------------------|---------------------------------------------------------------------|-------------|------------|
| <b>UNS</b>                                                                                   | <b>SAE/AMS</b>            | <b>MILITARY</b>                      | <b>ASTM</b>                                                         | <b>ASME</b> | <b>AWS</b> |
| R56410                                                                                       | 4984, 4986,<br>4987       | ---                                  | ---                                                                 | ---         | ---        |
| R56430                                                                                       | 4912, 4913                | T-9046                               | ---                                                                 | ---         | ---        |
| R56620                                                                                       | 4918                      | T-9046                               | ---                                                                 | ---         | ---        |
| R56620                                                                                       | 4936, 4971,<br>4978, 4979 | T-9047, T-81556,<br>T-81556, F-83142 | ---                                                                 | ---         | ---        |
| R56740                                                                                       | 4970, 4980                | T-9047, T-9047,<br>F-83142           | B 337 grade 10, B 338 grade 10,<br>B 348 grade 10, B 381 grade F-10 | ---         | ---        |
| R58010                                                                                       | 4917, 4959                | T-9046, T-9047,<br>F-83142           | ---                                                                 | ---         | ---        |
| R58030                                                                                       | 4977                      | T-9046                               | B 265 grade 10                                                      | ---         | ---        |
| R58153                                                                                       | 4914                      | ---                                  | ---                                                                 | ---         | ---        |
| R58450                                                                                       | 4982                      | ---                                  | ---                                                                 | ---         | ---        |
| R58640                                                                                       | 4957, 4958                | T-9046, T-9047,<br>F-83142           | ---                                                                 | ---         | ---        |
| R58650                                                                                       | 4995, 4997                | ---                                  | ---                                                                 | ---         | ---        |
| R58820                                                                                       | ---                       | T-9046, T-9047,<br>F-83142           | ---                                                                 | ---         | ---        |

a. Also includes former SAE J775 grade XEV-J.

This cross-reference table lists the basic specification or standard number, and since these standards are constantly being revised, it should be kept in mind that they are presented herein as a guide and may not reflect the latest revision.



| <b>COMMON NAMES OF TITANIUM &amp; TITANIUM ALLOYS WITH AMS No., UNS No. &amp; FORM</b> |                  |                     |
|----------------------------------------------------------------------------------------|------------------|---------------------|
| <b>Common Name</b>                                                                     | <b>AMS - UNS</b> | <b>Form</b>         |
| Ti-Unalloyed/0.26-0.35 O                                                               | 4900 - R50550    | Sheet, Strip, Plate |
| Ti-Unalloyed/0.36-0.40 O                                                               | 4901 - R50700    | Sheet, Strip, Plate |
| Ti-Unalloyed/0.19-0.25 O                                                               | 4902 - R50400    | Sheet, Strip, Plate |
| Ti-6Al-4V                                                                              | 4905 - R56400    | Plate               |
| Ti-6Al-4V                                                                              | 4906 - R56400    | Sheet, Strip        |
| Ti-6Al-4V ELI                                                                          | 4907 - R56401    | Sheet, Strip, Plate |
| Ti-8Mn                                                                                 | 4908 - R56080    | Sheet, Strip        |
| Ti-5Al-2.5Sn ELI                                                                       | 4909 - R54521    | Sheet, Strip, Plate |
| Ti-5Al-2.5Sn                                                                           | 4910 - R54520    | Sheet, Strip, Plate |
| Ti-6Al-4V                                                                              | 4911 - R56400    | Sheet, Strip, Plate |
| Ti-15V-3Cr-3Sn-3Al                                                                     | 4914 - R58153    | Sheet, Strip        |
| Ti-8Al-1Mo-1V                                                                          | 4915 - R54810    | Sheet, Strip, Plate |
| Ti-8Al-1Mo-1V                                                                          | 4916 - R54810    | Sheet, Strip, Plate |
| Ti-13V-11Cr-3Al                                                                        | 4917 - R58010    | Sheet, Strip, Plate |
| Ti-6Al-6V-2Sn                                                                          | 4918 - R56620    | Sheet, Strip, Plate |
| Ti-6Al-2Sn-4Zr-2Mo                                                                     | 4919 - R54620    | Sheet, Strip, Plate |
| Ti-6Al-4V                                                                              | 4920 - R56400    | Forging,            |
| Ti-Unalloyed/0.36-0.40 O                                                               | 4921 - R50700    | Bar, Forging, Ring  |
| Ti-5Al-2.5Sn ELI                                                                       | 4924 - R54521    | Bar, Forging, Ring  |
| Ti-5Al-2.5Sn                                                                           | 4926 - R54520    | Bar, Forging        |
| Ti-6Al-4V                                                                              | 4928 - R56400    | Bar, Forging, Ring  |
| Ti-6Al-4V ELI                                                                          | 4930 - R56401    | Bar, Forging, Ring  |
| Ti-6Al-4V ELI                                                                          | 4931 - R56401    | Bar, Forging, Ring  |
| Ti-8Al-1Mo-1V                                                                          | 4933 - R54810    | Extrusion, Ring     |
| Ti-6Al-4V                                                                              | 4934 - R56400    | Extrusion, Ring     |
| Ti-6Al-4V                                                                              | 4935 - R56400    | Extrusion, Ring     |
| Ti-6Al-6V-2Sn                                                                          | 4936 - R56620    | Extrusion, Ring     |

| <b>COMMON NAMES OF TITANIUM &amp; TITANIUM ALLOYS WITH AMS No., UNS No. &amp; FORM (Continued)</b> |                  |                    |
|----------------------------------------------------------------------------------------------------|------------------|--------------------|
| <b>Common Name</b>                                                                                 | <b>AMS - UNS</b> | <b>Form</b>        |
| Ti-Unalloyed/0.19-0.25 O                                                                           | 4941 - R50400    | Welded Tubing      |
| Ti-Unalloyed/0.19-0.25 O                                                                           | 4942 - R50400    | Seamless Tubing    |
| Ti-3Al-2.5V                                                                                        | 4943 - R56320    | Seamless Tubing    |
| Ti-3Al-2.5V                                                                                        | 4944 - R56320    | Seamless Tubing    |
| Ti-3Al-2.5V                                                                                        | 4945 - R56320    | Seamless Tubing    |
| Ti-Unalloyed/0.10-0.18 O                                                                           | 4951 - R50550    | Wire               |
| Ti-6Al-2Sn-4Zr-2Mo                                                                                 | 4952 - R54620    | Wire               |
| Ti-5Al-2.5Sn                                                                                       | 4953 - R54520    | Wire               |
| Ti-6Al-4V                                                                                          | 4954 - R56400    | Wire               |
| Ti-8Al-1Mo-1V                                                                                      | 4955 - R54810    | Wire               |
| Ti-6Al-4V ELI                                                                                      | 4956 - R56402    | Wire               |
| Ti-3Al-8V-6Cr-4Mo-4Zr                                                                              | 4957 - R58640    | Bar, Wire          |
| Ti-3Al-8V-6Cr-4Mo-4Zr                                                                              | 4958 - R58640    | Bar, Rod           |
| Ti-13V-11Cr-3Al                                                                                    | 4959 - R58010    | Wire               |
| Ti-6Al-4V                                                                                          | 4965 - R56400    | Bar, Forging, Ring |
| Ti-5Al-2.5Sn                                                                                       | 4966 - R54520    | Forging,           |
| Ti-6Al-4V                                                                                          | 4967 - R56400    | Bar, Forging, Ring |
| Ti-7Al-4Mo                                                                                         | 4970 - R56740    | Bar, Forging,      |
| Ti-6Al-6V-2Sn                                                                                      | 4971 - R56620    | Bar, Forging, Ring |
| Ti-8Al-1Mo-1V                                                                                      | 4972 - R54810    | Bar, Ring          |
| Ti-8Al-1Mo-1V                                                                                      | 4973 - R54810    | Forging            |
| Ti-11Sn-5Zr-2Al-1Mo                                                                                | 4974 - R54790    | Bar, Forging       |
| Ti-6Al-2Sn-4Zr-2Mo-0.10Si                                                                          | 4975 - R54620    | Bar, Ring          |
| Ti-6Al-2Sn-4Zr-2Mo                                                                                 | 4976 - R54620    | Forging            |
| Ti-6Al-6V-2Sn                                                                                      | 4978 - R56620    | Bar, Forging, Ring |
| Ti-6Al-6V-2Sn                                                                                      | 4979 - R56620    | Bar, Forging, Ring |
| Ti-6Al-2Sn-4Zr-6Mo                                                                                 | 4981 - R56260    | Bar, Forging       |

| <b>COMMON NAMES OF TITANIUM &amp; TITANIUM ALLOYS WITH AMS No., UNS No. &amp; FORM (Continued)</b> |                  |                        |
|----------------------------------------------------------------------------------------------------|------------------|------------------------|
| <b>Common Name</b>                                                                                 | <b>AMS - UNS</b> | <b>Form</b>            |
| Ti-44.5Cb                                                                                          | 4982 - R58450    | Wire                   |
| Ti-10V-2Fe-3Al                                                                                     | 4983 - R56410    | Forging                |
| Ti-10V-2Fe-3Al                                                                                     | 4984 - R56410    | Forging                |
| Ti-6Al-4V                                                                                          | 4985 - R56401    | Casting                |
| Ti-10V-2Fe-3Al                                                                                     | 4986 - R56410    | Forging                |
| Ti-10V-2Fe-3Al                                                                                     | 4987 - R56410    | Forging                |
| Ti-6Al-4V                                                                                          | 4991 - R56401    | Casting                |
| Ti-6Al-4V                                                                                          | 4993 - R56400    | Powder Compact         |
| Ti-6Al-4V                                                                                          | 4994 - R56400    | Powder product         |
| Ti-5Al-2Sn-2Zr-4Cr-4Mo                                                                             | 4995 - R58650    | Powder Product, Billet |
| Ti-6Al-4V                                                                                          | 4996 - R56401    | Powder Product, Billet |
| Ti-5Al-2Sn-2Zr-4Cr-4Mo                                                                             | 4997 - R58650    | Powder                 |
| Ti-6Al-4V                                                                                          | 4998 - R56401    | Powder                 |

| <b>BRITISH BSI AEROSPACE SERIES SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS (TA)</b> |                                                                                                                         |
|------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                                                | <b>Title</b>                                                                                                            |
| 2TA 1                                                                                    | Sheet and strip of commercially pure titanium (tensile strength 290-420 MPa)                                            |
| 2TA 2                                                                                    | Sheet and strip of commercially pure titanium (tensile strength 390-540 N/mm <sup>2</sup> )                             |
| 2TA 3                                                                                    | Bar and section for machining of commercially pure titanium (tensile strength 390-540 N/mm <sup>2</sup> ) (obsolescent) |
| 2TA 4                                                                                    | Forging stock of commercially pure titanium (tensile strength 390-540 N/mm <sup>2</sup> ) (obsolescent)                 |
| 2TA 5                                                                                    | Forgings of commercially pure titanium (tensile strength 390-540 N/mm <sup>2</sup> ) (obsolescent)                      |
| 2TA 6                                                                                    | Sheet and strip of commercially pure titanium (tensile strength 570-730 N/mm <sup>2</sup> )                             |
| 2TA 7                                                                                    | Bar and section for machining of commercially pure titanium (tensile strength 540-740 N/mm <sup>2</sup> )               |
| 2TA 8                                                                                    | Forging stock of commercially pure titanium (tensile strength 540-740 N/mm <sup>2</sup> )                               |

| <b>BRITISH BSI AEROSPACE SERIES SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS (TA) (Continued)</b> |                                                                                                                                                                                                                                           |
|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                                                            | <b>Title</b>                                                                                                                                                                                                                              |
| 2TA 9                                                                                                | Forgings of commercially pure titanium (tensile strength 540-740 N/mm <sup>2</sup> )                                                                                                                                                      |
| 2TA 10                                                                                               | Sheet of titanium-aluminium-vanadium alloy (tensile strength 960-1270 MPa)                                                                                                                                                                |
| 2TA 11                                                                                               | Bar and section for machining of titanium-aluminium-vanadium alloy (tensile strength 900-1160 MPa) (limiting ruling section 150 mm)                                                                                                       |
| 2TA 12                                                                                               | Forging stock of titanium-aluminium-vanadium alloy (tensile strength 900-1160 MPa) (limiting ruling section 150 mm)                                                                                                                       |
| 2TA 13                                                                                               | Forgings of titanium-aluminum-vanadium alloy (tensile strength 900-1160 MPa) (limiting ruling section 150mm)                                                                                                                              |
| 2TA 21                                                                                               | Sheet and strip of titanium-copper alloy (tensile strength 540-700 N/mm <sup>2</sup> )                                                                                                                                                    |
| 2TA 22                                                                                               | Bar and section for machining of titanium-copper alloy (tensile strength 540-770 N/mm <sup>2</sup> )                                                                                                                                      |
| 2TA 23                                                                                               | Forging stock of titanium-copper alloy (tensile strength 540-770 N/mm <sup>2</sup> )                                                                                                                                                      |
| 2TA 24                                                                                               | Forgings of titanium-copper alloy (tensile strength 540-770 N/mm <sup>2</sup> )                                                                                                                                                           |
| 2TA 28                                                                                               | Forging stock and wire of titanium-aluminium-vanadium alloy (tensile strength 1100-1300 MPa) (limiting ruling section 20 mm) (primarily intended for the manufacture of fasteners complying with the requirements of the 'A' series of BS |
| TA 38                                                                                                | Bar for machining of titanium-aluminium-molybdenum-tin-silicon-carbon alloy (tensile strength 1250-1420 N/mm <sup>2</sup> ) (limiting ruling section 25 mm)                                                                               |
| TA 39                                                                                                | Forging stock of titanium-aluminium-molybdenum-tin-silicon-carbon alloy (tensile strength 1250-1420 N/mm <sup>2</sup> ) (limiting ruling section 25 mm)                                                                                   |
| TA 40                                                                                                | Bar for machining of titanium-aluminium-molybdenum-tin-silicon-carbon alloy (tensile strength 1205-1375 N/mm <sup>2</sup> ) (limiting ruling section over 25 mm up to and including 75 mm)                                                |
| TA 41                                                                                                | Forging stock of titanium-aluminium-molybdenum-tin-silicon-carbon alloy (tensile strength 1205-1375 N/mm <sup>2</sup> ) (limiting ruling section over 25 mm up to and including 75 mm)                                                    |
| TA 42                                                                                                | Forgings of titanium-aluminium-molybdenum-tin-silicon-carbon alloy (tensile strength 1205-1375 N/mm <sup>2</sup> ) (limiting ruling section over 25 mm up to and including 75 mm)                                                         |
| TA 43                                                                                                | Forging stock of titanium-aluminium-zirconium-molybdenum-silicon alloy (tensile strength 990-1140 N/mm <sup>2</sup> ) (limiting ruling section 65 mm)                                                                                     |
| TA 44                                                                                                | Forgings of titanium-aluminium-zirconium-molybdenum-silicon alloy (tensile strength 990-1140 N/mm <sup>2</sup> ) (limiting ruling section 65 mm)                                                                                          |
| TA 45                                                                                                | Bar and section for machining of titanium-aluminium-molybdenum-tin-silicon alloy (tensile strength 1100-1280 N/mm <sup>2</sup> ) (limiting ruling section 25 mm)                                                                          |
| TA 46                                                                                                | Bar and section for machining of titanium-aluminium-molybdenum-tin-silicon alloy (tensile strength 1050-1220 N/mm <sup>2</sup> ) (limiting ruling section over 25 mm up to and including 100 mm)                                          |

| <b>BRITISH BSI AEROSPACE SERIES SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS (TA) (Continued)</b> |                                                                                                                                                                                                   |
|------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                                                            | <b>Title</b>                                                                                                                                                                                      |
| TA 47                                                                                                | Forging stock of titanium-aluminium-molybdenum-tin-silicon alloy (tensile strength 1050-1220 N/mm <sup>2</sup> ) (limiting ruling section 100 mm)                                                 |
| TA 48                                                                                                | Forgings of titanium-aluminium-molybdenum-tin-silicon alloy (tensile strength 1050-1200 N/mm <sup>2</sup> ) (limiting ruling section 100 mm)                                                      |
| TA 49                                                                                                | Bar and section for machining of titanium-aluminium-molybdenum-tin-silicon alloy (tensile strength 1000-1200 N/mm <sup>2</sup> ) (limiting ruling section over 100 mm up to and including 150 mm) |
| TA 50                                                                                                | Forging stock of titanium-aluminium-molybdenum-tin-silicon alloy (tensile strength 1000-1200 N/mm <sup>2</sup> ) (limiting ruling section over 100 mm up to and including 150 mm)                 |
| TA 51                                                                                                | Forgings of titanium-aluminium-molybdenum-tin-silicon alloy (tensile strength 1000-1200 N/mm <sup>2</sup> ) (limiting ruling section over 100 mm Up to and including 150 mm)                      |
| TA 52                                                                                                | Sheet and strip of titanium-copper alloy (tensile strength 690-920 N/mm <sup>2</sup> )                                                                                                            |
| TA 53                                                                                                | Bar and section for machining of titanium-copper alloy (tensile strength 650-880 N/mm <sup>2</sup> ) (limiting ruling section 75 mm)                                                              |
| TA 54                                                                                                | Forging stock of titanium-copper alloy (tensile strength 650-880 N/mm <sup>2</sup> ) (limiting ruling section 75 mm)                                                                              |
| TA 55                                                                                                | Forgings of titanium-copper alloy (tensile strength 650-880 N/mm <sup>2</sup> ) (limiting ruling section 75 mm)                                                                                   |
| TA 56                                                                                                | Plate of titanium-aluminium-vanadium alloy (tensile strength 895-1150 MPa) (maximum thickness 100 mm)                                                                                             |
| TA 57                                                                                                | Plate of titanium-aluminium-molybdenum-tin-silicon (tensile strength 1030-1220 MPa) (maximum thickness 65 mm)                                                                                     |
| TA 58                                                                                                | Plate of titanium-copper alloy (tensile strength 520-640 MPa) (maximum thickness 10 mm)                                                                                                           |
| TA 59                                                                                                | Sheet and strip of titanium-alumimum-vanadium alloy (tensile strength 920 MPa to 1180 MPa)                                                                                                        |
| 2TA 100                                                                                              | Procedure for inspection and testing of wrought titanium and titanium alloys                                                                                                                      |
| A 101                                                                                                | General requirements for titanium bolts                                                                                                                                                           |
| A254-A 259                                                                                           | Hexagonal head titanium alloy bolts 160 000 Lbf/in <sup>2</sup> (1100 MPa)                                                                                                                        |
| A266-A 271                                                                                           | Specification for 100° countersunk head titanium alloy bolts 160 000 lbf/in <sup>2</sup> (1100 MPa) with Hi-torque speed drive recesses                                                           |
| M 58                                                                                                 | Anodic coating of titanium and titanium alloys by the sulphuric acid process                                                                                                                      |
| BSEN 2497                                                                                            | Dry abrasive blasting of titanium and titanium alloys                                                                                                                                             |

| <b>GERMAN DIN SPECIFICATIONS- TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                                                                                                                                                     |
|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                       | <b>Title</b>                                                                                                                                                                                                        |
| 1737 Part 1                                                      | Filler metals for welding titanium and titanium-palladium alloys; chemical composition, technical delivery conditions                                                                                               |
| 9430                                                             | Aerospace; sampling of semi-finished products in light metals; titanium and titanium alloys                                                                                                                         |
| 17850                                                            | Titanium; chemical composition                                                                                                                                                                                      |
| 17851                                                            | Titanium alloys; chemical composition                                                                                                                                                                               |
| 17860                                                            | Titanium and titanium alloy plate, sheet and strip; technical delivery conditions                                                                                                                                   |
| 17861                                                            | Seamless circular titanium and titanium alloy tubes; technical delivery conditions                                                                                                                                  |
| 17862                                                            | Rods of titanium and wrought titanium alloys                                                                                                                                                                        |
| 17862 <sup>a</sup>                                               | Titanium and titanium alloy bars; technical conditions of delivery                                                                                                                                                  |
| 17863                                                            | Wire of titanium                                                                                                                                                                                                    |
| 17864 <sup>a</sup>                                               | Titanium and titanium alloys, die forgings and handforgings; technical conditions of delivery                                                                                                                       |
| 17864                                                            | Forging of titanium and wrought titanium alloys (open die and drop forgings)                                                                                                                                        |
| 17865                                                            | Titanium and titanium alloy investment castings and rammed graphite castings; technical delivery conditions                                                                                                         |
| 17866                                                            | Welded circular titanium and titanium alloy tubes; technical delivery conditions                                                                                                                                    |
| 17869                                                            | Material properties of titanium and titanium alloys; additional data                                                                                                                                                |
| 29783                                                            | Aerospace; precision castings of titanium and titanium alloys; technical specification                                                                                                                              |
| 65039                                                            | Aerospace; sheets, plates and strips of titanium and titanium alloys; technical specification                                                                                                                       |
| 65083                                                            | Aerospace; heat treatment of castings titanium and titanium alloys                                                                                                                                                  |
| 65084                                                            | Aerospace; heat treatment of wrought titanium and titanium alloys                                                                                                                                                   |
| 65174                                                            | Aerospace; round bars of titanium and titanium alloys; dimensions, masses                                                                                                                                           |
| 65179                                                            | Aerospace; countersunk head screws, close tolerances, with ribbed Torq-Set (ACR) recess and MJ thread, short thread length, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C         |
| 65179 <sup>b</sup>                                               | Aerospace; countersunk head bolts, close tolerance, with internal offset cruciform ribbed drive and MJ thread, short thread length, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C |
| 65197                                                            | Aerospace; titanium alloy round bars and wire for screw stock; dimensions, masses                                                                                                                                   |
| 65250                                                            | Aerospace; seamless internal pressure tubes in titanium and titanium alloys; dimensions, masses                                                                                                                     |

| <b>GERMAN DIN SPECIFICATIONS- TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                                                                                                                           |
|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                   | <b>Title</b>                                                                                                                                                                                              |
| 65265 <sup>b</sup>                                                           | Aerospace; screws, hexagon, with MJ thread, threaded approximately to head, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                                               |
| 65268 <sup>b</sup>                                                           | Aerospace; bolts hexagon with MJ thread, short thread, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                                                                    |
| 65289                                                                        | Aerospace; countersunk head screws, with ribbed Torq-Set (ACR) recess and MJ thread, short thread length, titanium alloy, nominal strength 1100 MPa, for temperatures up to 315°C                         |
| 65324                                                                        | Aerospace; pan head bolts, close tolerance, with ribbed Torq-Set (ACR) recess and short length MJ thread, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                 |
| 65324 <sup>b</sup>                                                           | Aerospace; panhead bolts, close tolerance, with internal offset cruciform ribbed drive recess and short length MJ thread, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C |
| 65338 <sup>b</sup>                                                           | Aerospace; hexagon bolts, close tolerance, with short length MJ thread, shoulder, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                                         |
| 65348                                                                        | Aerospace; seamless internal pressure tubes in titanium and titanium alloys; technical specification                                                                                                      |
| 65436                                                                        | Aerospace; standard quality (STQ) and disc quality (DQ) of titanium and titanium alloys; requirements and tests                                                                                           |
| 65437                                                                        | Aerospace; processed titanium scrap for reuse in titanium and titanium alloys; requirements and tests                                                                                                     |
| 65438                                                                        | Aerospace; bihexagonal head bolts, close tolerance, with MJ thread, medium thread length, in titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                              |
| 65438 <sup>b</sup>                                                           | Aerospace; bihexagonal head bolts, close tolerance, with MJ thread, short thread length, in titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                               |
| 65455                                                                        | Aerospace; seamless tubes in steel, nickel and titanium alloys; ultrasonic inspection                                                                                                                     |
| 65463 <sup>a</sup>                                                           | Aerospace; studs with MJ thread, captive ring lock, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                                                                       |
| 65464                                                                        | Aerospace; studs with MJ thread, ring locked, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                                                                             |
| 65464 <sup>a</sup>                                                           | Aerospace; studs with MJ thread, ring locked, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                                                                             |
| 65515                                                                        | Aerospace; cheese head bolts, with internal serration and MJ thread, short thread, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                                        |
| 65517                                                                        | Aerospace; cheese haed bolts, close tolerance, with internal serration and MJ thread, short thread, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                       |

| <b>GERMAN DIN SPECIFICATIONS- TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                                                                                                      |
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| <b>DIN</b>                                                                   | <b>Title</b>                                                                                                                                                                         |
| 65518                                                                        | Aerospace; pan head bolts with ribbed Torq-Set (ACR) recess and MJ thread, short thread, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C             |
| 65526 <sup>b</sup>                                                           | Aerospace; hexagon bolts, close tolerance, with short length MJ thread, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C                              |
| 65557                                                                        | Aerospace; pan head screws with ribbed Torq-Set (ACR) recess and MJ thread, fully threaded, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C          |
| 65558                                                                        | Aerospace; countersunk head screws, with ribbed Torq-Set (ACR) recess and MJ thread, fully threaded, titanium alloy, nominal tensile strength 1100 MPa, for temperatures up to 315°C |
| 65596 <sup>b</sup>                                                           | Aerospace; chemical check analysis limits of titanium and titanium alloys                                                                                                            |
| LN 9297                                                                      | Aerospace; sheet and plate in titanium and titanium alloys, rolled; dimensions, masses                                                                                               |
| LN 9425 Part 3                                                               | Filler metals for welding magnesium and titanium; welding rods; dimensions, weights                                                                                                  |
| LN 29792                                                                     | Aerospace; bolts, hexagon, close tolerance, of titanium alloy                                                                                                                        |
| LN 29796                                                                     | Aerospace; pin protruding head, of titanium alloy for shear loads                                                                                                                    |
| LN 29798                                                                     | Aerospace; collars, threaded self-locking for head pins of titanium alloy                                                                                                            |
| LN 65027                                                                     | Aerospace; hexagon screws of titanium alloy, threaded approximately to head                                                                                                          |
| LN 65047 Part 1                                                              | Aerospace; bolts, close tolerance, in titanium alloy, with self-locking collars in aluminum alloy; procurement specification, bolts                                                  |
| LN 65047 Part 2                                                              | Aerospace; bolts, close tolerance, in titanium alloy, with self-locking collars in aluminum alloy; procurement specification, collars                                                |
| LN 65047 Part 3                                                              | Aerospace; bolts, close tolerance, in titanium alloy, with self-locking collars in aluminum alloy; technical specification; performance test                                         |
| LN 65072 Part 1                                                              | Joining elements made from titanium alloy; technical specification                                                                                                                   |
| WL 3.7000 Part 10                                                            | Aerospace; titanium and titanium alloys; index                                                                                                                                       |
| WL 3.7000 Part 20                                                            | Aerospace; titanium and titanium alloys; materials and semi-finished products; survey                                                                                                |
| WL 3.7024 Part 2                                                             | Aerospace; titanium with approx. 0.1 O; filler metal for welding                                                                                                                     |
| WL 3.7024 Part 100                                                           | Aerospace; titanium with approx. 0.1 O; sheet and filler metal for welding; design and production data, conversion                                                                   |
| WL3.7034 Part 1                                                              | Titanium, unalloyed, with about 0.2 O <sub>2</sub> ; sheets                                                                                                                          |
| WL 3.7034 Part 2                                                             | Aerospace; titanium with approx. 0.2 O; bars and forgings                                                                                                                            |
| WL 3.7034 Part 3                                                             | Titanium, unalloyed, with about 0.2 O <sub>2</sub> ; filler metal                                                                                                                    |
| WL 3.7034 Part 100                                                           | Aerospace; titanium with approx. 0.2 O; sheet, bars, forgings and filler metal for welding; design and production data, conversion                                                   |



| <b>GERMAN DIN SPECIFICATIONS- TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                                                                  |
|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                   | <b>Title</b>                                                                                                                                     |
| WL 3.7064 Part 1                                                             | Titanium, unalloyed, with about 0.3 O <sub>2</sub> ; sheets                                                                                      |
| WL 3.7064 Part 2                                                             | Titanium, unalloyed, with about 0.3 O <sub>2</sub> ; rods and forgings                                                                           |
| WL 3.7064 Part 100                                                           | Aerospace; titanium with approx. 0.3 O; sheet, bars and forgings; design and production data                                                     |
| WL 3.7114 Part 1                                                             | Titanium alloy; TiAl5Sn2; sheets, strip and plates                                                                                               |
| WL 3.7114 Part 2                                                             | Titanium alloy; TiAl5Sn2; rods and forgings                                                                                                      |
| WL 3.7114 Part 3                                                             | Aerospace; titanium alloy with approx. 5Al-2Sn; filler metal for welding                                                                         |
| WL 3.7124 Part 1                                                             | Aerospace; titanium alloy with approx. 2Cu; sheet and strips                                                                                     |
| WL 3.7124 Part 2                                                             | Aerospace; titanium alloy with approx. 2Cu; bars and forgings                                                                                    |
| WL 3.7124 Part 3                                                             | Aerospace; titanium alloy with approx. 2Cu; filler metal for welding                                                                             |
| WL 3.7124 Part 100                                                           | Aerospace; titanium alloy with approx. 2Cu; sheet, strip, bars, forgings and filler metal for welding; design and production data, conversion    |
| WL 3.7144 Part 1                                                             | Aerospace; titanium alloy with approx. 6Al-2Sn-4Zr-2Mo; bars and forgings; inactive for new design                                               |
| WL 3.7144 Part 100                                                           | Aerospace; titanium alloy with approx. 6Al-2Sn-4Zr-2Mo; bars and forgings; design and production data, conversion; inactive for new design       |
| WL 3.7154 Part 1                                                             | Aerospace; titanium alloy with approx. 6Al-5Zr; bars and forgings                                                                                |
| WL 3.7154 Part 100                                                           | Aerospace; titanium alloy with approx. 6Al-5Zr; bars and forgings; design and production data, conversion                                        |
| WL 3.7164 Part 1                                                             | Aerospace; titanium alloy with approx. 6Al-4V; sheet and plate                                                                                   |
| WL 3.7164 Part 2                                                             | Aerospace; titanium alloy with approx. 6Al-4V; bars and forgings                                                                                 |
| WL 3.7164 Part 3                                                             | Aerospace; titanium alloy with approx. 6Al-4V; filler metal for welding                                                                          |
| WL 3.7164 Part 100                                                           | Aerospace; titanium alloy with approx. 6Al-4V; sheet, plate, bars, forgings and filler metal for welding; design and production data, conversion |
| WL 3.7174 Sheet 1                                                            | Titanium alloy with about 6Al-6V-2Sn; sheets, strips, plates, rods and forgings                                                                  |
| WL 3.7174 Part 1                                                             | Titanium alloy; TiAl6V6Sn2; sheets, strops and plates                                                                                            |
| WL 3.7174 Part 2                                                             | Titanium alloy; 6Al-6V-Sn2; rods and forgings                                                                                                    |
| WL 3.7184 Part 1                                                             | Aerospace; titanium alloy with approx. 4Al-4Mo-2Sn; plate                                                                                        |
| WL 3.7184 Part 2                                                             | Aerospace; titanium alloy with approx. 4Al-4Mo-2Sn; bars and forgings                                                                            |
| WL 3.7184 Part 100                                                           | Aerospace; titanium alloy with approx. 4Al-4Mo-2Sn; plate, bars and forgings; design and production data, conversion                             |
| WL 3.7194 Part 1                                                             | Aerospace; titanium alloy with approx. 3Al-2.5V, seamless internal pressure tubes                                                                |
| WL 3.7194 Part 2                                                             | Aerospace; titanium alloy with approx. 3Al-2.5V; filler for welding                                                                              |

| <b>GERMAN DIN SPECIFICATIONS- TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                    |
|------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                   | <b>Title</b>                                                                       |
| WL 3.7264 Part 1                                                             | Aerospace; cast titanium alloy with approx. 6Al-4V; investment casting             |
| WL 3.7264 Part 100                                                           | Aerospace; cast titanium alloy with approx. 6Al-4V; investment casting, conversion |

- a. Draft of a standard or technical rule.
- b. Published or withdrawn during 1992; draft of a standard or technical rule.

| <b>GERMAN DIN - EUROPEAN HARMONIZED STANDARDS &amp; EC LEGAL PROVISIONS - TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                                                                                                                                                 |
|--------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                                                   | <b>Title</b>                                                                                                                                                                                                    |
| EN 2497 <sup>b</sup>                                                                                         | Aerospace series; dry abrasive blasting of titanium and titanium alloys; german version EN 2497:1989                                                                                                            |
| EN 2500 <sup>a</sup> Part 4                                                                                  | Aerospace series; instructions for the drafting and use of metallic material standards; part 4: specific requirements for titanium and titanium alloys                                                          |
| EN 2545 <sup>a</sup> Part 1                                                                                  | Aerospace series; titanium and titanium alloy remelting stock and castings; technical specification; part 1: general requirements                                                                               |
| EN 2545 <sup>a</sup> Part 2                                                                                  | Aerospace series; titanium and titanium alloy remelting stock and castings; technical specification; part 2: remelting stock                                                                                    |
| EN 2545 <sup>a</sup> Part 3                                                                                  | Aerospace series; titanium and titanium alloy remelting stock and castings; technical specification; part 3: pre-productions and production castings                                                            |
| EN 2617 <sup>a</sup>                                                                                         | Aerospace; plate in titanium alloys 5 £ a £ 100 mm; dimensions                                                                                                                                                  |
| EN 2858 <sup>a</sup> Part 1                                                                                  | Aerospace series; titanium and titanium alloy forging stock and forgings; technical specification; part 1: general requirements                                                                                 |
| EN 2858 <sup>a</sup> Part 2                                                                                  | Aerospace series; titanium and titanium alloy forging stock and forgings; technical specification; part 2: forging stock                                                                                        |
| EN 2858 <sup>a</sup> Part 3                                                                                  | Aerospace series; titanium and titanium alloy forging stock and forgings; technical specification; part 3: pre-production and production forgings                                                               |
| EN 2870 <sup>a</sup>                                                                                         | Aerospace series; bolts, bihexagonal normal head, close tolerance normal shank, short thread, in titanium alloy, anodized, MoS <sub>2</sub> lubricated; classification: 1100 MPa (at ambient temperature)/315°C |
| EN 2884 <sup>a</sup>                                                                                         | Aerospace series; bolts, pan head, Torq-Set recess, coarse tolerance shank, short thread, in titanium alloy, anodized; classification: 1100 MPa/315°C                                                           |
| EN 2955 <sup>a</sup>                                                                                         | Aerospace series; recycling of titanium and titanium alloy scrap                                                                                                                                                |
| EN 3242 <sup>a</sup>                                                                                         | Aerospace series; pipe coupling 8° 30' in titanium alloy union, welded, threaded                                                                                                                                |

| <b>GERMAN DIN - EUROPEAN HARMONIZED STANDARDS &amp; EC LEGAL PROVISIONS - TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                       |
|--------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                                                               | <b>Title</b>                                                                                          |
| EN 3243 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; ferrule, welded, with dynamic beam seal end |
| EN 3244 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; union, double ended                         |
| EN 3245 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; union reducer                               |
| EN 3246 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; union, bulkhead                             |
| EN 3247 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; union, bulkhead, welded                     |
| EN 3249 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; elbow 90°                                   |
| EN 3250 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; elbow 90° swivel nut                        |
| EN 3251 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; elbow 90° welded                            |
| EN 3252 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; elbow 90°, swivel nut, welded               |
| EN 3253 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; elbow 90°, bulkhead                         |
| EN 3254 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; elbow 90°, bulkhead, welded                 |
| EN 3255 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; elbow 45°                                   |
| EN 3256 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; elbow 45°, swivel nut, welded               |
| EN 3257 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; elbow 45°, bulkhead                         |
| EN 3258 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; tee                                         |
| EN 3260 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; tee, branch with swivel nut                 |
| EN 3261 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; tee with swivel nut                         |
| EN 3262 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; tee, bulkhead branch                        |
| EN 3263 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; tee, bulkhead end                           |
| EN 3264 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; nut, swivel                                 |
| EN 3265 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; nut, union                                  |
| EN 3266 <sup>a</sup>                                                                                                     | Aerospace series; nut, bulkhead, in titanium alloy                                                    |
| EN 3267 <sup>a</sup>                                                                                                     | Aerospace series; washer, bulkhead, in titanium alloy                                                 |

| <b>GERMAN DIN - EUROPEAN HARMONIZED STANDARDS &amp; EC LEGAL PROVISIONS - TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                                                                                                                           |
|--------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                                                               | <b>Title</b>                                                                                                                                                                                              |
| EN 3268 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; plug, pressure                                                                                                                                  |
| EN 3269 <sup>a</sup>                                                                                                     | Aerospace series; pipe coupling 8° 30' in titanium alloy; blind ferrule with dynamic beam end seal                                                                                                        |
| EN 3306 <sup>b</sup>                                                                                                     | Aerospace series; 100° countersunk normal head, offset cruciform-ribbed recess, threaded to head, in titanium alloy, MoS <sub>2</sub> lubricated; classification: 1100 MPa (at ambient temperature)/315°C |
| EN 3307 <sup>b</sup>                                                                                                     | Aerospace series; screws, pan head, offset cruciform-ribbed recess, threaded to head, in titanium alloy, MoS <sub>2</sub> lubricated; classification: 1100 MPa (at ambient temperature)/315°C             |
| EN 3308 <sup>b</sup>                                                                                                     | Aerospace series; screws, normal hexagonal head, threaded to head, in titanium alloy, MoS <sub>2</sub> lubricated; classification: 1100 MPa (at ambient temperature)/315°C                                |
| EN 3381 <sup>a</sup>                                                                                                     | Aerospace series; bolts, 100° countersunk normal head, offset cruciform-ribbed recess, close tolerance shank, short thread, in titanium, anodized; classification: 1100 MPa/315°C                         |
| EN 3424 <sup>b</sup>                                                                                                     | Aerospace series; rivets, solid, universal head, in titanium alloy Ti45,5Cb; metric series                                                                                                                |
| EN 3441 <sup>b</sup>                                                                                                     | Aerospace series; titanium TI-P99001; annealed, sheet and strip, hot rolled, a £ 6 mm, 290 MPa £ R <sub>m</sub> £ 420 MPa                                                                                 |
| EN 3442 <sup>b</sup>                                                                                                     | Aerospace series; titanium TI-P99002; annealed, sheet and strip, hot rolled, a £ 6 mm, 390 MPa £ R <sub>m</sub> £ 540 MPa                                                                                 |
| EN 3443 <sup>b</sup>                                                                                                     | Aerospace series; titanium TI-P99003; annealed, sheet and strip, hot rolled, a £ 6 mm, 570 MPa £ R <sub>m</sub> £ 730 MPa                                                                                 |
| EN 3456 <sup>b</sup>                                                                                                     | Aerospace series; titanium alloy TI-P64001; annealed, sheet and strip, hot rolled, a £ 6 mm                                                                                                               |
| EN 3497 <sup>b</sup>                                                                                                     | Aerospace series; titanium TI-P99001; annealed, sheet and strip, cold rolled, a £ 3 mm, 290 MPa £ R <sub>m</sub> £ 420 MPa                                                                                |
| EN 3498 <sup>b</sup>                                                                                                     | Aerospace series; titanium TI-P99002; annealed, sheet and strip, cold rolled, a £ 3 mm, 390 MPa £ R <sub>m</sub> £ 540 MPa                                                                                |
| EN 3499 <sup>b</sup>                                                                                                     | Aerospace series; titanium TI-P99003; annealed, sheet and strip, cold rolled, a £ 3 mm, 570 MPa £ R <sub>m</sub> £ 730 MPa                                                                                |
| EN 3642 <sup>a</sup>                                                                                                     | Aerospace series; rivets, solid, 100° normal countersunk head with dome, in titanium TI-PO2, anodized                                                                                                     |
| EN 3643 <sup>a</sup>                                                                                                     | Aerospace series; rivets, solid 100° normal countersunk head, in titanium TI-PO2, anodized                                                                                                                |
| EN 3644 <sup>a</sup>                                                                                                     | Aerospace series; rivets, solid, universal head, in titanium TI-PO2, anodized                                                                                                                             |
| EN 3738 <sup>b</sup>                                                                                                     | Aerospace series; rivets, solid, 100° normal countersunk head with dome, in titanium alloy Ti 45,5 Cb; metric series                                                                                      |
| EN 3739 <sup>b</sup>                                                                                                     | Aerospace series; rivets, solid, 100° normal countersunk head, in titanium alloy Ti 45,5 Cb; metric series                                                                                                |
| EN 3859 <sup>b</sup>                                                                                                     | Aerospace series; titanium alloy TI-P19001; annealed, sheet and strip, hot rolled, a £ 6 mm                                                                                                               |

| <b>GERMAN DIN - EUROPEAN HARMONIZED STANDARDS &amp; EC LEGAL PROVISIONS - TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                                                                                                                                                         |
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| <b>DIN</b>                                                                                                               | <b>Title</b>                                                                                                                                                                                                                            |
| EN 3860 <sup>b</sup>                                                                                                     | Aerospace series; titanium alloy TI-P19001; annealed, sheet and strip, cold rolled, a £ 3 mm                                                                                                                                            |
| EN 3870 <sup>b</sup>                                                                                                     | Aerospace series; titanium alloy TI-P19001; solution treated and aged, sheet and strip, hot rolled, a £ 6 mm                                                                                                                            |
| EN 3871 <sup>b</sup>                                                                                                     | Aerospace series; titanium alloy TI-P19001; solution treated and aged, sheet and strip, cold rolled, a £ 3 mm                                                                                                                           |
| EN 6024 <sup>b</sup>                                                                                                     | Aerospace series; screws 100° countersunk reduced head, offset cruciform recess, close tolerance shank, short thread, in titanium alloy, anodized, MoS <sub>2</sub> lubricated; classification: 1100 MPa (at ambient temperature)/315°C |
| V EN 2098<br>Part 2                                                                                                      | Aerospace series; inspection and testing requirements for titanium and heat resisting alloy wrought products; part 2: inspection and testing requirements for sheets, strips and plates                                                 |
| V EN 2098<br>Part 5                                                                                                      | Aerospace series; inspection and testing requirements for titanium and heat resisting alloy wrought products; part 5: inspection and testing requirements for wires                                                                     |
| V EN 2098<br>Part 6                                                                                                      | Aerospace series; inspection and testing requirements for titanium and heat resisting alloy wrought products; part 6: inspection and testing requirements for bars and wires for fasteners                                              |

a. Draft of a standard or technical rule.

b. Published or withdrawn during 1992; draft of a standard or technical rule.

| <b>EUROPEAN AECMA<sup>a</sup> SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                                                                                                                                                    |
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| <b>AECMA</b>                                                                      | <b>Title</b>                                                                                                                                                                                                       |
| prEN 2500 Part 4                                                                  | Instructions for the drafting and use of metallic material standards - part 4 - specific requirements for titanium and titanium alloys                                                                             |
| prEN 2545 Part 1                                                                  | Titanium and titanium alloy remelting stock and castings - technical specification - part 1 - general requirements                                                                                                 |
| prEN 2545 Part 2                                                                  | Titanium and titanium alloy remelting stock and castings - technical specification - part 2 - remelting stock                                                                                                      |
| prEN 2545 Part 3                                                                  | Titanium and titanium alloy remelting stock and castings - technical specification - part 3 - pre-production and production castings                                                                               |
| prEN 2808                                                                         | Anodizing of titanium and titanium alloys                                                                                                                                                                          |
| prEN 2870                                                                         | Bolts, bihexagonal normal head, close tolerance normal shank short thread in titanium alloy, anodized, MoS <sub>2</sub> lubricated classification: 1100 MPa (at ambient temperature)/315°C                         |
| prEN 2955                                                                         | Recycling of titanium and titanium alloy scrap                                                                                                                                                                     |
| prEN 3248                                                                         | Pipe coupling 8° 30' in titanium alloy adaptor-reduced pipe end with locking ring                                                                                                                                  |
| prEN 3270                                                                         | Pipe coupling 8° 30' in titanium alloy blanking plug with locking ring                                                                                                                                             |
| prEN 3275                                                                         | Pipe coupling 8° 30' dynamic beam seal up to 28000 kPa metric series technical specification                                                                                                                       |
| prEN 3304                                                                         | Bolts, 100° countersunk reduced head, offset cruciform recess, close tolerance shank, short thread, in titanium alloy, MoS <sub>2</sub> lubricated classification: 1100 MPa (at ambient temperature)/315°C         |
| prEN 3306                                                                         | Screws, 100° countersunk normal head, offset cruciform-ribbed recess, threaded to head, in titanium alloy, MoS <sub>2</sub> lubricated classification: 1100 MPa (at ambient temperature)/315°C                     |
| prEN 3307                                                                         | Screws, pan head, offset cruciform recess, threaded to head, in titanium alloy, MoS <sub>2</sub> lubricated classification: 1100 MPa (at ambient temperature)/315°C                                                |
| prEN 3308                                                                         | Screws, normal hexagonal head, threaded to head, in titanium alloy, MoS <sub>2</sub> lubricated classification: 1100 MPa (at ambient temperature)/315°C                                                            |
| prEN 3381                                                                         | Bolts, 100° countersunk normal head, offset cruciform - ribbed recess, close tolerance shank short thread in titanium anodized, MoS <sub>2</sub> lubricated classification: 100 MPa (at ambient temperature)/315°C |
| prEN 3424                                                                         | Rivets, solid, universal head, in titanium alloy Ti 45,5 Cb, metric series                                                                                                                                         |
| prEN 3504                                                                         | Tube for hydraulic systems titanium and titanium alloys                                                                                                                                                            |
| prEN 3544 Part 1                                                                  | Titanium and titanium alloy wrought products - technical specification - part 1 - general requirements                                                                                                             |
| prEN 3544 Part 2                                                                  | Titanium and titanium alloy wrought products - technical specification - part 2 - plate, sheet and strip                                                                                                           |
| prEN 3544 Part 3                                                                  | Titanium and titanium alloy wrought products - technical specification - part 3 - bar and section                                                                                                                  |

| <b>EUROPEAN AECMA<sup>a</sup> SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                                                             |
|-----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AECMA</b>                                                                                  | <b>Title</b>                                                                                                                                |
| prEN 3544 Part 4                                                                              | Titanium and titanium alloy wrought products - technical specification - part 4 - seamless tube                                             |
| prEN 3544 Part 5                                                                              | Titanium and titanium alloy wrought products - technical specification - part 5 - wire                                                      |
| prEN 3561                                                                                     | Pipe coupling 8° 30' in titanium alloy ferrule with dynamic beam seal end, welded and reduced at pipe end                                   |
| prEN 3562                                                                                     | Pipe coupling in titanium alloy elbow 90° double welded                                                                                     |
| prEN 3563                                                                                     | Pipe coupling in titanium alloy elbow 45° double welded                                                                                     |
| prEN 3564                                                                                     | Pipe coupling 8° 30' in titanium alloy tee, bulkhead fitting on limb                                                                        |
| prEN 3565                                                                                     | Pipe coupling 8° 30' in titanium alloy cross                                                                                                |
| prEN 3566                                                                                     | Pipe coupling 8° 30' in titanium alloy adaptor with locking ring                                                                            |
| prEN 3572                                                                                     | PTFE flexible hose assembly with convoluted inner tube of a nominal pressure up to 6800 kPa and 8° 30' fitting in titanium product standard |
| prEN 3574                                                                                     | PTFE flexible hose assembly with convoluted inner tube of a nominal pressure up to 6800 kPa and 24° fitting in titanium product standard    |
| prEN3576                                                                                      | PTFE flexible hose assembly of a nominal pressure equal to 10 500 kPa with 8° 30' fitting in titanium product standard                      |
| prEN 3578                                                                                     | PTFE flexible hose assembly of a nominal pressure equal to 10 500 kPa with 24° fitting in titanium product standard                         |
| prEN 3580                                                                                     | Aerospace series; PTFE flexible hose assembly of a nominal pressure equal to 21 000 kPa with 8° 30' fitting in titanium product standard    |
| prEN 3582                                                                                     | Standard weight PTFE flexible hose assembly of a nominal pressure equal to 21 000 kPa with 24° fitting in titanium product standard         |
| prEN 3584                                                                                     | Lightweight PTFE flexible hose assembly of a nominal pressure equal to 21 000 kPa with 8° 30' fitting in titanium product standard          |
| prEN 3586                                                                                     | Lightweight PTFE flexible hose assembly of a nominal pressure equal to 21 000 kPa with 24° fitting in titanium product standard             |
| prEN 3588                                                                                     | Lightweight PTFE flexible hose assembly of a nominal pressure equal to 28 000 kPa with 8° 30' fitting in titanium product standard          |
| prEN 3590                                                                                     | PTFE flexible hose assembly of a nominal pressure equal to 28 000 kPa with 24° fitting in titanium product standard                         |
| prEN 3658                                                                                     | Tube bend radii, for engine application design standard                                                                                     |
| prEN 3688                                                                                     | T-Ring filler in titanium alloy for welding pipes 14 000 kPa nominal pressure                                                               |
| prEN 3689                                                                                     | T-Ring filler in titanium alloy for welding pipes 28 000 kPa nominal pressure                                                               |
| prEN 3690                                                                                     | Pipe coupling 8° 30' in titanium alloy union bulkhead long                                                                                  |
| prEN 3691                                                                                     | Pipe coupling 8° 30' in titanium alloy union - bulkhead long welded                                                                         |
| prEN 3692                                                                                     | Pipe coupling 8° 30' in titanium alloy elbow 90° - bulkhead long                                                                            |
| prEN 3693                                                                                     | Pipe coupling 8° 30' in titanium alloy elbow 90° - bulkhead long welded                                                                     |
| prEN 3694                                                                                     | Pipe coupling 8° 30' in titanium alloy tee - bulkhead long branch                                                                           |

| <b>EUROPEAN AECMA<sup>a</sup> SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS (Continued)</b> |                                                                                                                                                                                                                                     |
|-----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AECMA</b>                                                                                  | <b>Title</b>                                                                                                                                                                                                                        |
| prEN 3695                                                                                     | Pipe coupling 8° 30' in titanium alloy tee - reduced one T-End with swivel nut end                                                                                                                                                  |
| prEN 3724                                                                                     | Bolts, double hexagon head relieved shank, long thread, in titanium alloy TI-P63, MoS <sub>2</sub> coated classification: 1100 MPa (at ambient temperature)/350°C                                                                   |
| prEN 3725                                                                                     | Bolts, pan head, 6 lobe recess, long thread, in titanium alloy TI-P63, MoS <sub>2</sub> coated classification: 1100 MPa (at ambient temperature)/350°C                                                                              |
| prEN 3738                                                                                     | Rivets, solid, 100° normal countersunk head with dome, in titanium alloy Ti 45,5 Cb, metric series                                                                                                                                  |
| prEN 3739                                                                                     | Rivets, solid, 100° normal countersunk head, in titanium alloy Ti 45,5 Cb, metric series                                                                                                                                            |
| prEN 3740                                                                                     | Bolts, shouldered, thin hexagonal head, close tolerance shank, short thread, in titanium alloy, MoS <sub>2</sub> lubricated classification: 1100 MPa (at ambient temperature)/315°C                                                 |
| prEN 3784                                                                                     | Pipe coupling 8° 30' in titanium alloy tee reduced bulkhead branch long                                                                                                                                                             |
| prEN 3785                                                                                     | Pipe coupling 8° 30' in titanium alloy tee reduced bulkhead branch                                                                                                                                                                  |
| prEN 3786                                                                                     | Pipe coupling 8° 30' in titanium alloy tee reduced bulkhead long                                                                                                                                                                    |
| prEN 3787                                                                                     | Pipe coupling 8° 30' in titanium alloy tee reduced bulkhead                                                                                                                                                                         |
| prEN 3818                                                                                     | Bolts in titanium alloy TI-P63 classification: 1100 MPa (at ambient temperature) technical specification                                                                                                                            |
| prEN 3851                                                                                     | Nuts, for spherical tube coupling, in titanium alloy TI-P63 use temperature 350°C                                                                                                                                                   |
| prEN 3852                                                                                     | Welding nipple, spherical tube, in titanium alloy TI-P63 use temperature 300°C                                                                                                                                                      |
| prEN 3853                                                                                     | Nipple, spherical tube coupling, in titanium alloy TI-P63 use temperature 300°C                                                                                                                                                     |
| prEN 3854                                                                                     | Welding fende, spherical tube coupling, in titanium alloy TI-P63 use temperature 300°C                                                                                                                                              |
| prEN 3907                                                                                     | Bolts, double hexagon head, normal shank, long thread, in titanium alloy TI-P63, MoS <sub>2</sub> coated classification: 1100 MPa (at ambient temperature)/350°C                                                                    |
| prEN 6024                                                                                     | Bolts, 100° countersunk reduced head, offset cruciform recess, close tolerance shank, short thread, titanium alloy, lubricated classification: 1100 MPa (at ambient temperature)/315°C, inch series                                 |
| prEN 6024                                                                                     | Screws, 100° countersunk reduced head, offset cruciform recess, close tolerance shank, short thread, in titanium alloy, anodized, MoS <sub>2</sub> lubricated, classification: 1100 MPa (at ambient temperature)/315°C, inch series |

a. AECMA - Association Européenne des Constructeurs de Matériel Aérospatial.



| <b>JAPANESE JIS SPECIFICATIONS - TITANIUM &amp; TITANIUM ALLOYS</b> |                                                                                   |
|---------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| <b>JIS</b>                                                          | <b>Title</b>                                                                      |
| G 3603                                                              | Titanium clad steels                                                              |
| H 0511                                                              | Testing methods for brinell hardness of titanium sponge                           |
| H 4605                                                              | Titanium-Palladium alloy sheet, plates and strips                                 |
| H 4607                                                              | Sheets and plates of titanium alloys                                              |
| H 4630                                                              | Titanium pipes and tubes for ordinary piping                                      |
| H 4631                                                              | Titanium tubes for heat exchangers                                                |
| H 4635                                                              | Titanium-Palladium alloy pipes and tubes for ordinary piping                      |
| H 4636                                                              | Titanium-Palladium alloy pipes and tubes for heat exchanger                       |
| H 4650                                                              | Titanium rods and bars                                                            |
| H 4655                                                              | Titanium-Palladium alloy rods and bars                                            |
| H 4657                                                              | Rods, bars and forgings of titanium alloys                                        |
| H 4670                                                              | Titanium wires                                                                    |
| H 4675                                                              | Titanium-Palladium alloy wires                                                    |
| H 7001                                                              | Glossary of terms used in shape memory alloys                                     |
| H 7101                                                              | Method for Determining the Transformation Temperatures of Shape Memory Alloys     |
| H 7103                                                              | Method of fixed temperature tensile test for wires of Ti - Ni shape memory alloys |
| Z 3107                                                              | Methods of radiographic test and classification of radiographs for titanium welds |
| Z 3331                                                              | Titanium and titanium alloy rods and wires for inert gas shielded arc welding     |

| CHEMICAL COMPOSITION OF UNALLOYED (PURE) TITANIUM |                                                                                 |                  |                                  |       |      |      |       |      |      |       |
|---------------------------------------------------|---------------------------------------------------------------------------------|------------------|----------------------------------|-------|------|------|-------|------|------|-------|
| UNS                                               | ASTM Spec.                                                                      | AMS Spec.        | MIL Spec.                        | Grade | C    | Fe   | H     | N    | O    | Other |
| R50250                                            | B265, B337, B338, B348, B381 <sup>a</sup> , F467, F468, F67                     | ---              | T-81556, T-81915                 | 1     | 0.10 | 0.20 | 0.015 | 0.03 | 0.18 | c     |
| R50400                                            | B265, B337, B338, B348, B367 <sup>b</sup> , B381 <sup>a</sup> , F467, F468, F67 | 4902, 4941, 4942 | T-9046, T-81556                  | 2     | 0.10 | 0.30 | 0.015 | 0.03 | 0.25 | c     |
| R50550                                            | B265, B337, B338, B348, B367 <sup>b</sup> , B381, F67                           | 4900             | T-9046, T-81556                  | 3     | 0.10 | 0.30 | 0.015 | 0.05 | 0.35 | c     |
| R50700                                            | B265, B348, B381, F67, F467, F468                                               | 4901, 4921       | T-9046, T-9047, T-81556, F-83142 | 4     | 0.10 | 0.50 | 0.015 | 0.05 | 0.40 | c     |

a. ASTM B381 have grade designations as follows: F-1 to F-4; rather than grades 1 to 4, respectively. b. ASTM B367 have grade designations are as follows: C-2 and C-3; rather than grades 2 and 3, respectively. c. Maximum allowable concentration for residual elements shall be 0.1% each and 0.4% maximum total. Single values are maximum. Titanium is the remainder.

| CHEMICAL COMPOSITION OF ALLOYED TITANIUM                 |    |        |                                                                              |                                           |      |      |       |      |      |                        |
|----------------------------------------------------------|----|--------|------------------------------------------------------------------------------|-------------------------------------------|------|------|-------|------|------|------------------------|
| ASTM Spec.                                               | Gr | UNS    | AMS Spec.                                                                    | MIL Spec.                                 | C    | Fe   | H     | N    | O    | Other <sup>c</sup>     |
| B265, B348, B367 <sup>a</sup> , B381 <sup>b</sup> , F467 | 5  | R56400 | 4905, 4906, 4911, 4920, 4928, 4930, 4931, 4934, 4935, 4954, 4965, 4967, 4993 | T-9046, T-9047, T-81556, T-81915          | 0.10 | 0.40 | 0.015 | 0.05 | 0.20 | 5.5-6.75 Al, 3.5-4.5 V |
| B265, B348, B367 <sup>a</sup> , B381 <sup>b</sup>        | 6  | R54520 | 4910, 4926, 4966                                                             | T-9046, T-9047, T-81556, T-81915, F-83142 | 0.10 | 0.50 | 0.020 | 0.05 | 0.20 | 4.0-6.0 Al, 2.0-3.0 Sn |

| CHEMICAL COMPOSITION OF ALLOYED TITANIUM (Continued)  |    |        |            |                |                    |      |                    |      |      |                                     |
|-------------------------------------------------------|----|--------|------------|----------------|--------------------|------|--------------------|------|------|-------------------------------------|
| ASTM Spec.                                            | Gr | UNS    | AMS Spec.  | MIL Spec.      | C                  | Fe   | H                  | N    | O    | Other <sup>c</sup>                  |
| B265, B337 B338, B348, B381 <sup>b</sup> , F467, F468 | 7  | R52400 | ---        | ---            | 0.10               | 0.30 | 0.015              | 0.03 | 0.25 | 0.12-0.25 Pd,                       |
| B265, B337, B338, B348, B381 <sup>b</sup>             | 9  | R56320 | 4943, 4944 | T-9046, T-9047 | 0.10               | 0.25 | 0.015              | 0.02 | 0.15 | 2.5-3.5Al, 2.0-3.0 V                |
| B265, B337, B338, B348, B381 <sup>b</sup>             | 11 | R52250 | ---        | ---            | 0.10               | 0.20 | 0.015              | 0.03 | 0.18 | 0.12-0.25 Pd                        |
| B265, B337, B338, B348, B381 <sup>b</sup>             | 12 | R53400 | ---        | ---            | 0.08               | 0.30 | 0.015              | 0.03 | 0.25 | 0.2-0.4 Mo, 0.6-0.9 Ni              |
| B265, B348, B381 <sup>b</sup>                         | 13 | ---    | ---        | ---            | 0.10               | 0.20 | 0.015 <sup>d</sup> | 0.03 | 0.10 | 0.04-0.06 Ru, 0.40-0.60 Ni          |
| B265, B348, B381 <sup>b</sup>                         | 14 | ---    | ---        | ---            | 0.010 <sup>e</sup> | 0.30 | 0.015 <sup>d</sup> | 0.03 | 0.15 | 0.04-0.06 Ru, 0.40-0.60 Ni          |
| B265, B348, B381 <sup>b</sup>                         | 15 | ---    | ---        | ---            | 0.10               | 0.30 | 0.015 <sup>d</sup> | 0.05 | 0.25 | 0.04-0.06 Ru, 0.40-0.60 Ni          |
| B265, B348, B381 <sup>b</sup>                         | 16 | ---    | ---        | ---            | 0.10               | 0.30 | 0.015 <sup>d</sup> | 0.03 | 0.25 | 0.04-0.08 Pd                        |
| B265, B348, B381 <sup>b</sup>                         | 17 | ---    | ---        | ---            | 0.10               | 0.20 | 0.015 <sup>d</sup> | 0.03 | 0.18 | 0.04-0.08 Pd                        |
| B265, B348, B381 <sup>b</sup>                         | 18 | ---    | ---        | ---            | 0.10               | 0.25 | 0.015 <sup>d</sup> | 0.05 | 0.15 | 0.04-0.08 Pd, 2.5-3.5 Al, 2.0-3.0 V |

a. ASTM B367 have grade designations are as follows: C-5, C-6, Ti-Pd 7B, Ti-Pd 8A; rather than grades 5, 6, 7, 8, respectively. b. ASTM B381 have grade designations as follows: F-5 to F-18; rather than grades 5 to 18, respectively. c. Maximum allowable concentration for residual elements shall be 0.1% each and 0.4% maximum total. d. See B348 and B381 for specific hydrogen requirements; hydrogen content listed is for B265. e. Carbon content listed is for B265 and B348; carbon content for B381 is 0.10% maximum. Single value are maximum. Titanium is the remainder.

| CHEMICAL COMPOSITION OF TITANIUM BARE ELECTRODE & ROD FILLER METAL <sup>a, b, c</sup> |         |      |           |       |       |         |         |      |                                   |
|---------------------------------------------------------------------------------------|---------|------|-----------|-------|-------|---------|---------|------|-----------------------------------|
| AWS A5.16 Classification                                                              | UNS No. | C    | O         | H     | N     | Al      | V       | Fe   | Other                             |
| ERTi-1                                                                                | R50100  | 0.03 | 0.10      | 0.005 | 0.015 |         | ---     | 0.10 | ---                               |
| ERTi-2                                                                                | R50120  | 0.03 | 0.10      | 0.008 | 0.020 |         | ---     | 0.20 | ---                               |
| ERTi-3                                                                                | R50125  | 0.03 | 0.10-0.15 | 0.008 | 0.020 |         | ---     | 0.20 | ---                               |
| ERTi-4                                                                                | R50130  | 0.03 | 0.15-0.25 | 0.008 | 0.020 |         | ---     | 0.30 | ---                               |
| ERTi-5                                                                                | R56400  | 0.05 | 0.18      | 0.015 | 0.030 | 5.5-6.7 | 3.5-4.5 | 0.30 | 0.005 Y                           |
| ERTi-5ELI                                                                             | R56402  | 0.03 | 0.10      | 0.005 | 0.012 | 5.5-6.5 | 3.5-4.5 | 0.15 | 0.005 Y                           |
| ERTi-6                                                                                | R54522  | 0.08 | 0.18      | 0.015 | 0.050 | 4.5-5.8 | ---     | 0.50 | 0.005 Y; 2.0-3.0 Sn               |
| ERTi-6ELI                                                                             | R54523  | 0.03 | 0.10      | 0.005 | 0.012 | 4.5-5.8 | ---     | 0.20 | 0.005 Y; 2.0-3.0 Sn               |
| ERTi-7                                                                                | R52401  | 0.03 | 0.10      | 0.008 | 0.020 | ---     | ---     | 0.20 | 0.12-0.25 Pd                      |
| ERTi-9                                                                                | R56320  | 0.03 | 0.12      | 0.008 | 0.020 | 2.5-3.5 | 2.0-3.0 | 0.25 | 0.005 Y                           |
| ERTi-9ELI                                                                             | R56321  | 0.03 | 0.10      | 0.005 | 0.012 | 2.5-3.5 | 2.0-3.0 | 0.20 | 0.005 Y                           |
| ERTi-12                                                                               | R53400  | 0.03 | 0.25      | 0.008 | 0.020 | ---     | ---     | 0.30 | 0.2-0.4 Mo; 0.6-0.9 Ni            |
| ERTi-15                                                                               | R56210  | 0.03 | 0.10      | 0.005 | 0.015 | 5.5-6.5 | ---     | 0.15 | 0.5-1.5 Mo; 1.5-2.5 Cb 0.5-1.5 Ta |

a. Titanium constitutes the remainder of the composition.

b. Single values are maximum.

c. Residual elements, total, shall not exceed 0.20%, with no single element exceeding 0.05%. See AWS A5.16 specification for more details.

| MECHANICAL PROPERTIES OF WROUGHT TITANIUM & TITANIUM ALLOYS |       |       |                               |     |                             |         |                   |                                       |                    |
|-------------------------------------------------------------|-------|-------|-------------------------------|-----|-----------------------------|---------|-------------------|---------------------------------------|--------------------|
| ASTM Standard                                               |       |       | Tensile Strength <sup>a</sup> |     | Yield Strength <sup>a</sup> |         | % El <sup>a</sup> | Bend Test for ASTM B 265 <sup>b</sup> |                    |
| B 265                                                       | B 337 | B 338 |                               |     |                             |         |                   | Under 0.070 in.                       | 0.070 to 0.187 in. |
| Gr                                                          | Gr    | Gr    | ksi                           | MPa | ksi                         | MPa     |                   | in thickness                          | in thickness       |
| 1                                                           | 1     | 1     | 35                            | 240 | 25-45                       | 170-310 | 24                | 3T                                    | 4T                 |
| 2                                                           | 2     | 2     | 50                            | 345 | 40-65                       | 275-450 | 20                | 4T                                    | 5T                 |
| 3                                                           | 3     | 3     | 65                            | 450 | 55-80                       | 380-550 | 18                | 4T                                    | 5T                 |

| MECHANICAL PROPERTIES OF WROUGHT TITANIUM & TITANIUM ALLOYS (Continued) |                 |                |                               |     |                             |         |                   |                                       |                                    |
|-------------------------------------------------------------------------|-----------------|----------------|-------------------------------|-----|-----------------------------|---------|-------------------|---------------------------------------|------------------------------------|
| ASTM Standard                                                           |                 |                | Tensile Strength <sup>a</sup> |     | Yield Strength <sup>a</sup> |         | % El <sup>a</sup> | Bend Test for ASTM B 265 <sup>b</sup> |                                    |
| B 265                                                                   | B 337           | B 338          |                               |     |                             |         |                   | Under 0.070 in.<br>in thickness       | 0.070 to 0.187 in.<br>in thickness |
| Gr                                                                      | Gr              | Gr             | ksi                           | MPa | ksi                         | MPa     |                   |                                       |                                    |
| 4                                                                       | ---             | ---            | 80                            | 550 | 70-95                       | 485-655 | 15                | 5T                                    | 6T                                 |
| 5                                                                       | ---             | ---            | 130                           | 895 | 120                         | 830     | 10 <sup>c,d</sup> | 9T                                    | 10T                                |
| 6                                                                       | ---             | ---            | 120                           | 830 | 115                         | 795     | 10 <sup>c</sup>   | 8T                                    | 9T                                 |
| 7                                                                       | 7               | 7              | 50                            | 345 | 40-65                       | 275-450 | 20                | 4T                                    | 5T                                 |
| 9                                                                       | g <sup>f</sup>  | g <sup>f</sup> | 90                            | 620 | 70                          | 485     | 15 <sup>e</sup>   | 5T                                    | 6T                                 |
| ---                                                                     | g <sup>g</sup>  | g <sup>g</sup> | 125                           | 860 | 105                         | 725     | 10                | ---                                   | ---                                |
| ---                                                                     | 10 <sup>h</sup> | ---            | 100                           | 690 | 90                          | 620     | 10                | ---                                   | ---                                |
| 11                                                                      | 11              | 11             | 35                            | 240 | 25-45                       | 170-310 | 24                | 3T                                    | 4T                                 |
| 12                                                                      | 12              | 12             | 70                            | 483 | 50                          | 345     | 18                | 4T                                    | 5T                                 |
| 13                                                                      | ---             | ---            | 40                            | 275 | 25                          | 170     | 24                | 3T                                    | 4T                                 |
| 14                                                                      | ---             | ---            | 60                            | 410 | 40                          | 275     | 20                | 4T                                    | 5T                                 |
| 15                                                                      | ---             | ---            | 70                            | 483 | 55                          | 380     | 18                | 4T                                    | 5T                                 |
| 16                                                                      | ---             | ---            | 50                            | 345 | 40-65                       | 275-450 | 20                | 4T                                    | 5T                                 |
| 17                                                                      | ---             | ---            | 35                            | 240 | 25-45                       | 170-310 | 24                | 3T                                    | 4T                                 |
| 18                                                                      | ---             | ---            | 90                            | 620 | 70                          | 483     | 15 <sup>e</sup>   | 5T                                    | 6T                                 |

a. Single values are minimum unless otherwise noted.

b. Bend tests applicable to ASTM B 265 only. T equals the thickness of the bend test specimen. Bend tests are not applicable to material over 0.187 in. (4.75 mm) in thickness.

c. For grades 5 and 6 the elongation on materials under 0.025 in. (0.635 mm) in thickness may be obtained only by negotiation.

d. For grade 5, the elongation will be 8% minimum for thicknesses between 0.025 in. and 0.063 in.

e. Elongation for continuous rolled and annealed (strip product from coil) for grade 9 and grade 18 shall be 12% minimum in the longitudinal direction and 8% minimum in the transverse direction. See ASTM B 265 for more details.

f. Properties for material in the annealed condition.

g. Properties for cold-worked and stress-relieved material. h. Properties for material in the solution treated condition.

| <b>MECHANICAL PROPERTIES OF WROUGHT TITANIUM &amp; TITANIUM ALLOYS</b> |                    |                                     |            |                                   |            |                         |                         |
|------------------------------------------------------------------------|--------------------|-------------------------------------|------------|-----------------------------------|------------|-------------------------|-------------------------|
| <b>ASTM Standard</b>                                                   |                    | <b>Tensile Strength<sup>a</sup></b> |            | <b>Yield Strength<sup>a</sup></b> |            | <b>% El<sup>a</sup></b> | <b>% RA<sup>a</sup></b> |
| <b>B 348 Grade</b>                                                     | <b>B 381 Grade</b> | <b>ksi</b>                          | <b>MPa</b> | <b>ksi</b>                        | <b>MPa</b> |                         |                         |
| 1                                                                      | F-1                | 35                                  | 240        | 25                                | 170        | 24                      | 30                      |
| 2                                                                      | F-2                | 50                                  | 345        | 40                                | 275        | 20                      | 30                      |
| 3                                                                      | F-3                | 65                                  | 450        | 55                                | 380        | 18                      | 30                      |
| 4                                                                      | F-4                | 80                                  | 550        | 70                                | 483        | 15                      | 25                      |
| 5                                                                      | F-5                | 130                                 | 895        | 120                               | 825        | 10                      | 25                      |
| 6                                                                      | F-6                | 120                                 | 825        | 115                               | 795        | 10                      | 25                      |
| 7                                                                      | F-7                | 50                                  | 345        | 40                                | 275        | 20                      | 30                      |
| 9                                                                      | F-9                | 90                                  | 620        | 70                                | 483        | 15                      | 25                      |
| 11                                                                     | F-11               | 35                                  | 240        | 25                                | 170        | 24                      | 30                      |
| 12                                                                     | F-12               | 70                                  | 483        | 50                                | 345        | 18                      | 25                      |
| 13                                                                     | F-13               | 40                                  | 275        | 25                                | 170        | 24                      | 30                      |
| 14                                                                     | F-14               | 60                                  | 410        | 40                                | 275        | 20                      | 30                      |
| 15                                                                     | F-15               | 70                                  | 483        | 55                                | 380        | 18                      | 25                      |
| 16                                                                     | F-16               | 50                                  | 345        | 40                                | 275        | 20                      | 30                      |
| 17                                                                     | F-17               | 35                                  | 240        | 25                                | 170        | 24                      | 30                      |
| 18                                                                     | F-18               | 90                                  | 620        | 70                                | 483        | 15                      | 25                      |

a. Single values are minimum.

| MECHANICAL PROPERTIES OF CAST TITANIUM & TITANIUM ALLOYS <sup>a</sup> |                       |                       |                  |     |                |     |      |                     |                  |
|-----------------------------------------------------------------------|-----------------------|-----------------------|------------------|-----|----------------|-----|------|---------------------|------------------|
| Casting Standards                                                     |                       |                       | Tensile Strength |     | Yield Strength |     | % El | Hardness            |                  |
| ASTM B 367                                                            | AMS 4985              | AMS 4991              | ksi              | MPa | Ksi            | MPa |      | Rockwell max        | HB max           |
| C-2                                                                   | ---                   | ---                   | 50               | 345 | 40             | 275 | 15   | 96 HRB <sup>b</sup> | 210 <sup>b</sup> |
| C-3                                                                   | ---                   | ---                   | 65               | 450 | 55             | 380 | 12   | 24 HRC <sup>b</sup> | 235 <sup>b</sup> |
| C-5                                                                   | ---                   | ---                   | 130              | 895 | 120            | 825 | 6    | 39 HRC <sup>b</sup> | 365 <sup>b</sup> |
| C-6                                                                   | ---                   | ---                   | 115              | 795 | 105            | 725 | 8    | 36 HRC <sup>b</sup> | 335 <sup>b</sup> |
| Ti-Pd 7B                                                              | ---                   | ---                   | 50               | 345 | 40             | 275 | 15   | 96 HRB <sup>b</sup> | 210 <sup>b</sup> |
| Ti-Pd 8A                                                              | ---                   | ---                   | 65               | 450 | 55             | 380 | 12   | 24 HRC <sup>b</sup> | 235 <sup>b</sup> |
| ---                                                                   | 6Al - 4V <sup>c</sup> | ---                   | 130              | 895 | 120            | 825 | 6    | 39 HRC              | ---              |
| ---                                                                   | 6Al - 4V <sup>d</sup> | ---                   | 130              | 895 | 120            | 825 | 6    | 39 HRC              | ---              |
| ---                                                                   | 6Al - 4V <sup>e</sup> | ---                   | 125              | 860 | 108            | 745 | 4.5  | 39 HRC              | ---              |
| ---                                                                   | ---                   | 6Al - 4V <sup>d</sup> | 130              | 895 | 120            | 825 | 6    | 39 HRC <sup>f</sup> | ---              |
| ---                                                                   | ---                   | 6Al - 4V <sup>e</sup> | 127              | 875 | 110            | 760 | 4.5  | 39 HRC <sup>f</sup> | ---              |
| ---                                                                   | ---                   | 6Al - 4V <sup>c</sup> | 130              | 895 | 120            | 825 | 6    | 39 HRC <sup>f</sup> | ---              |

a. Single values are minimum unless otherwise noted.

b. Supplementary requirement applied only when specified by the purchaser. Values are averages of three tests. See ASTM B 367 for more details.

c. Separately-cast specimens or specimens cut from attached coupons.

d. Specimens cut from castings - designated areas.

e. Specimens cut from castings - non-designated areas.

f. Castings shall not be rejected on the basis of hardness if tensile property requirements of AMS 4991 are met.

| MECHANICAL PROPERTIES OF SURGICAL IMPLANT TITANIUM & TITANIUM ALLOYS <sup>a</sup> |        |                    |                  |     |                  |                  |      |      |                              |                                 |
|-----------------------------------------------------------------------------------|--------|--------------------|------------------|-----|------------------|------------------|------|------|------------------------------|---------------------------------|
| ASTM Standards                                                                    |        |                    | Tensile Strength |     | Yield Strength   |                  | % El | % RA | Bend Test <sup>f</sup>       |                                 |
|                                                                                   |        |                    |                  |     |                  |                  |      |      | Under 0.070 in. in thickness | 0.070 to 0.187 in. in thickness |
| F 67                                                                              | F 136  | F 620 <sup>e</sup> | ksi              | MPa | Ksi              | MPa              |      |      |                              |                                 |
| gr 1                                                                              | ---    | ---                | 35               | 240 | 25-45            | 170-310          | 24   | ---  | 3T                           | 4T                              |
| gr 2                                                                              | ---    | ---                | 50               | 345 | 40-65            | 275-450          | 20   | ---  | 4T                           | 5T                              |
| gr 3                                                                              | ---    | ---                | 65               | 450 | 55-80            | 380-550          | 18   | ---  | 4T                           | 5T                              |
| gr 4                                                                              | ---    | ---                | 80               | 550 | 70-95            | 483-655          | 15   | ---  | 5T                           | 6T                              |
| ---                                                                               | 6Al-4V | ---                | 130              | 896 | 120 <sup>c</sup> | 827 <sup>c</sup> | 10   | ---  | 9T                           | 10T                             |
| ---                                                                               | 6Al-4V | ---                | 125              | 860 | 115 <sup>d</sup> | 795 <sup>d</sup> | 10   | 25   | ---                          | ---                             |
| ---                                                                               | ---    | 6Al-4V             | ---              | --- | ---              | ---              | ---  | ---  | ---                          | ---                             |

a. Single values are minimum unless otherwise noted. c. Applies to under 0.187 in. (4.75 mm) thickness or diameter.

d. Applies to 0.187 in. (4.75 mm) to 1.75 in. (44.45 mm) inclusive.

e. When specified by the implant manufacturer, the mechanical properties shall be tested and confirmed by the forger, upon completion of forgings, to comply with the minimum mechanical properties as specified by the implant manufacturer. See ASTM F 620 for more details.

f. T equals the thickness of the bend test specimen.

| ASME P-No. - BASE METAL TITANIUM & TITANIUM ALLOYS |       |                            |                                  |                        |
|----------------------------------------------------|-------|----------------------------|----------------------------------|------------------------|
| ASME Specification                                 | Grade | Specified Tensile min, ksi | Nominal Composition              | Product Form           |
| <b>P No. 51</b>                                    |       |                            |                                  |                        |
| SB-265                                             | 1     | 35                         | Unalloyed                        | Plate, Sheet, Strip    |
|                                                    | 2     | 50                         | Unalloyed                        | Plate, Sheet, Strip    |
|                                                    | 7     | 50                         | Alloyed (0.18Pd)                 | Plate, Sheet, Strip    |
|                                                    | 11    | 35                         | 0.18Pd-Low Fe-Low O <sub>2</sub> | Plate, Sheet, Strip    |
| SB-337                                             | 1     | 35                         | Unalloyed                        | Seamless & Welded Pipe |



| ASME P-No. - BASE METAL TITANIUM & TITANIUM ALLOYS (Continued) |       |                            |                       |                           |
|----------------------------------------------------------------|-------|----------------------------|-----------------------|---------------------------|
| ASME Specification                                             | Grade | Specified Tensile min, ksi | Nominal Composition   | Product Form              |
| <b>P No. 51 (Continued)</b>                                    |       |                            |                       |                           |
| SB-337                                                         | 2     | 50                         | Unalloyed             | Seamless & Welded Pipe    |
| (continued)                                                    | 7     | 50                         | Alloyed (0.18Pd)      | Seamless & Welded Pipe    |
| SB-338                                                         | 1     | 35                         | Unalloyed             | Seamless & Welded Tube    |
|                                                                | 2     | 50                         | Unalloyed             | Seamless & Welded Tube    |
|                                                                | 7     | 50                         | Alloyed (0.18Pd)      | Seamless & Welded Tube    |
| SB-348                                                         | 1     | 35                         | Unalloyed             | Bar & Billet              |
|                                                                | 2     | 50                         | Unalloyed             | Bar & Billet              |
|                                                                | 7     | 50                         | Alloyed (0.18Pd)      | Bar & Billet              |
| SB-363                                                         | WPT 1 | 35                         | Unalloyed             | Seamless & Welded Fitting |
|                                                                | WPT 2 | 50                         | Unalloyed             | Seamless & Welded Fitting |
| SB-381                                                         | F-1   | 35                         | Unalloyed             | Forging                   |
|                                                                | F-2   | 50                         | Unalloyed             | Forging                   |
|                                                                | F-7   | 50                         | Alloyed (0.18Pd)      | Forging                   |
| <b>P No. 52</b>                                                |       |                            |                       |                           |
| SB-265                                                         | 3     | 65                         | Unalloyed             | Plate, Sheet, Strip       |
|                                                                | 12    | 70                         | Alloyed (03.Mo-0.8Ni) | Plate, Sheet, Strip       |
| SB-337                                                         | 3     | 65                         | Unalloyed             | Seamless & Welded Pipe    |
|                                                                | 12    | 70                         | Alloyed (03.Mo-0.8Ni) | Seamless & Welded Pipe    |
| SB-338                                                         | 3     | 65                         | Unalloyed             | Seamless & Welded Tube    |
|                                                                | 12    | 70                         | Alloyed (03.Mo-0.8Ni) | Seamless & Welded Tube    |
| SB-348                                                         | 3     | 65                         | Unalloyed             | Bar & Billet              |
|                                                                | 12    | 70                         | Alloyed (03.Mo-0.8Ni) | Bar & Billet              |
| SB-363                                                         | WPT 3 | 65                         | Unalloyed             | Seamless & Welded Fitting |
| SB-381                                                         | F-3   | 65                         | Unalloyed             | Forging                   |
|                                                                | F-12  | 70                         | Alloyed (03.Mo-0.8Ni) | Forging                   |

| ASME F-No. - WELDING FILLER METAL TITANIUM & TITANIUM ALLOYS |                        |                                |
|--------------------------------------------------------------|------------------------|--------------------------------|
| F No.                                                        | ASME Specification No. | AWS Classification No.         |
| 51                                                           | SFA-5.16               | ERTi-1, ERTi-2, ERTi-3, ERTi-4 |
| 52                                                           | SFA-5.16               | ERTi-7, ERTi-11                |
| 53                                                           | SFA-5.16               | ERTi-9, ERTi-9 ELI             |
| 54                                                           | SFA-5.16               | ERTi-12                        |

| INTERNATIONAL CROSS REFERENCED SPECIFICATIONS - TITANIUM & TITANIUM ALLOYS |                  |                                       |                                                                                                                                                            |                                                                                        |               |        |
|----------------------------------------------------------------------------|------------------|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------|--------|
| UNS                                                                        | SAE/AMS          | MILITARY                              | ASTM                                                                                                                                                       | ASME                                                                                   | BS1           | DIN    |
| R50250                                                                     | ---              | T-81556, T-81915                      | B 265 grade 1, B 337 grade 1,<br>B 338 grade 1, B 348 grade 1,<br>B 381 grade F-1, F 67 grade 1,<br>F 467 alloy Ti 1, F 468 alloy Ti 1                     | SB-265 grade 1, SB-337 grade 1,<br>SB-338 grade 1, SB-348 grade 1,<br>SB-381 grade F-1 | TA 1          | 3.7025 |
| R50400                                                                     | 4902, 4941, 4942 | T-9046 CP-3, T-81556                  | B 265 grade 2, B 337 grade 2,<br>B 338 grade 2, B 348 grade 2,<br>B 367 grade C-2,<br>B 381 grade F-2, F 67 grade 2,<br>F 467 alloy Ti 2, F 468 alloy Ti 2 | SB-265 grade 2, SB-337 grade 2,<br>SB-338 grade 2, SB-348 grade 2,<br>SB-381 grade F-2 | TA 2, 3, 4, 5 | 3.7035 |
| R50550                                                                     | 4900             | T-9046 CP-2, T-81556                  | B 265 grade 3, B 337 grade 3,<br>B 338 grade 3, B 348 grade 3,<br>B 367 grade C-3, B 381 grade F-3,<br>F 67 grade 3                                        | SB-265 grade 3, SB-337 grade 3,<br>SB-338 grade 3, SB-348 grade 3,<br>SB-381 grade F-3 | ---           | 3.7055 |
| R50700                                                                     | 4901             | T-9046 CP-1,<br>T-9047 CP-70, F-83142 | B 265 grade 4, B 348 grade 4,<br>B 381 grade F-4, F 67 grade 4,<br>F 467 alloy Ti 4, F 468 alloy Ti 4                                                      | ---                                                                                    | TA 6, 7, 8, 9 | 3.7065 |

| INTERNATIONAL CROSS REFERENCED SPECIFICATIONS - TITANIUM & TITANIUM ALLOYS |                                                                                          |                                                        |                                                                   |                   |                                       |        |
|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------|-------------------|---------------------------------------|--------|
| UNS                                                                        | SAE/AMS                                                                                  | MILITARY                                               | ASTM                                                              | ASME              | BS1                                   | DIN    |
| R56400                                                                     | 4905, 4906, 4911,<br>4920, 4928, 4930,<br>4931, 4934, 4935,<br>4954, 4965, 4967,<br>4993 | T-9046 AB1/2, T-9047,<br>T-81556, T-81915,<br>F-83142, | B 265 grade 5, B 348 grade 5,<br>B 367 grade C-5, B 381 grade F-5 | SFA-5.16 (ERTi-5) | TA 10, 11,<br>12,<br>TA 28, 56,<br>59 | 3.7165 |

a. It is not practical to directly correlate the various metal designations from country to country, let alone comparing several countries and their metal designations; from the view that chemical composition may be similar, but not identical, and that manufacturing technologies may differ greatly. Consequently, the cross references made in this table are, at best, only listed as a guide to assist in finding comparable metal designations, rather than equivalent metal designations.

UNS - Unified Numbering System; SAE/AMS - Society of Automotive Engineers/Aerospace Material Specifications; MILITARY - U.S. Military Specifications; ASTM - American Society for Testing Materials; ASME - American Society of Mechanical Engineers; BS - British Standards; DIN - Deutsches Institut für Normung.

# Chapter 4

## ***REACTIVE & REFRACTORY METALS***

The refractory metals group includes niobium (also known as columbium), tantalum, molybdenum, tungsten, and rhenium. The name of this group of metals arises from their very high melting temperatures, which range from 2468 to 3410°C (4474 to 6170°F). The metals and their alloys find specialized applications in the electronics, aerospace, nuclear, and chemical process industries.

Except for niobium, the refractory metals are produced as metal powders which are consolidated by sintering or melting into ingots. These are then processed by combinations of forging, extrusion, and rolling into bar, plate, sheet, foil, and tubing. They can be machined, generally using carbide tools, and a range of techniques is available for their fabrication. Alloys of niobium and tantalum are the most easily fabricated, while more specialized techniques are required for molybdenum and tungsten. Joining is accomplished using electron beam, gas tungsten arc, and resistance welding processes.

Despite their high melting temperatures, the refractory metals react with oxidizing atmospheres at moderate temperatures and this has restricted their use as high temperature materials. In attempts to compensate for this, coatings of the silicide or aluminide type have been developed which enable niobium to be used at temperatures up to about 1650°C (3002°F). For the other refractory metals, coatings developments have been less successful to date, although research continues. Refractory metals and alloys in general have good resistance to corrosion by liquid metals and by acid solutions, and this is responsible for some of their applications.

### **Niobium (Columbium)**

Although most of the niobium produced is used as alloy additions in the steel industry, the combination of relatively light weight and high temperature strength has led to the use of niobium alloys in the

aerospace industry. In many cases these applications are only possible when the materials are protected by coatings, for example, a coating of Si-20%Cr-20%Fe applied as a slurry which is subsequently baked to stimulate reaction bonding and diffusion. Niobium alloys such as C-103 (UNS R04295) with 10%Hf and 1%Ti, C-129Y with 10%W, 10%Hf and 0.1%Y, Cb-752 (UNS R04271) with 10%W and 2.5%Zr, and FS-85 (28%Ta, 10%W, 1%Zr) find aerospace applications such as thrust chambers and radiation skirts for rocket and aircraft engines, rocket nozzles, thermal shields, leading edges and nose caps for hypersonic flight vehicles, and guidance structure for glide re-entry vehicles. A Nb-1%Zr alloy (commercial grade UNS R04261, reactor grade UNS R04251) finds applications in the nuclear industry. Several commercial and nuclear grades of unalloyed niobium (UNS R04200, UNS R04210, and UNS R04211) are also available.

## **Tantalum**

The major application of tantalum is in electronics where it is used in the form of porous sintered powder metallurgy electrodes in electrolytic capacitors and as precision foil in foil capacitors, as well as lead wires, seals, and containment cans. Tantalum is also produced in the form of mill products including sheet, plate, rod, bar, and tubing. Tubing can be either seamless or welded and drawn. Tantalum and tantalum-clad steel are used in chemical process applications under many severe conditions including the condensing, reboiling, preheating, and cooling of nitric, hydrochloric, and sulphuric acids. It is used as heating elements and heat shields for furnaces and in specialized aerospace, nuclear, and biomedical applications. Unalloyed tantalum is designated by UNS R05200 (cast), UNS R05210, and UNS R05400 (sintered). Tantalum alloys include Ta-2.5%W (63 metal) which is used in chemical processing for heat exchangers, tower linings, valves, and tubing, and Ta-7.5%W, a powder product which is cold drawn to springs and other components for severe acid service. The alloy Ta-10%W (UNS R05255) finds high temperature applications up to 2480°C (4496°F) in the aerospace industry, for example as hot gas valves and rocket engine components, and also in corrosive and abrasive environments in the chemical process and nuclear industries. Other commercial tantalum alloys include T-111 (8%W, 2%Hf), T-222 (10%W, 10%Hf) and Ta-40%Nb (UNS R05240).

## **Molybdenum**

Like niobium, most molybdenum production goes for use as an alloying element in steels and superalloys; however, some sheet, wire, bar, and tube are produced by forging, rolling and extrusion. Aerospace applications include high temperature structural parts such as nozzles,

supports, shields, and pumps. Molybdenum is used for tools in the metalworking industry, for acid service in the chemical process industry, for electrical resistance furnace heating elements, and for numerous components in the electronics, nuclear, metallizing, and glass industries. Unprotected molybdenum oxidizes rapidly above 500°C (932°F) so it cannot be used in oxidizing atmospheres. Commercial alloys include alloy 362 (UNS R03620) which contains 0.5%Ti, the alloy TZC which contains 1%Ti and 0.3%Zr, and the alloy TZM (UNS R03630, which is also known as alloy 363 when arc cast and UNS R03640, or alloy 364 when in powder metallurgical form) which contains 0.5%Ti and 0.1%Zr. Other alloys include HCM (1.1%Hf, 0.07%C), HWM-25 (25%W, 1.0%Hf), and HWM-45 (45%W, 0.9%Hf). Several grades of unalloyed molybdenum are also available.

## **Tungsten**

The main use of tungsten is as tungsten carbide which is discussed in Chapter 5; however, tungsten is also used extensively in metal or alloy form where advantage is taken of its high melting point, density, and elastic modulus. For example, it is used in wire form in lighting, electronic devices, and thermocouples (lamp filaments, electron tube grids, and heating elements were among its original applications). It is also used in counterweights, flywheels, radiation shields, furnace parts, crucibles, and in the metalworking industry. Tungsten mill products can be classified into three groups, based on recrystallization temperature. The first group, including high purity tungsten and its alloys with rhenium or molybdenum, recrystallizes at or below 900°C (1652°F), while the second group, commercial purity (undoped) tungsten, recrystallizes above 1200°C (2192°F). The third group consists of AKS doped tungsten (doped with small amounts of aluminum, potassium, and silicon), doped tungsten alloyed with rhenium, and tungsten containing particles of thoria. These materials recrystallize above 1800°C (3272°F), forming a characteristic microstructure of elongated interlocking grains.

The high strength and creep resistance of tungsten is offset by strong reactivity in air and poor low temperature ductility. Tungsten exhibits a ductile-brittle transition which occurs above 200°C (392°F) in recrystallized material but at lower temperatures after cold work. The retardation of recrystallization which is caused by AKS doping or by additions of a dispersion of thoria particles improves the ductility and also allows the material to retain tensile strength and creep resistance at high temperatures; this is particularly important for applications in filaments for incandescent lamps where sagging is undesirable. In addition to AKS doped tungsten and a range of unalloyed tungsten materials (e.g., UNS R07005 and R07006), commercially available alloys

include tungsten containing 1% or 2%ThO<sub>2</sub>, tungsten alloyed with 2% or 15%Mo, or with 1.5%, 3% (UNS R07031) or 25%Re. Also available are arc welding electrode materials consisting of tungsten containing either thorium (UNS R07911 with 1%ThO<sub>2</sub> and UNS R07912 with 2%ThO<sub>2</sub>), zirconia (UNS R07920 with 0.3%ZrO), ceria (UNS R07932 with 2%CeO<sub>2</sub>) or lanthana (UNS R07941 with 1%La<sub>2</sub>O<sub>3</sub>).

The machinability of tungsten can be a problem, but machinable tungsten heavy-metal alloys bonded with copper, nickel, and iron have been developed. These are produced by liquid phase sintering to create a soft ductile matrix phase in which particles of the tungsten alloy are embedded. Included in this category are the Class 1 alloys containing 6-7%Ni and 3-4%Cu, and a group of alloys containing nickel and iron in the ratio of 4Ni:1Fe (Class 2), 7Ni:3Fe (Class 3), and 1Ni:1Fe (Class 4).

## **Zirconium**

Zirconium, along with metals such as titanium and hafnium, falls into the category of reactive metals. It is similar in many respects chemically and mechanically to titanium, but has both a higher density and a higher melting temperature (6.51 g.cm<sup>-3</sup> and 1852°C [3366°F] as compared to titanium at 4.51 g cm<sup>-3</sup> and 1668°C [3034°F]). Zirconium is chemically very reactive, such that in finely divided form it is pyrophoric. This property gives it applications in flashbulbs and as getters for absorbing gases in sealed evacuated devices. However, the oxide formed on bulk zirconium is dense, stable, and protective (self-healing and adherent) so that zirconium and its alloys have excellent corrosion resistance in many media, including superheated water. This, combined with its low capture cross section for thermal neutrons, is responsible for its most important application, namely as a structural (e.g., pressure tubes) and fuel cladding material in water cooled nuclear reactors. It is also used in pressure vessels, pumps, valves, and heat exchangers in chemical processing equipment for severe corrosion environments. Zirconium alloys are processed by most available techniques including forging, rolling, and extrusion as well as by casting. They are generally machinable and are also weldable, most frequently by GTAW (gas tungsten arc welding) and GMAW (gas metal arc welding) techniques using appropriate atmosphere control.

Like titanium, zirconium is allotropic with the hexagonal close-packed (*alpha* phase) crystal structure being stable at low temperatures, and the body centered cubic (*beta*) phase stable above 870°C (1598°F) in the pure metal. As in the case of titanium, particular alloying elements stabilize either the *alpha* or the *beta* phase, and a wide range of microstructures are possible depending on composition and heat treatment. However, the

most common commercial zirconium alloys are dilute *alpha* phase alloys, not unlike unalloyed zirconium in metallurgical behaviour. The four commercial alloys used in nuclear applications are reactor grade zirconium (UNS R60001), Zr-2.5%Nb (UNS R60901), Zircaloy-2 (UNS R60802), which contains 1.5%Sn as well as a total of about 0.3% Fe+Cr+Ni, and Zircaloy-4 (UNS R60804), which also contains 1.5%Sn with a total of about 0.35% Fe+Cr. The non-nuclear industrial zirconium alloys are quite similar and include Grade 702, a commercially pure zirconium (UNS R60702), the alloy Grade 704 (UNS R60704), which is similar to the Zircaloys, and two Zr-2.5%Nb alloys known as Grade 705 (UNS R60705) and Grade 706 (UNS R60706).

## **Cobalt**

Cobalt is a metal which is comparable in many of its properties with nickel and iron. For example its melting point, density, and thermal expansion are all close to those of nickel and iron and it is ferromagnetic. Like iron, it is allotropic, its crystal structure below 417°C (783°F) being hexagonal close-packed (hcp) while above this temperature it is face centered cubic (fcc). Cobalt and its alloys find commercial applications as heat-resistant, corrosion-resistant, and wear-resistant alloys and as the matrix component of cemented carbide cutting tools which are discussed in Chapter 5.

Heat-resistant cobalt alloys are used for components in gas turbines and in power generating and chemical processing equipment where their high strength at high temperatures and their resistance to sulphidation are often superior to those of the nickel and nickel-iron based high temperature alloys. Applicable cobalt alloys include the wrought Haynes alloys 25 (also called L-605, UNS R30605) and 188 (UNS R30188) and the casting alloy MAR-M 509. These contain 20-23% chromium and 7-15% tungsten for solution strengthening along with 10-22% nickel to stabilize the fcc phase, and are heat treated to control the distribution of strengthening carbide particles.

The corrosion-resistant cobalt alloys are designed for use where corrosion resistance is required in combination with resistance to wear and high strength over a wide range of temperature. Included in this category are the wrought alloys MP35N (UNS R30035, which contains 20% Cr, 10%Mo, 35%Ni) and Haynes alloy 1233 (UNS R31233, with 26%Cr, 5%Mo, 2%W, 9%Ni). Typical applications are as pump and valve components. The corrosion-resistant cobalt-based alloy Vitallium (30%Cr, 6%Mo in cast form, 20%Cr, 15%W in wrought form), and alloy MP35N are used for biomedical applications such as prosthetic devices and implants



as well as dental implants where advantage can be taken of their compatibility with body fluids and tissues.

Cobalt-based wear-resistant alloys are widely used, often as weld overlays (hardfacing alloys), although some are also available as castings or wrought products and some in powder metallurgy versions. They find applications where resistance to wear is required under moderately corrosive and/or elevated temperature environments in the automotive, chemical processing, marine, power generation, pulp and paper, oil and gas, steel, and textile industries. A major application is as weld overlay on valve seating surfaces and they are also used as overlays on bearing surfaces and on knife and shear blades. Wrought applications include erosion shields and guide bars.

The microstructures of these alloys consist basically of particles of a hard carbide phase dispersed throughout a softer matrix, with the amount of carbide exceeding 30% by volume in some cases. The matrix controls resistance to sliding wear (e.g., fretting and galling) and to liquid droplet and cavitation erosion, while resistance to abrasive wear as well as to solid particle and slurry erosion relies on both constituents in a complex manner. Typical compositions include 20-30% chromium with up to 15% tungsten and small amounts of molybdenum, iron, nickel, silicon, and manganese (a few alloys contain substantial additions of nickel, molybdenum, or niobium). These provide solution strengthening and wear resistance along with oxidation and corrosion resistance to the matrix as well as additional strength and wear resistance through carbide precipitation. Carbon contents lie in the range 0.5-3%; the carbide particles are generally of the chromium-rich  $M_7C_3$  type, although in high tungsten alloys the tungsten-rich  $M_6C$  type also form. Distribution of carbide particles is not readily controlled in the weld overlay and cast structures, and grain boundary carbides and segregation are common.

A wide range of alloys is available including the Stellite alloys 1, 6, 12, and 21 (UNS R30001, R30006, R30012, and R30021). Of these, Stellite 1 is the hardest, most abrasion resistant, and least ductile, while Stellite 21 is the most corrosion resistant. Haynes alloy 6B is a wrought version of Stellite 6 which has improved properties by virtue of the improved microstructural control which is possible during wrought processing. Other commercial alloys include Havar (UNS R30004), Elgiloy (UNS R30003), and Stellite F (UNS R30002).

The Tribaloy alloys, such as Tribaloy T-400 (UNS R30400) and T-800 have reduced chromium (8% and 17% respectively) and carbon contents and much increased amounts of molybdenum (28%) and silicon (3%), to

suppress carbides and stimulate the formation of hard, corrosion-resistant intermetallic "Laves phase" particles which impart excellent abrasion resistance. Some other alloys are designed to be precipitation hardening, including the cobalt-nickel-chromium-molybdenum-tungsten alloys Duratherm 2602 (UNS R30280), Duratherm 477 (UNS R30477), Duratherm 700 (UNS R30700), and wrought Duratherm 600 (UNS R30600), as well as the cobalt-chromium-iron-nickel alloy ARNAVAR (UNS R30007).

| <b>SAE/AMS SPECIFICATIONS - REACTIVE &amp; REFRACTORY ALLOYS</b> |                                                                                                  |
|------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                       | <b>Title</b>                                                                                     |
| 7817                                                             | Molybdenum Alloy Sheet, Strip, and Plate, 0.48Ti - 0.09Zr - 0.02C, Arc Cast, Stress Relieved     |
| 7819                                                             | Molybdenum Alloy Bars, 0.48Ti - 0.09Zr - 0.02C, Arc Cast, Stress Relieved, UNS R03640            |
| 7846                                                             | Tantalum Alloy Bars and Rods, 90Ta - 10W, Annealed, UNS R05255                                   |
| 7847                                                             | Tantalum Alloy Sheet, Strip, and Plate, 90Ta - 10W, UNS R05255                                   |
| 7848                                                             | Tantalum Alloy Bars and Rods, 90Ta - 10W, UNS R05255                                             |
| 7849                                                             | Tantalum Sheet, Strip, and Plate, Annealed, UNS R05210                                           |
| 7850                                                             | Columbium Sheet, Strip, Plate, and Foil, UNS R04211                                              |
| 7851                                                             | Foil, sheet, Strip, and Plate, Columbium Alloy, 10W - 2.5Zr, Recrystallized, UNS R04271          |
| 7852                                                             | Sheet, Strip, and Plate, Columbium Alloy, 10Hf - 1.0Ti, UNS R04295                               |
| 7855                                                             | Columbium Alloy Bars, Rods, and Wire, 10W - 2.5Zr, Recrystallized, UNS R04271                    |
| 7857                                                             | Columbium Alloy Bars, Rods, and Extrusions, 10Hf - 1.0Ti, Recrystallization Annealed, UNS R04295 |
| 7875                                                             | Powder, Chromium Carbide Plus Nickel-Chromium Alloy, 75Cr2C3 + 25 (80Ni - 20Cr Alloy)            |
| 7897                                                             | Tungsten Forgings, Pressed, Sintered, and Forged, UNS R07005                                     |
| 7898                                                             | Tungsten Sheet, Strip, Plate, and Foil, Pressed, Sintered, and Wrought, UNS R07006               |

| <b>ASTM SPECIFICATIONS - REACTIVE &amp; REFRACTORY ALLOYS</b> |                                                               |
|---------------------------------------------------------------|---------------------------------------------------------------|
| <b>Molybdenum and Molybdenum Alloys</b>                       |                                                               |
| B 387                                                         | Molybdenum and Molybdenum Alloy Bar, Rod, and Wire            |
| B 386                                                         | Molybdenum and Molybdenum Alloy Plate, Sheet, Strip, and Foil |
| F 289                                                         | Molybdenum Wire and Rod for Electronic Applications           |
| F 290                                                         | Round Wire for Winding Electron Tube Grid Laterals            |
| <b>Tantalum and Tantalum Alloys</b>                           |                                                               |
| B 364                                                         | Tantalum and Tantalum Alloy Ingots                            |
| B 365                                                         | Tantalum and Tantalum Alloy Rod and Wire                      |
| B 521                                                         | Tantalum and Tantalum Alloy Seamless and Welded Tubes         |
| B 708                                                         | Tantalum and Tantalum Alloy Plate, Sheet, and Strip           |

| <b>ASTM SPECIFICATIONS - REACTIVE &amp; REFRACTORY ALLOYS (Continued)</b> |                                                                                                        |
|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| <b>Tungsten</b>                                                           |                                                                                                        |
| B 390                                                                     | Evaluating Apparent Grain Size and Distribution of Cemented Tungsten Carbides                          |
| B 482                                                                     | Preparation of Tungsten and Tungsten Alloys for Electroplating                                         |
| B 760                                                                     | Tungsten Plate, Sheet, and Foil                                                                        |
| B 777                                                                     | Tungsten Base, High-Density Metal                                                                      |
| F 288                                                                     | Tungsten Wire for Electron Devices and Lamps                                                           |
| F 290                                                                     | Round Wire for Winding Electron Tube Grid Laterals                                                     |
| <b>Niobium and Niobium Alloys</b>                                         |                                                                                                        |
| B 391                                                                     | Niobium and Niobium Alloy Ingots                                                                       |
| B 392                                                                     | Niobium and Niobium Alloy Bar, Rod, and Wire                                                           |
| B 393                                                                     | Niobium and Niobium Alloy Strip, Sheet, and Plate                                                      |
| B 394                                                                     | Niobium and Niobium Alloy Seamless and Welded Tubes                                                    |
| B 652                                                                     | Niobium-Hafnium Alloy Ingots                                                                           |
| B 654                                                                     | Niobium-Hafnium Alloy Foil, Sheet, Strip, and Plate                                                    |
| B 655                                                                     | Niobium-Hafnium Alloy Bar, Rod, and Wire                                                               |
| <b>Zirconium and Zirconium Alloys</b>                                     |                                                                                                        |
| B 349                                                                     | Zirconium Sponge and Other Forms of Virgin Metal for Nuclear Application                               |
| B 350                                                                     | Zirconium and Zirconium Alloy Ingots for Nuclear Application                                           |
| B 351                                                                     | Hot-Rolled and Cold-Finished Zirconium and Zirconium Alloy Bars, Rod, and Wire for Nuclear Application |
| B 352                                                                     | Zirconium and Zirconium Alloy Sheet, Strip, and Plate for Nuclear Application                          |
| B 353                                                                     | Wrought Zirconium and Zirconium Alloy Seamless and Welded Tubes for Nuclear Service                    |
| B 493                                                                     | Zirconium and Zirconium Alloy Forgings                                                                 |
| B 494                                                                     | Primary Zirconium                                                                                      |
| B 495                                                                     | Zirconium and Zirconium Alloy Ingots                                                                   |
| B 523                                                                     | Seamless and Welded Zirconium and Zirconium Alloy Tubes                                                |
| B 550                                                                     | Zirconium and Zirconium Alloy Bar and Wire                                                             |
| B 551                                                                     | Zirconium and Zirconium Alloy Strip, Sheet, and Plate                                                  |
| B 653                                                                     | Seamless and Welded Zirconium and Zirconium Alloy Welding Fittings                                     |

| <b>ASTM SPECIFICATIONS - REACTIVE &amp; REFRACTORY ALLOYS (Continued)</b> |                                                                          |
|---------------------------------------------------------------------------|--------------------------------------------------------------------------|
| <b>Zirconium and Zirconium Alloys (Continued)</b>                         |                                                                          |
| B 658                                                                     | Seamless and Welded Zirconium and Zirconium Alloy Pipe                   |
| B 752                                                                     | Castings, Zirconium-Base, Corrosion Resistant, for General Application   |
| B 811                                                                     | Wrought Zirconium Alloy Seamless Tubes for Nuclear Reactor Fuel Cladding |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - REACTIVE &amp; REFRACTORY ALLOYS</b> |                  |                                |             |            |
|------------------------------------------------------------------------------------|------------------|--------------------------------|-------------|------------|
| <b>UNS</b>                                                                         | <b>AMS</b>       | <b>ASTM</b>                    | <b>ASME</b> | <b>AWS</b> |
| R03600                                                                             | ---              | B 386 (360); B 387 (360)       | ---         | ---        |
| R03603                                                                             | ---              | F 364 (II)                     | ---         | ---        |
| R03604                                                                             | ---              | F 364 (I)                      | ---         | ---        |
| R03605                                                                             | 7801             | ---                            | ---         | ---        |
| R03606                                                                             | 7805             | ---                            | ---         | ---        |
| R03610                                                                             | ---              | B 386 (361); B 387 (361)       | ---         | ---        |
| R03630                                                                             | 7817             | B 386 (363); B 387 (363)       | ---         | ---        |
| R03640                                                                             | ---              | B 386 (364); B 387 (364)       | ---         | ---        |
| R03650                                                                             | ---              | B 386 (365); B 387 (365)       | ---         | ---        |
| R04200                                                                             | ---              | B 391; B 392; B 393; B 394     | ---         | ---        |
| R04210                                                                             | ---              | B 391; B 392; B 393; B 394     | ---         | ---        |
| R04211                                                                             | 7850             | ---                            | ---         | ---        |
| R04251                                                                             | ---              | B 391; B 392; B393; B394       | ---         | ---        |
| R04261                                                                             | ---              | B 391; B 392 (4); B 393; B 394 | ---         | ---        |
| R04271                                                                             | 7851; 7855       | ---                            | ---         | ---        |
| R04295                                                                             | 7852; 7857       | B 652; B 654; B 655            | ---         | ---        |
| R05200                                                                             | ---              | B 364; B 365; B 521            | ---         | ---        |
| R05210                                                                             | 7849             | ---                            | ---         | ---        |
| R05240                                                                             | ---              | B 364; B 365; B 521; B 708     | ---         | ---        |
| R05255                                                                             | 7846; 7847; 7848 | B 364; B 365; B 521; B 708     | ---         | ---        |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - REACTIVE &amp; REFRACTORY ALLOYS (Continued)</b> |            |                                                                  |                                                               |                |
|------------------------------------------------------------------------------------------------|------------|------------------------------------------------------------------|---------------------------------------------------------------|----------------|
| <b>UNS</b>                                                                                     | <b>AMS</b> | <b>ASTM</b>                                                      | <b>ASME</b>                                                   | <b>AWS</b>     |
| R05400                                                                                         | ---        | B 364; B 365; B 521; B 708                                       | ---                                                           | ---            |
| R07005                                                                                         | 7897       | F 288 (1A, 1B); F 290                                            | ---                                                           | ---            |
| R07006                                                                                         | 7898       | ---                                                              | ---                                                           | ---            |
| R07030                                                                                         | ---        | F 73 (electronic grade)                                          | ---                                                           | ---            |
| R07900                                                                                         | ---        | ---                                                              | SFA-5.12 (EWP)                                                | A5.12 (EWP)    |
| R07911                                                                                         | ---        | ---                                                              | SFA-5.12 (EWTh-1)                                             | A5.12 (EWTh-1) |
| R07912                                                                                         | ---        | ---                                                              | SFA-5.12 (EWTh-2)                                             | A5.12 (EWTh-2) |
| R07920                                                                                         | ---        | ---                                                              | SFA-5.12 (EWZr-1)                                             | A5.12 (EWZr-1) |
| R07932                                                                                         | ---        | ---                                                              | SFA-5.12 (EWCe-2)                                             | A5.12 (EWCe-2) |
| R07941                                                                                         | ---        | ---                                                              | SFA-5.12 (EWLa-1)                                             | A5.12 (EWLa-1) |
| R19800                                                                                         | 7901; 7902 | ---                                                              | ---                                                           | ---            |
| R19920                                                                                         | 7900       | ---                                                              | ---                                                           | ---            |
| R60001                                                                                         | ---        | B 349; B3 50; B 351; B 352; B 353                                | ---                                                           | ---            |
| R60701                                                                                         | ---        | B 494; B 550                                                     | ---                                                           | ---            |
| R60702                                                                                         | ---        | B 493; B 495; B 523; B 550; B 551;<br>B 653; B 658; B 752 (702C) | SB493; SB494; SB495; SB523;<br>SB550; SB551; SFA-5.24 (ERZr2) | A5.24 (ERZ r2) |
| R60703                                                                                         | ---        | B 494; B 495                                                     | ---                                                           | ---            |
| R60704                                                                                         | ---        | B 493; B 495; B 523; B 550; B 551;<br>B 653; B 658; B 752 (704C) | SFA-5.24 (ERZr3)                                              | A5.24 (ERZr3)  |
| R60705                                                                                         | ---        | B 493; B 495; B 523; B 550; B 551;<br>B 653; B 658; B 752 (705C) | ---                                                           | ---            |
| R60706                                                                                         | ---        | B 495; B 551                                                     | ---                                                           | ---            |
| R60707                                                                                         | ---        | ---                                                              | SFA-5.24 (ERZr4)                                              | A5.24 (ERZr4)  |
| R60802                                                                                         | ---        | B 350; B 351; B 352; B 353                                       | ---                                                           | ---            |
| R60804                                                                                         | ---        | B 350; B 351; B 352; B 353                                       | ---                                                           | ---            |
| R60901                                                                                         | ---        | B 350; B 351; B 352; B 353                                       | ---                                                           | ---            |
| R60904                                                                                         | ---        | B 353                                                            | ---                                                           | ---            |

**AMERICAN CROSS REFERENCED SPECIFICATIONS - REACTIVE & REFRACTORY ALLOYS (Continued)**

a. This cross-reference table lists the basic specification or standard number, and since these standards are constantly being revised, it should be kept in mind that they are presented herein as a guide and may not reflect the latest revision.

**COMMON NAMES OF REACTIVE & REFRACTORY ALLOYS WITH UNS No.**

|                                                              |
|--------------------------------------------------------------|
| Molybdenum, Unalloyed, R03600                                |
| Molybdenum Sealing Alloy, R03601                             |
| Molybdenum Sealing Alloy, R03602                             |
| Molybdenum, R03603                                           |
| Molybdenum, R03604                                           |
| Molybdenum Metal, R03605                                     |
| Molybdenum Metal, R03606                                     |
| Molybdenum Unalloyed, R03610                                 |
| Molybdenum Alloy, R03620                                     |
| Molybdenum Alloy, R03630                                     |
| Molybdenum Alloy, R03640                                     |
| Molybdenum Unalloyed, Low Carbon, R03650                     |
| Niobium (Columbium), Unalloyed, Reactor Grade, R04200        |
| Niobium (Columbium), Unalloyed, Commercial Grade, R04210     |
| Niobium (Columbium), Unalloyed, Commercial Grade, R04211     |
| Niobium (Columbium) - 1% Zirconium, Reactor Grade, R04251    |
| Niobium (Columbium) - 1% Zirconium, Commercial Grade, R04261 |
| Niobium (Columbium) Alloy, 10W-2.5Zr, R04271                 |
| Niobium (Columbium) Alloy, R04295                            |
| Tantalum, Unalloyed, Cast, R05200                            |
| Tantalum Metal, R05210                                       |
| Tantalum - 40 Nb (Cb) Alloy, R05240                          |
| 90 Tantalum - 10 Tungsten, R05255                            |

| <b>COMMON NAMES OF REACTIVE &amp; REFRACTORY ALLOYS WITH UNS No. (Continued)</b> |
|----------------------------------------------------------------------------------|
| Tantalum, Unalloyed, Sintered, R05400                                            |
| Tungsten, R07005                                                                 |
| Tungsten Metal, R07006                                                           |
| Tungsten, R07030                                                                 |
| Tungsten-Rhenium, R07031                                                         |
| Tungsten, R07080                                                                 |
| Tungsten, R07100                                                                 |
| Tungsten Arc Welding Electrode, R07900                                           |
| Tungsten-Thorium Alloy Arc Welding Electrode, R07911                             |
| Tungsten-Thorium Alloy Arc Welding Electrode, R07912                             |
| Tungsten-Zirconium Alloy Arc Welding Electrode, R07920                           |
| Tungsten-Cerium Alloy Arc Welding Electrode, R07932                              |
| Tungsten-Lanthanum Alloy Arc Welding Electrode, R07941                           |
| Zirconium Unalloyed Reactor Grade, R60001                                        |
| Zirconium, Unalloyed, R60701                                                     |
| Zirconium, Unalloyed, R60702                                                     |
| Zirconium Alloy, R60703                                                          |
| Zirconium Alloy, R60704                                                          |
| Zirconium Alloy, R60705                                                          |
| Zirconium Alloy, R60706                                                          |
| Zirconium Alloy (2.5 Cb) Welding Filler Metal, R60707                            |
| Zirconium Alloy Reactor Grade, R60802                                            |
| Zirconium Alloy Reactor Grade, R60804                                            |
| Zirconium Alloy Reactor Grade, R60901                                            |
| Zirconium Alloy Reactor Grade, R60902                                            |
| Zirconium - 0.65 Nb, R60904                                                      |



| <b>CHEMICAL COMPOSITION OF REACTIVE &amp; REFRACTORY ALLOYS</b> |                                                                                                                                                                                  |
|-----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                      | <b>CHEMICAL COMPOSITION</b>                                                                                                                                                      |
| R03600                                                          | Mo rem C 0.010-0.040 Fe 0.010 max N 0.0010 max Ni 0.005 max O 0.0030 max Si 0.10 max                                                                                             |
| R03601                                                          | Mo 99.90 min C 0.04 max Fe 0.01 max N 0.001 max Ni 0.01 max O 0.005 max Si 0.01 max W 0.02 max Other each 0.005 max                                                              |
| R03602                                                          | Mo 99.90 min C 0.005 max Fe 0.01 max N 0.002 max Ni 0.01 max O 0.008 max Si 0.01 max W 0.02 max Other each 0.005 max                                                             |
| R03603                                                          | Mo 99.90 min Al 0.015 max C 0.0015 max Fe 0.001 max H 0.001 max N 0.001 max O 0.175 max Si 0.035 max Sn 0.0025 max W 0.02 max<br>Other each 0.005 max, Ca 0.005 max, K 0.015 max |
| R03604                                                          | Mo 99.90 min Al 0.015 max C 0.005 max Fe 0.01 max H 0.001 max N 0.002 max O 0.008 max Si 0.01 max Sn 0.0025 max W 0.02 max<br>Other each 0.005 max, Ca 0.005 max, K 0.015 max    |
| R03605                                                          | Mo 99.90 min C 0.030 max Fe 0.020 max N 0.0010 max Ni 0.010 max O 0.0030 max Si 0.010 max                                                                                        |
| R03606                                                          | Mo 99.95 min C 0.030 max Fe 0.008 max H 0.0005 max N 0.002 max Ni 0.002 max O 0.0015 max Si 0.008 max                                                                            |
| R03610                                                          | Mo rem C 0.010 max Fe 0.010 max N 0.0020 max Ni 0.005 max O 0.0070 max Si 0.010 max                                                                                              |
| R03620                                                          | Mo rem C 0.010-0.040 Fe 0.010 max N 0.0010 max Ni 0.005 max O 0.0030 max Si 0.010 max Ti 0.40-0.55                                                                               |
| R03630                                                          | Mo rem C 0.010-0.040 Fe 0.010 max N 0.0010 max Ni 0.005 max O 0.0030 max Si 0.010 max Ti 0.40-0.55 Zr 0.06-0.12                                                                  |
| R03640                                                          | Mo rem C 0.010-0.040 Fe 0.010 max N 0.0020 max Ni 0.005 max O 0.030 max Si 0.005 max Ti 0.40-0.55 Zr 0.06-0.12                                                                   |
| R03650                                                          | Mo rem C 0.010 max Fe 0.010 max N 0.0010 max Ni 0.005 max O 0.0030 max Si 0.010 max                                                                                              |
| R04200                                                          | Mo 0.005 max C 0.01 max Fe 0.005 max H 0.001 max Hf 0.01 max N 0.01 max Nb rem Ni 0.005 max O 0.015 max Si 0.005 max Ta 0.1 max<br>W 0.03 max Zr 0.01 max                        |
| R04210                                                          | Mo 0.005 max C 0.01 max Fe 0.01 max H 0.001 max Hf 0.01 max N 0.01 max Nb rem Ni 0.005 max O 0.025 max Si 0.005 max Ta 0.2 max<br>W 0.05 max Zr 0.01 max                         |
| R04211                                                          | Nb rem C 0.005 max Fe 0.010 max H 0.002 max N 0.010 max O 0.030 max Si 0.005 max Ta 0.10 max Ti 0.005 max Zr 0.010 max<br>Other each 0.010 max, total 0.15 max                   |
| R04251                                                          | Nb rem C 0.01 max Fe 0.005 max H 0.001 max Hf 0.01 max Mo 0.005 max N 0.01 max Ni 0.005 max O 0.015 max Si 0.005 max Ta 0.1 max<br>W 0.03 max Zr 0.8-1.2                         |
| R04261                                                          | Nb rem C 0.01 max Fe 0.01 max H 0.001 max Hf 0.01 max Mo 0.005 max N 0.01 max Ni 0.005 max O 0.025 max Si 0.005 max Ta 0.2 max<br>W 0.05 max Zr 0.8-1.2                          |
| R04271                                                          | Nb rem C 0.030 max Fe 0.02 max H 0.001 max N 0.010 max O 0.020 max Si 0.02 max Ta 0.15 max Ti 0.01 max W 9.00-11.00 Zr 2.00-3.00                                                 |
| R04295                                                          | Nb rem C 0.015 max H 0.0015 max Hf 9-11 N 0.010 max O 0.020 max Ta 0.500 max Ti 0.7-1.3 W 0.500 max Zr 0.700 max                                                                 |

| <b>CHEMICAL COMPOSITION OF REACTIVE &amp; REFRACTORY ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                                                  |
|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                                  | <b>CHEMICAL COMPOSITION</b>                                                                                                                                                                                                                                                      |
| R05200                                                                      | Ta rem C 0.01 max Cb 0.05 max Fe 0.01 max H 0.001 max Mo 0.01 max N 0.01 max Ni 0.01 max O 0.015 max Si 0.005 max Ti 0.01 max W 0.03 max                                                                                                                                         |
| R05210                                                                      | Ta 99.85 min C 0.0075 max Cb 0.100 max Co 0.002 max Fe 0.01 max H 0.0010 max Mo 0.01 max N 0.0075 max Ni 0.005 max O 0.015 max Si 0.005 max Ti 0.005 max W 0.03 max Zr 0.01 max Other total 0.15 max                                                                             |
| R05240                                                                      | Ta rem C 0.010 max Cb 35.0-42.0 H 0.0015 max Fe 0.010 max Mo 0.020 max Ni 0.010 max Ni 0.010 max O 0.020 max Si 0.005 max Ti 0.010 max W 0.050 max Trace impurities 0.00 max                                                                                                     |
| R05255                                                                      | Ta rem C 0.01 max Cb 0.10 max Fe 0.01 max H 0.001 max Mo 0.01 max N 0.01 max Ni 0.01 max O 0.015 max Si 0.005 max Ti 0.01 max W 9.0-11.0                                                                                                                                         |
| R05400                                                                      | Ta rem C 0.01 max Cb 0.05 max Fe 0.01 max H 0.001 max Mo 0.01 max N 0.015 max Ni 0.01 max O 0.03 max Si 0.005 max Ti 0.01 max W 0.03 max                                                                                                                                         |
| R60001                                                                      | Zr rem Al 0.0075 max B 0.00005 max C 0.027 max Cd 0.00005 max Co 0.0020 max Cr 0.020 max Cu 0.0050 max Fe 0.150 max H 0.0025 max Hf 0.010 max Mn 0.0050 max N 0.0065 max Ni 0.0070 max Si 0.0120 max Ti 0.0050 max U 0.00055 max W 0.010 max                                     |
| R60701                                                                      | Zr+Hf 99.5 min C 0.05 max H 0.005 max Hf 4.5 max N 0.025 max Other Fe+Cr 0.05 max                                                                                                                                                                                                |
| R60702                                                                      | Zr+Hf 99.2 min C 0.05 max H 0.005 max Hf 4.5 max N 0.025 max Other Fe+Cr 0.2 max                                                                                                                                                                                                 |
| R60703                                                                      | Zr+Hf 98.0 min Hf 4.5 max                                                                                                                                                                                                                                                        |
| R60704                                                                      | Zr+Hf 97.5 min C 0.05 max H 0.005 max Hf 4.5 max N 0.025 max Sn 1.00-2.00 Other Fe+Cr 0.20-0.40                                                                                                                                                                                  |
| R60705                                                                      | Zr+Hf 95.5 min C 0.05 max Cb 2.0-3.0 H 0.005 max Hf 4.5 max N 0.025 max O 0.18 max                                                                                                                                                                                               |
| R60706                                                                      | Zr+Hf 95.5 min C 0.050 max Cb 2.0-3.0 H 0.005 max Hf 4.5 max N 0.025 max O 0.16 max Other Fe+Cr 0.2 max                                                                                                                                                                          |
| R60707                                                                      | Zr+Hf 95.5 min C 0.05 max Cb 2.0-3.0 Fe 0.20 max includes Cr H 0.005 max Hf 4.5 max N 0.025 max                                                                                                                                                                                  |
| R60802                                                                      | Zr rem Al 0.0075 max B 0.00005 max C 0.027 max Cd 0.00005 max Co 0.0020 max Cr 0.05-0.15 Cu 0.0050 max Fe 0.07-0.20 H 0.0025 max Hf 0.010 max Mn 0.0050 max N 0.0065 max Ni 0.05-0.08 Si 0.020 max Sn 1.20-1.70 Ti 0.0050 max U 0.00035 max W 0.010 max Other Fe+Cr+Ni 0.18-0.38 |
| R60804                                                                      | Zr rem Al 0.0075 max B 0.00005 max C 0.027 max Cd 0.00005 max Co 0.0020 max Cr 0.07-0.13 Cu 0.0050 max Fe 0.18-0.24 H 0.0025 max Hf 0.010 max Mn 0.0050 max N 0.0065 max Ni 0.0070 max Si 0.0120 max Sn 1.20-1.70 Ti 0.0050 max U 0.00035 max W 0.010 max Other Fe+Cr 0.28-0.37  |
| R60901                                                                      | Zr rem Al 0.0075 max B 0.00005 max C 0.027 max Cb 2.40-2.80 Cd 0.00005 max Co 0.0020 max Cr 0.020 max Cu 0.0050 max Fe 0.150 max H 0.0025 max Hf 0.010 max Mn 0.0050 max N 0.0065 max Ni 0.0070 max O 0.09-0.13 Si 0.0120 max Ti 0.0050 max U 0.00035 max W 0.010 max            |

| <b>CHEMICAL COMPOSITION OF REACTIVE &amp; REFRACTORY ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                                                                                                         |
|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                                  | <b>CHEMICAL COMPOSITION</b>                                                                                                                                                                                                                                                                                                             |
| R60902                                                                      | Zr rem Al 0.0075 max B 0.00005 max C 0.030 max Cb 2.4-2.8 Cd 0.00005 max Co 0.0020 max Cr 0.020 max Cu 0.3-0.7 Fe 0.15 max<br>H 0.0025 max Hf 0.010 max Mg 0.0020 max Mn 0.0050 max N 0.0065 max Ni 0.0070 max O 0.08-0.12 Pb 0.013 max Si 0.012 max Sn 0.0050 max<br>Ta 0.020 max Ti 0.0050 max U 0.00035 max V 0.0050 max W 0.010 max |
| R60904                                                                      | Zr remAl 0.0075 max B 0.00005 max Cb 2.50-2.80 Co 0.0020 max Cu 0.0050 max Fe 0.0650 max H 0.0020 max Hf 0.0050 max Mg 0.0020 max<br>Mn 0.0050 max Mo 0.0050 max N 0.0065 max Ni 0.0035 max Pb 0.0050 max Si 0.0120 max Sn 0.0100 max Ta 0.0100 max Ti 0.0050 max<br>U 0.00035 max V 0.0050 max W 0.0050 max                            |

# Chapter 5

## ***CEMENTED CARBIDES***

These materials are composites consisting of particles of a hard, brittle, nonmetallic refractory material, typically carbides but sometimes carbonitrides or nitrides, in a metallic binder (matrix) phase, typically cobalt but sometimes nickel, iron, or their alloys. The matrix phase, which imparts ductility, toughness, and thermal conductivity to the composite, typically occupies 10-15% of the volume. The outer surface may or may not be coated for improved surface properties. The original material in this category was WC-Co; however, there has been a long history of development which has led to many other formulations. Applications include metal cutting, mining, construction, rock drilling, metal forming, structural components, and wear parts, but of these metal cutting is the most important, accounting for approximately half of production. The steps involved in manufacture of these materials include powder preparation, then compaction or consolidation by pill or hydrostatic pressing or extrusion, followed by sintering, and finally forming. During sintering, the metallic binder melts and draws the carbide particles together. Pressure can be applied during the sintering, for example this can be carried out by hot isostatic pressing in a vacuum. The properties of sintered hardmetals are profoundly influenced by microstructure, including the compositions of the phases, and the sizes, shapes, and distributions of carbide particles. One of the problems which can arise is that when there is a deficiency of carbon, some of the original WC particles can dissolve, and particles of a mixed cobalt-tungsten carbide ("*eta* phase") can form, giving rise to serious embrittlement.

Carbides produced for use in hardmetals include WC, TiC, TaC, NbC, and solid solution mixed carbides such as WC-TiC, WC-TiC-TaC, and WC-TiC-(Ta,Nb)C.

The basic WC-Co alloys, referred to as straight grades, have excellent resistance to abrasive wear and find many applications in metal cutting. Although alloys ranging between 3% and 30%Co are produced, those most widely used in machining typically contain 3-12% Co and WC particles

with grain sizes between 0.5 and 5 micrometers (0.00002 in.). When more toughness or edge strength is required, finer (submicron) grain size carbide particles are used, for example in indexable inserts and solid carbide drilling and milling tools. The fine grain size is achieved by additions of other carbides, such as vanadium, tantalum, niobium, or chromium carbide. Higher Co contents, up to 30%, and larger carbide grain sizes, up to 15 micrometers (0.00006 in.) are used in tools, dies, and wear parts subjected to shock loading. Mixed WC-TiC-Co hardmetals were developed for machining steel, where WC-Co materials are subject to chemical attack. Here the TiC is in solid solution with the WC, and is used in amounts up to 18% of the total WC-TiC-Co alloy; higher proportions of TiC cause the carbides to be excessively brittle. Further developments have led to these WC-TiC-Co alloys being replaced by more advanced alloys containing in addition to WC and Co, both TiC and solid solution (Ta,Nb)C. These are called complex grades, multigrades, or steel-cutting grades. Their microstructures contain angular WC particles in a cobalt matrix, as do the straight grades, but in addition they contain rounded particles of solid solution WC-TiC or WC-TiC-(Ta,Nb)C grains. The need for even more advanced alloys has been partially met by the development of surface coatings for these alloys.

Widespread use is now being made of hardmetals to which a surface coating has been applied in order to combine a tougher substrate with a more wear resistant surface layer. Initially surface layers of TiC were applied, first by sintering and then later by chemical vapour deposition (CVD). These have now been superseded by multilayer coatings consisting of combinations of TiC, TiCN, TiN, or more recently  $\text{Al}_2\text{O}_3$ , Hf, Ta, and Zr carbides and nitrides, and many other complex compounds in as many as 13 different layers. The total thickness of surface coatings is typically about 10 micrometers (0.00004 in.), and even the thickest coatings rarely exceed 15 micrometers (0.00006 in.). Production with a cobalt enriched zone beneath the surface coating improves performance in some cases and permits use of higher cutting speeds and feed rates in machining. Coating by physical vapour deposition (PVD), at lower temperatures than is possible with CVD, has also become common; here the formation of brittle phases is avoided and fine grain size can be obtained in the coating. Furthermore, it is possible to obtain sharper edges using the PVD technique, and coatings as thin as 3 micrometers (0.00001 in) can be produced.

There is no universally recognized classification scheme for hardmetals, but two application-oriented systems are in use. The C-Grade (U.S.) system, based on the General Motors Buick system, classifies according to application category (Table 1) with no reference to material or properties; hence, materials in the same category produced by different

manufacturers can exhibit different properties and performance. Both machining and non-machining applications are included. The same limitations apply to the more recent ISO codes. ISO Recommendation R513 divides machining grades into three colour-coded groups: straight WC grades (letter K, colour red); alloyed WC grades (letter M, colour yellow); and highly alloyed grades (letter P, colour blue). Within each grade, a number is assigned giving the approximate position in the range between maximum hardness and maximum toughness (shock resistance). These are shown with their applications in Table 2. It must be noted that with this system the coding is assigned to a given material by its manufacturer and that quality control cannot be applied. The ISO R513 has been revised to take into account the increasing use of coated hardmetals, as well as the superhard ceramics, polycrystalline diamond, and cubic boron nitride.

**Table 1 American Cemented Carbide Classifications**

| <b>Buick Code</b>                                                    | <b>IndustryCode</b> | <b>Application</b>                                                    |
|----------------------------------------------------------------------|---------------------|-----------------------------------------------------------------------|
| <b>Machining - cast iron, nonferrous &amp; nonmetallic materials</b> |                     |                                                                       |
| TC-1                                                                 | C-1                 | Roughing cuts                                                         |
| TC-2                                                                 | C-2                 | General purpose                                                       |
| TC-3                                                                 | C-3                 | Light finishing                                                       |
| TC-4                                                                 | C-4                 | Precision machining                                                   |
| <b>Machining - steel</b>                                             |                     |                                                                       |
| TC-5                                                                 | C-5                 | Roughing cuts                                                         |
| TC-6                                                                 | C-6                 | General purpose                                                       |
| TC-7                                                                 | C-7                 | Light finishing                                                       |
| TC-8                                                                 | C-8                 | Precision machining                                                   |
| <b>Wear Surface</b>                                                  |                     |                                                                       |
| TC-9                                                                 | C-9                 | No shock                                                              |
| TC-10                                                                | C-10                | Light shock                                                           |
| TC-11                                                                | C-11                | Heavy shock                                                           |
| <b>Impact</b>                                                        |                     |                                                                       |
| TC-12                                                                | C-12                | Light                                                                 |
| TC-13                                                                | C-13                | Medium                                                                |
| TC-14                                                                | C-14                | Heavy                                                                 |
| <b>Miscellaneous</b>                                                 |                     |                                                                       |
| ---                                                                  | C-15                | Light cut hot flash weld removal                                      |
| ---                                                                  | C-15A               | Heavy cut hot flash weld removal                                      |
| ---                                                                  | C-16                | Rock bits                                                             |
| ---                                                                  | C-17                | Cold Header dies                                                      |
| ---                                                                  | C-18                | Wear at elevated temperatures and/or resistance to chemical reactions |
| ---                                                                  | C-19                | Radioactive shielding, counterbalances and kinetics applications      |

**Table 2 ISO Std. 513 Classification of Cutting Tool Materials**

| <b>Material Categories</b>                                                   | <b>Color Code</b> | <b>ISO</b> | <b>Material Machined</b>                                                                                                                                                                     |
|------------------------------------------------------------------------------|-------------------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ferrous metals with long chips                                               | Blue              | P01        | Steel, steel castings                                                                                                                                                                        |
|                                                                              |                   | P10        | Steel, steel castings                                                                                                                                                                        |
|                                                                              |                   | P20        | Steel, steel castings, malleable cast iron with long chips                                                                                                                                   |
|                                                                              |                   | P30        | Steel, steel castings, malleable cast iron with long chips                                                                                                                                   |
|                                                                              |                   | P40        | Steel, steel castings with sand inclusion and cavities                                                                                                                                       |
|                                                                              |                   | P50        | Steel, steel castings of medium or low tensile strength, with sand inclusion and cavities                                                                                                    |
| Ferrous metals with long or short chips and nonferrous metals                | Yellow            | M10        | Steel, steel castings, manganese steel, grey cast iron, alloy cast iron                                                                                                                      |
|                                                                              |                   | M20        | Steel, steel castings, austenitic or manganese steel, grey cast iron                                                                                                                         |
|                                                                              |                   | M30        | Steel, steel castings, austenitic steel, grey cast iron, high temperature resistant alloys                                                                                                   |
|                                                                              |                   | M40        | Mild free-cutting steel, low tensile steel, nonferrous metals, light alloys                                                                                                                  |
| Ferrous metals with short chips, nonferrous metals and nonmetallic materials | Red               | K01        | Very hard grey cast iron, chilled castings over 85 Shore, high silicon-aluminum alloys, hardened steel, highly abrasive plastics, hard cardboard, ceramics                                   |
|                                                                              |                   | K10        | Grey cast iron over 220 Brinell, malleable cast iron with short chips, hardened steel, silicon-aluminum alloys, copper alloys, plastic, glass, hard rubber, hard cardboard, porcelain, stone |
|                                                                              |                   | K20        | Grey cast iron over 220 Brinell, nonferrous metals: copper, brass, aluminum                                                                                                                  |
|                                                                              |                   | K30        | Low hardness grey cast iron, low tensile steel, compressed wood                                                                                                                              |
|                                                                              |                   | K40        | Soft wood or hard wood, nonferrous metals                                                                                                                                                    |

| COATED CEMENTED CARBIDES CROSS REFERENCE |                              |         |                                            |                              |                         |
|------------------------------------------|------------------------------|---------|--------------------------------------------|------------------------------|-------------------------|
| Trade Name                               | Company Name                 | Grade   | Layer Composition                          | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Allenite Gold                            | Edgar Allen Tools Ltd        | EM100   | TiC+Ti(C,N)+TiN                            | 12                           | M05-M20/K05-K30         |
|                                          |                              | EM100   | TiC+TiN                                    | 5-10                         | M05-M20/K05-K30         |
|                                          |                              | ES200   | TiC+Ti(C,N)+TiN                            | 12                           | P10-P25                 |
|                                          |                              | ES201   | TiC+TiN                                    | 5-10                         | P10-P25                 |
|                                          |                              | ES350   | TiC+Ti(C,N)+TiN                            | 12                           | P30-P40                 |
|                                          |                              | ES351   | TiC+TiN                                    | 5-10                         | P30-P40                 |
| ANC                                      | American National Carbide Co | AOX     | TiC+Al <sub>2</sub> O <sub>3</sub>         | 8                            | P15-P35/K15-K30         |
|                                          |                              | CAD     | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN    | 10                           | P15-P35/K15-K30         |
|                                          |                              | CAM     | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN    | 10                           | P25-P35/K25-K35         |
|                                          |                              | TEX     | Ti(C,N)+TiC+TiN                            | 8                            | P30-P40/K30-K40         |
|                                          |                              | TEXO    | TiN                                        | 4                            | P30-P40/K30-K40         |
|                                          |                              | TNT     | Ti(C,N)+TiC+TiN                            | 8                            | P20-P35/K20-K30         |
|                                          |                              | TNTO    | TiN                                        | 4                            | P20-P35/K20-K30         |
|                                          |                              | TOX     | TiC+Al <sub>2</sub> O <sub>3</sub>         | 8                            | P25-P35/K25-K35         |
| Arsenal                                  | Arsenal Company              | BGC015  | TiC+Al <sub>2</sub> O <sub>3</sub>         | 7+1.5                        | P05-P30                 |
|                                          |                              | BGC135  | TiC                                        | 5                            | P25-P45/M15-M30         |
|                                          |                              | BGC315  | TiC                                        | 5                            | M15-M20/K05-K25         |
|                                          |                              | BGC1025 | TiC                                        | 7                            | P10-P35                 |
| Atrax                                    | Atrax                        | A6G     | TiN+Ti(C,N)+TiC+TiN                        | 8                            | M05-M20/K05-K20         |
|                                          |                              | A7G     | TiN+Ti(C,N)+TiC+TiN                        | 8                            | M05-M15/K05-K15         |
|                                          |                              | A62G    | TiN+Ti(C,N)+TiC+TiN                        | 8                            | M05-M25/K05-K25         |
|                                          |                              | T50G    | TiN+Ti(C,N)+TiC+TiN                        | 8                            | P10-P30                 |
|                                          |                              | T55B    | TiN+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub> | 8                            | P20-P45/M30-M40/K30-K40 |
|                                          |                              | T55G    | TiN+Ti(C,N)+TiC+TiN                        | 8                            | P20-P45                 |
|                                          |                              | T70B    | TiN+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub> | 8                            | P05-P25/M05-M20/K05-K20 |
|                                          |                              | T70G    | TiN+Ti(C,N)+TiC+TiN                        | 8                            | P05-P25                 |



| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                      |       |                                         |                              |                         |
|------------------------------------------------------|----------------------|-------|-----------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name         | Grade | Layer Composition                       | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Atrax (con't)                                        | Atrax                | T76G  | TiN+Ti(C,N)+TiC+TiN                     | 8                            | P10-P25                 |
| Bohlerit Royal                                       | Bohlerit GmH & Co KG | 111   | TiC                                     | 4                            | K05-K20                 |
|                                                      |                      | 121   | TiC                                     | 4                            | P10-P35/K05-K20         |
|                                                      |                      | 131   | TiC                                     | 4.5                          | P25-P45                 |
|                                                      |                      | 321   | TiC+TiN+Ti(C,N)                         | 8.5                          | P10-P35/M10-M20         |
|                                                      |                      | 331   | TiC+TiN+TiC+TiN                         | 8.5                          | M15-M20                 |
|                                                      |                      | 341   | TiC+TiN+TiC+TiN                         | 11.5                         | P20-P50/M20-M40         |
|                                                      |                      | 421   | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 8                            | P05-P30/K05-K20         |
|                                                      |                      | 432   | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 7                            | P25-P45/M15-M25         |
|                                                      |                      | 610   | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 6                            | K05-K15                 |
|                                                      |                      | 615   | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 6                            | K05-K20                 |
|                                                      |                      | 625   | TiN+TiC+TiN                             | 4.5                          | P10-P30                 |
|                                                      |                      | 630   | TiN+TiC+TiN                             | 4.5                          | P15-P35                 |
|                                                      |                      | 635   | TiN+TiC+TiN                             | 4.5                          | P15-P35                 |
|                                                      |                      | 640   | TiN+TiC+TiN                             | 3                            | P20-P35                 |
| Bonastre                                             | Bonastre SA          | HK10  | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 8                            | M10-M20/K01-K20         |
|                                                      |                      | HK20  | TiC                                     | 5                            | M15-M25/K10-K35         |
|                                                      |                      | HK25  | TiN                                     | 3                            | M10-M25/K10-K30         |
|                                                      |                      | SK10  | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 8                            | P05-P35/M10-M30/K05-K30 |
|                                                      |                      | SK15  | TiC+TiN                                 | 8                            | P10-P30/M10-M25/K10-K25 |
|                                                      |                      | SK25  | TiN                                     | 3                            | P10-P35/M15-M35         |
|                                                      |                      | SK30  | TiC+TiN                                 | 8                            | P20-P35/M15-M35         |
|                                                      |                      | SK35  | TiN                                     | 3                            | P25-P40                 |
|                                                      |                      | SK40  | TiC                                     | 5                            | P25-P40/M25-M40         |
| Carbex                                               | Carbex SA            | CNX25 | composite TiC                           | 8-10                         | P10-P30/M10-M30         |
|                                                      |                      | CNX35 | composite TiC                           | 3-4                          | P20-P40/K10-K25         |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                |        |                                                 |                              |                         |
|------------------------------------------------------|----------------|--------|-------------------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name   | Grade  | Layer Composition                               | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Carbex<br>(continued)                                | Carbex SA      | CNX45  | composite TiC                                   | 3-4                          | P30-P50/M20-M40         |
|                                                      |                | CNX725 | TiN                                             | 2-3                          | P10-P35/M10-M30         |
|                                                      |                | CNX745 | TiN                                             | 2-3                          | P30-P50/M20-M40         |
|                                                      |                | CS130  | TiC                                             | 5-6                          | P20-P40                 |
|                                                      |                | CS310  | TiC                                             | 5-6                          | K05-K20                 |
|                                                      |                | RW2110 | TiC+TiN                                         | 8-10                         | P10-P35/K10-K20         |
|                                                      |                | RW2115 | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN         | 8-10                         | P05-P30/M10-M30         |
| Carboloy                                             | Carboloy Inc   | RW2310 | TiC+TiN                                         | 8-10                         | P30-P50/M20-M40         |
|                                                      |                | 550    | TiN+TiC+TiN                                     | 9                            | P20-P45                 |
|                                                      |                | 560    | TiN+TiC+Al <sub>2</sub> O <sub>3</sub> +TiN     | 10                           | P10-P35/K10-K20         |
|                                                      |                | 570    | Al <sub>2</sub> O <sub>3</sub>                  | 6                            | P05-P25/M10-M20/K05-K20 |
|                                                      |                | T25M   | Ti(C,N)+TiC+TiN                                 | 5                            | P05-P40/M30-M40/K30-K40 |
|                                                      |                | TP05   | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN         | 9                            | P05/K10                 |
|                                                      |                | TP10   | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN         | 11                           | P10/K15                 |
|                                                      |                | TP15   | TiC+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub> +TiN | 7                            | P05-P25/M05-M20/K05-K20 |
|                                                      |                | TP20   | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN         | 7                            | P10-P35/M20             |
|                                                      |                | TP30   | TiC+Ti(C,N)+TiN                                 | 12                           | P30/M30                 |
|                                                      |                | TP40   | Ti(C,N)+TiC+TiN                                 | 5                            | P40/M40                 |
|                                                      |                | TP301  | Ti(C,N)+TiC+TiN                                 | 4                            | P30/M40                 |
| Carmet                                               | Carmet Company | TP401  | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN         | 7                            | P40/M40                 |
|                                                      |                | 7000   | TiN+TiC+Al <sub>2</sub> O <sub>3</sub> +TiN     | 12                           | P05-P25/M10-M20/K05-K20 |
|                                                      |                | 9443   | TiN+TiC+TiN                                     | 7                            | M10-M20/K10-K20         |
|                                                      |                | 9720   | TiN+TiC+TiN                                     | 7                            | P10-P20                 |
|                                                      |                | 9721   | TiN+TiC+TiN                                     | 7                            | P20-P40                 |
|                                                      |                | 9740   | TiN+TiC+TiN                                     | 7                            | P25-P50                 |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                         |        |                                          |                              |                         |
|------------------------------------------------------|-------------------------|--------|------------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name            | Grade  | Layer Composition                        | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| CRH                                                  | Pulvi Metalurgia Rossi  | K155   | TiC+TiN                                  | 5                            | K10-K20                 |
|                                                      |                         | KTiN   | TiC+TiN                                  | 4                            | K10+K20                 |
|                                                      |                         | P156   | TiC-TiN                                  | 5                            | P10-P30                 |
|                                                      |                         | PTiC   | TiC                                      | 4                            | P20-P30                 |
|                                                      |                         | PTiN   | TiC+TiN                                  | 4                            | P10-P30                 |
|                                                      |                         | R15    | TiC+TiN+Al <sub>2</sub> O <sub>3</sub>   | 5                            | P10-P20/K10-K20         |
|                                                      |                         | R157   | TiC+TiN+ Al <sub>2</sub> O <sub>3</sub>  | 7                            | P10-P30/K10-K20         |
| Denitool                                             | H Deni AG               | DC15   | TiC+TiN                                  | 7-8                          | P05-P30/M10-M20/K05-K20 |
|                                                      |                         | DC25   | TiC+Ti(C,N)+TiN                          | 9-11                         | P10-P30/M15-M25/K10-K25 |
|                                                      |                         | DP25   | TiN                                      | 2-3                          | P10-P20/M10-M25         |
|                                                      |                         | DP35   | Ti(C,N)                                  | 2-3                          | P10-P20/M10-M20         |
|                                                      |                         | DX10   | Ti(C,N)+TiN                              | 7-8                          | P05-P15/M10-M15/K05-K15 |
|                                                      |                         | DX20   | TiN                                      | 2-3                          | P05-P20/M10-M20/K05-K15 |
|                                                      |                         | DX30   | Ti(C,N)                                  | 2-3                          | P05-P10/M10-M15/K05-K10 |
| Dijet                                                | Dijet Industrial Co Ltd | JC220  | TiC+ Al <sub>2</sub> O <sub>3</sub>      | 5-10                         | P10-P30/M10-M30/K20-K40 |
|                                                      |                         | JC330  | TiC+ Al <sub>2</sub> O <sub>3</sub> +TiN | 5-10                         | P20-P40/M20-M40         |
|                                                      |                         | JC1211 | TiC+ Al <sub>2</sub> O <sub>3</sub>      | 5-10                         | P01-P15/M05-M15/K01-K15 |
|                                                      |                         | JC1231 | TiC+ Al <sub>2</sub> O <sub>3</sub>      | 5-10                         | P05-P20/M05-M20/K05-K20 |
|                                                      |                         | JC1341 | TiC+Ti(C,N)+TiN                          | 5-10                         | P15-P35/M10-M30         |
|                                                      |                         | JC1361 | TiC+Ti(C,N)+TiN                          | 5-10                         | P20-P40/M20-M40         |
|                                                      |                         | JC3512 | TiN                                      | 2-4                          | P01-P20/M05-M20/K01-K20 |
|                                                      |                         | JC3562 | TiN                                      | 2-4                          | P10-P30/M10-M30/K10-K30 |
| DoALL                                                | DoAll Company           | DO40   | TiC                                      | 5                            | P20-P30                 |
|                                                      |                         | DO42   | TiC                                      | 5                            | P10-P20                 |
|                                                      |                         | DO44   | TiC                                      | 5                            | P25-P30                 |
|                                                      |                         | DO46   | TiC                                      | 5                            | K10-K20                 |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                     |        |                                             |                              |                         |
|------------------------------------------------------|---------------------|--------|---------------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name        | Grade  | Layer Composition                           | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| DoALL<br>(continued)                                 | DoAll Company       | DO50   | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN     | 10                           | P05-P30/M10-M25/K05-K20 |
|                                                      |                     | DO51   | TiC+Ti(C,N)+TiN                             | 7                            | P25-P45/M30-M40         |
|                                                      |                     | DO52   | TiC+Ti(C,N)+TiN                             | 7                            | P10-P35/M20-M30         |
| Duracarb                                             | Duracarb            | DC120  | TiN                                         | ---                          | P15-P30                 |
|                                                      |                     | DC150  | TiN                                         | ---                          | P20-P30                 |
|                                                      |                     | DC710  | TiC+Ti(C,N)+TiN                             | 8                            | P05-P25/K05-K25         |
|                                                      |                     | DC720  | TiC+Ti(C,N)+TiN                             | 8                            | K05-K20                 |
|                                                      |                     | DC725  | Ti(C,N)                                     | 6                            | P15-P35/K10-K30         |
|                                                      |                     | DC735  | TiN+TiC+TiN                                 | 6                            | P25-P45                 |
| Duramet                                              | Duramet Corporation | DU227  | TiN+TiC+TiN                                 | 4-8                          | K20                     |
|                                                      |                     | DU577  | TiN+TiC+TiN                                 | 4-8                          | P40                     |
|                                                      |                     | DU607  | TiN+TiC+TiN                                 | 4-8                          | P30                     |
|                                                      |                     | DU811P | TiN                                         | 2-3                          | P30-P50                 |
|                                                      |                     | DU817  | TiN+TiC+TiN                                 | 4-8                          | P30-P50                 |
|                                                      |                     | DU857  | TiN+TiC+TiN                                 | 4-8                          | P30                     |
|                                                      |                     | DU859  | TiC+Al <sub>2</sub> O <sub>3</sub>          | 3-5                          | P20-P30                 |
| Fansteel<br>VR/Wesson                                | Fansteel VR/Wesson  | 623    | TiC+Ti(C,N)+TiN                             | 5                            | P40-P50                 |
|                                                      |                     | 630    | TiN+TiC                                     | 5                            | M10-M30/K10-K25         |
|                                                      |                     | 633    | TiC+Ti(C,N)+TiN                             | 7                            | M10-M30/K10-K25         |
|                                                      |                     | 643    | TiC+Ti(C,N)+TiN                             | 7                            | P30-P45                 |
|                                                      |                     | 650    | TiN+TiC                                     | 5                            | P30-P45/M30-M40         |
|                                                      |                     | 653    | TiN+TiC+TiN                                 | 7                            | P25-P45/M30-M40         |
|                                                      |                     | 655    | TiN+TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 10                           | P20-P40/M25-M35         |
|                                                      |                     | 660    | TiN+TiC                                     | 5                            | P10-P35/K15-K25         |
|                                                      |                     | 663    | TiC+Ti(C,N)+TiN                             | 7                            | P10-P35/M20-M30         |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                       |                                   |                                                 |                              |                         |
|------------------------------------------------------|-----------------------|-----------------------------------|-------------------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name          | Grade                             | Layer Composition                               | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Fansteel<br>VR/Wesson<br>(continued)                 | Fansteel VR/Wesson    | 680                               | TiN+TiC+Al <sub>2</sub> O <sub>3</sub> +TiN     | 10                           | P05-P30/K05-K20/M10-M25 |
|                                                      |                       | 689                               | TiN+TiC+Al <sub>2</sub> O <sub>3</sub> +TiN+TiC | ---                          | P01-P10/K01-K15         |
|                                                      |                       | 690                               | TiN+TiC+Al <sub>2</sub> O <sub>3</sub> +TiN     | 7                            | P01-P10/K01-K15         |
| Greenleaf                                            | Greenleaf Corporation | G1                                | TiC+Al <sub>2</sub> O <sub>3</sub>              | ---                          | P05-P35/M10-M20/K15     |
|                                                      |                       | G2                                | TiC+Al <sub>2</sub> O <sub>3</sub>              | ---                          | M05-M15/K01-K20         |
|                                                      |                       | GA6                               | TiC-Ti(C,N)+TiN                                 | ---                          | P10-P35/M10-M20         |
|                                                      |                       | GA56                              | TiC+Ti(C,N)+TiN                                 | ---                          | P35-P50/M10-M40/K10-K35 |
|                                                      |                       | GA60                              | TiC+Ti(C,N)+TiN                                 | ---                          | P15-P35/M10-M40         |
|                                                      |                       | Ti5                               | TiC                                             | ---                          | P20-P45/M15-M30         |
|                                                      |                       | Ti6                               | TiC                                             | ---                          | P10-P45/M10-M20/K10     |
| Groovall                                             | US Tool & Cutter Co   | C2/Al <sub>2</sub> O <sub>3</sub> | Al <sub>2</sub> O <sub>3</sub>                  | ---                          | K01-K20                 |
|                                                      |                       | C2/TiC                            | TiC                                             | ---                          | K05/K20                 |
|                                                      |                       | C2/TiN                            | TiN                                             | ---                          | K05-K20                 |
|                                                      |                       | C5/Al <sub>2</sub> O <sub>3</sub> | Al <sub>2</sub> O <sub>3</sub>                  | ---                          | P05-P20                 |
|                                                      |                       | C5/TiC                            | TiC                                             | ---                          | P10-P20                 |
|                                                      |                       | C5/TiN                            | TiN                                             | ---                          | P10-P20                 |
|                                                      |                       | C7/Al <sub>2</sub> O <sub>3</sub> | Al <sub>2</sub> O <sub>3</sub>                  | ---                          | P01-P10                 |
|                                                      |                       | C7/TiC                            | TiC                                             | ---                          | P01-P10                 |
| Walmet                                               | Walmet Inc            | C7/TiN                            | TiN                                             | ---                          | P01-P10                 |
|                                                      |                       | A60                               | TiC+Al <sub>2</sub> O <sub>3</sub>              | ---                          | P01-P20/K10-K20         |
|                                                      |                       | P2                                | TiC+TiN                                         | 10                           | K01-K20                 |
|                                                      |                       | P5                                | TiC+TiN                                         | 10                           | P05-P30                 |
|                                                      |                       | P47                               | TiC+TiN                                         | 10                           | P01-P20                 |
|                                                      |                       | P52                               | TiC+TiN                                         | 10                           | P01-P20/K10-K20         |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                                     |       |                                                 |                              |                         |
|------------------------------------------------------|-------------------------------------|-------|-------------------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name                        | Grade | Layer Composition                               | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Walmet<br>(continued)                                | Walmet Inc                          | P54   | TiC+TiN                                         | 10                           | P20-P40                 |
|                                                      |                                     | P57   | TiC+TiN                                         | 10                           | P10-P35                 |
| Hardmet                                              | Nippon Hardmetal Co Ltd             | NC115 | ---                                             | 8                            | P10-P30/M10-M20/K10-K30 |
|                                                      |                                     | NC22H | ---                                             | 8                            | K01-K20                 |
|                                                      |                                     | NC110 | ---                                             | 8                            | P01-P20/K10-K20         |
|                                                      |                                     | NC120 | ---                                             | 8                            | P10-P40/M10-M30         |
|                                                      |                                     | NC210 | ---                                             | 8                            | P01-P20/K10-K20         |
|                                                      |                                     | NCA2H | ---                                             | 8                            | K01-K20                 |
|                                                      |                                     | NCA20 | ---                                             | 8                            | P10-P40/M10-M30         |
|                                                      |                                     | NPN10 | ---                                             | 2                            | P01-P20/K10-K20         |
|                                                      |                                     | NPN20 | ---                                             | 2                            | P10-P40/M10-M30         |
| Hertel                                               | Hertel AG Werkzeuge &<br>Hartstoffe | 13E   | TiN+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub> +TiN | 8                            | P05-P25/M05-M15/K05-K20 |
|                                                      |                                     | CD2   | TiN+Ti(C,N)+TiN                                 | 1.5                          | P30-P45/K15-K25         |
|                                                      |                                     | CF2   | TiN+Ti(C,N)+TiN                                 | 5                            | P10-P35/M15-M30         |
|                                                      |                                     | CF3   | TiN+Ti(C,N)+TiN                                 | 5                            | K05-K20                 |
|                                                      |                                     | CM2   | TiN+Ti(C,N)+TiN                                 | 8                            | P10-P30/M10-M20/K10-K20 |
|                                                      |                                     | CM3   | TiN+Ti(C,N)+TiN                                 | 8                            | P15-P40/M15-M25/K15-K25 |
|                                                      |                                     | CM4   | TiN+Ti(C,N)+TiN                                 | 8                            | P20-P45/M20-M30/K20-K25 |
| Hertel                                               | Hertel Cutting Technologies         | 13E   | TiN+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub> +TiN | 10                           | P05-P25/M05-M15/K05-K20 |
|                                                      |                                     | CD2   | TiN+Ti(C,N)+TiN                                 | 1.5                          | P30-P45/K15-K25         |
|                                                      |                                     | CF2   | TiN+Ti(C,N)+TiN                                 | 5                            | P10-P35/M15-M30         |
|                                                      |                                     | CF3   | TiN+Ti(C,N)+TiN                                 | 5                            | K10-K30                 |
|                                                      |                                     | CM2   | TiN+Ti(C,N)+TiN                                 | 8                            | P10-P30/M10-M20/K05-K20 |
|                                                      |                                     | CM3   | TiN+Ti(C,N)+TiN                                 | 8                            | P15-P40/M15-M25/K15-K25 |
|                                                      |                                     | CM4   | TiN+Ti(C,N)+TiN                                 | 8                            | P20-P45/M20-M30/K20-K25 |
|                                                      |                                     | CNC   | Ti(C,N)+TiC+TiN                                 | 6                            | P15-P40                 |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                             |          |                                             |                              |                         |
|------------------------------------------------------|-----------------------------|----------|---------------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name                | Grade    | Layer Composition                           | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Hertel<br>(continued)                                | Hertel Cutting Technologies | CNCM     | Ti(C,N)+TiC+TiN                             | 6                            | P20-P30                 |
|                                                      |                             | CNCT     | Ti(C,N)+TiC+TiN                             | 6                            | P40-P50/K30-K40         |
|                                                      |                             | CNCW     | Ti(C,N)+TiC+TiN                             | 6                            | K05-K15                 |
|                                                      |                             | CP1      | TiN+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub>  | 9                            | P05-P20/K05-K10         |
|                                                      |                             | Roxide   | Ti(C,N)+Al <sub>2</sub> O <sub>3</sub>      | 10                           | P10-P40/K10-K30         |
|                                                      |                             | Roxide-M | Ti(C,N)+Al <sub>2</sub> O <sub>3</sub>      | 10                           | P30-P40/K20-K30         |
|                                                      |                             | Roxide-W | Ti(C,N)+Al <sub>2</sub> O <sub>3</sub>      | 10                           | K01-K20                 |
| Hitachi                                              | Hitachi Tool Engineering    | HC500    | Al <sub>2</sub> O <sub>3</sub> +TiC         | 7                            | P01/K01-K10             |
|                                                      |                             | HC512    | Al <sub>2</sub> O <sub>3</sub> +TiC+Ti(C,N) | 7                            | P10-P20/M20/K20         |
|                                                      |                             | HC514    | Al <sub>2</sub> O <sub>3</sub> +TiC         | 7                            | P30/M30/K30             |
|                                                      |                             | HC516    | Al <sub>2</sub> O <sub>3</sub> +TiC         | 7                            | P40/M40                 |
|                                                      |                             | HC730    | Al <sub>2</sub> O <sub>3</sub> +TiC         | 7                            | K01                     |
|                                                      |                             | HC830    | TiN                                         | 3                            | K01                     |
|                                                      |                             | HC831    | TiN                                         | 3                            | K10-K20                 |
|                                                      |                             | HC842    | TiN                                         | 3                            | P20/M20                 |
|                                                      |                             | HC843    | TiN                                         | 3                            | P30/M30                 |
|                                                      |                             | HC844    | TiN                                         | 3                            | P40/M40                 |
|                                                      |                             | HC5000   | Al <sub>2</sub> O <sub>3</sub> +TiC+Ti(C,N) | 12                           | K01-K20                 |
| Impero                                               | Impero SpA                  | SK05     | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN     | 9                            | K05-K20                 |
|                                                      |                             | SK3      | TiN                                         | 3                            | P01-P15                 |
|                                                      |                             | SK8      | TiN                                         | 3                            | P20-P40                 |
|                                                      |                             | SK10     | TiC+Al <sub>2</sub> O <sub>3</sub>          | 9                            | P05-P30/M10-M20/K05-K20 |
|                                                      |                             | SK15     | TiC+TiN                                     | 6                            | P10-P30/M10-M30         |
|                                                      |                             | SK20     | TiC+Al <sub>2</sub> O <sub>3</sub>          | 6                            | P20-P30                 |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                                      |        |                                            |                              |                 |
|------------------------------------------------------|--------------------------------------|--------|--------------------------------------------|------------------------------|-----------------|
| Trade Name                                           | Company Name                         | Grade  | Layer Composition                          | Coating Depth, $\mu\text{m}$ | ISO Code(s)     |
| Impero<br>(continued)                                | Impero SpA                           | SK30   | TiC+TiN                                    | 5                            | P25-P40/M10-M40 |
|                                                      |                                      | SK45   | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN    | 9                            | P25-P45/M15-M25 |
|                                                      |                                      | SK50   | TiN+TiC+TiN                                | 3                            | P30-P50/M20-M40 |
|                                                      |                                      | SK90   | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN    | 9                            | K05-K30/M10-M30 |
|                                                      |                                      | SKM    | TiN                                        | 3                            | P10-P40/M20-M30 |
| Iscar                                                | Iscar Ltd                            | IC220  | TiN                                        | 3                            | K10-K20         |
|                                                      |                                      | IC250  | TiN                                        | 3                            | P20-P30         |
|                                                      |                                      | IC428  | Composite + Al <sub>2</sub> O <sub>3</sub> | 7                            | K05-K20         |
|                                                      |                                      | IC520M | Ti(C,N)                                    | 5                            | P15-P30/K10-K25 |
|                                                      |                                      | IC540  | Ti(C,N)                                    | 6                            | P20-P40         |
|                                                      |                                      | IC635  | TiN+TiC+TiN                                | 3                            | P30-P50         |
|                                                      |                                      | IC656  | TiC+Ti(C,N)+TiN                            | 8                            | P20-P40         |
|                                                      |                                      | IC805  | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN    | 11                           | P05-P35/K05-K25 |
| ISG                                                  | ISG Szerszam es<br>Porkohaszati Gyar | EK1    | TiC                                        | 5-8                          | K10-K20         |
|                                                      |                                      | EN1    | TiC                                        | 5-8                          | P20-P40/M20-M30 |
|                                                      |                                      | ENN1   | TiC                                        | 5-8                          | P30-P30         |
|                                                      |                                      | ES1    | TiC                                        | 5-8                          | P10-P30/M10-M20 |
|                                                      |                                      | TK14   | TiC+Al <sub>2</sub> O <sub>3</sub>         | 6-8                          | K10-K20         |
|                                                      |                                      | TK123  | TiC+Ti(C,N)+TiN                            | 6-8                          | K10-K30         |
|                                                      |                                      | TKM    | Ti(C,N)+TiC+TiN                            | 4-6                          | K10-K20         |
|                                                      |                                      | TN123  | TiC+Ti(C,N)+TiN                            | 6-8                          | P20-P40/M20-M30 |
|                                                      |                                      | TNM23  | Ti(C,N)+TiC+TiN                            | 4-6                          | P25-P40         |
|                                                      |                                      | TS14   | TiC+Al <sub>2</sub> O <sub>3</sub>         | 6-8                          | P10-P20/K10-K20 |
|                                                      |                                      | TS123  | TiC+Ti(C,N)+TiN                            | 6-8                          | P10-P30/M10-M20 |
|                                                      |                                      | TS143  | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN    | 6-8                          | P10-P30/K10-K20 |



| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                                                                 |          |                                                                                                                                 |                              |                         |
|------------------------------------------------------|-----------------------------------------------------------------|----------|---------------------------------------------------------------------------------------------------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name                                                    | Grade    | Layer Composition                                                                                                               | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| ISG<br>(continued)                                   | ISG Szerszam es<br>Porkohaszati Gyar                            | TSM23    | Ti(C,N)+TiC+TiN                                                                                                                 | 4-6                          | P15-P25                 |
| Kennametal                                           | Kennametal Inc                                                  | KC210    | TiC+Ti(C,N)+TiN                                                                                                                 | 10                           | K05-K30                 |
|                                                      |                                                                 | KC250    | TiC+Ti(C,N)+TiN                                                                                                                 | 10                           | M30-M45/K25-K35         |
|                                                      |                                                                 | KC710    | TiN                                                                                                                             | 3                            | P15-P25/M15-M25         |
|                                                      |                                                                 | KC720    | TiN                                                                                                                             | 3                            | P25-P45/M30-M40/K25-K35 |
|                                                      |                                                                 | KC729M   | TiN+Ti(C,N)(CVD)+TiN(PVD)                                                                                                       | 8                            | P10-P30                 |
|                                                      |                                                                 | KC730    | TiN                                                                                                                             | 3                            | M05-M15/K05-K15         |
|                                                      |                                                                 | KC740    | TiN                                                                                                                             | 3                            | P05-P15                 |
|                                                      |                                                                 | KC810    | TiC+Ti(C,N)+TiN                                                                                                                 | 10                           | P10-P30/M15-M35         |
|                                                      |                                                                 | KC820    | TiC+Ti(C,N)+TiN                                                                                                                 | 10                           | P25-P35/M10-M25         |
|                                                      |                                                                 | KC840    | TiC+Ti(C,N)+TiN                                                                                                                 | 10                           | P35-P45                 |
|                                                      |                                                                 | KC850    | TiC+Ti(C,N)+TiN                                                                                                                 | 10                           | P25-P45/M25-M45         |
|                                                      |                                                                 | KC910    | TiC+Al <sub>2</sub> O <sub>3</sub>                                                                                              | 9                            | P01-P20/M05-M20/K01-K15 |
|                                                      |                                                                 | KC950    | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN                                                                                         | 10                           | P05-P25/M10-M25/K10-K20 |
|                                                      |                                                                 | KC990    | Ti(C,N)+Al <sub>2</sub> O <sub>3</sub> +TiN+Al <sub>2</sub> O <sub>3</sub> +<br>TiN+Al <sub>2</sub> O <sub>3</sub> +Ti(C,N)+TiN | 11                           | P05-P25/M10-M25/K05-K25 |
|                                                      |                                                                 | KC992M   | Ti(C,N)+Al <sub>2</sub> O <sub>3</sub>                                                                                          | 4                            | K10-K25                 |
| Komet                                                | Komet Stahlhalter-und<br>Werkzeugfabrik Robert<br>Breuning GmbH | BK/BK60  | TiC+Ti(C,N)+TiN                                                                                                                 | ---                          | P10-P30                 |
|                                                      |                                                                 | BK1/BK61 | TiC+Al <sub>2</sub> O <sub>3</sub>                                                                                              | ---                          | K05-K15                 |
|                                                      |                                                                 | BK3/BK65 | TiC+Ti(C,N)+TiN                                                                                                                 | ---                          | P15-P35                 |
|                                                      |                                                                 | BK4/BK64 | TiC+Ti(C,N)+TiN                                                                                                                 | ---                          | P20-P40                 |
|                                                      |                                                                 | BK65     | TiC+Ti(C,N)+TiN                                                                                                                 | ---                          | ---                     |
|                                                      |                                                                 | BK66     | TiC+Ti(C,N)+TiN                                                                                                                 | ---                          | P25-P40                 |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                                                                 |        |                                         |                              |                         |
|------------------------------------------------------|-----------------------------------------------------------------|--------|-----------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name                                                    | Grade  | Layer Composition                       | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Komet<br>(continued)                                 | Komet Stahlhalter-und<br>Werkzeugfabrik Robert<br>Breuning GmbH | BK85   | TiN                                     | ---                          | P25                     |
|                                                      |                                                                 | BK86   | TiN                                     | ---                          | P35                     |
| KT/Korea<br>Tungsten                                 | Korea Tungsten Mining Co Ltd                                    | KT150  | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 5+3+1                        | P05-P20/M10/K05-K20     |
|                                                      |                                                                 | KT200  | TiC+Al <sub>2</sub> O <sub>3</sub>      | 6+1                          | P10-P30/M10-M20/K10-K25 |
|                                                      |                                                                 | KT250  | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 4+3+1                        | P15-P35/M15-M25         |
|                                                      |                                                                 | KT300  | TiC+Ti(C,N)+TiN                         | 4+2+2                        | P10-P35/M10-M20/K15-K35 |
|                                                      |                                                                 | KT350  | TiC+Ti(C,N)+TiN                         | 3+2+2                        | P25-P40/M20-M30         |
|                                                      |                                                                 | KT650  | Ti(C,N)+TiC+TiN                         | 4+1+1                        | K10-K30                 |
| Manchester                                           | Manchester Tool Company                                         | GC     | TiN+TiC+TiN                             | ---                          | ---                     |
|                                                      |                                                                 | M40    | TiN                                     | ---                          | ---                     |
|                                                      |                                                                 | M50    | TiN                                     | ---                          | ---                     |
|                                                      |                                                                 | PTN    | TiN+TiC+TiN                             | ---                          | ---                     |
| Mircona                                              | Mircona AB                                                      | ALC150 | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 10                           | P25-P45/M15-M25         |
|                                                      |                                                                 | ALC250 | TiC+Al <sub>2</sub> O <sub>3</sub>      | 12                           | K05-K25                 |
|                                                      |                                                                 | ALC300 | TiC+Al <sub>2</sub> O <sub>3</sub>      | 4                            | P05-P25/M10-M20/K05-K15 |
|                                                      |                                                                 | ALC350 | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 10                           | P05-P25/K05-K20         |
|                                                      |                                                                 | TNC100 | TiC+Ti(C,N)+TiN                         | 5                            | P45/M20-M40             |
|                                                      |                                                                 | TNC150 | TiC+Ti(C,N)+TiN                         | 10                           | P25+P40                 |
|                                                      |                                                                 | TNC250 | TiC+Ti(C,N)+TiN                         | 10                           | P10-P25/M10-M20/K20-K30 |
| Mitsubishi                                           | Mitsubishi Materials<br>Corporation                             | F515   | TiC+Al <sub>2</sub> O <sub>3</sub>      | 4                            | K10-K20                 |
|                                                      |                                                                 | U66    | TiC+Al <sub>2</sub> O <sub>3</sub>      | 8                            | P01-P10/K01-K10         |
|                                                      |                                                                 | U77    | TiC+Al <sub>2</sub> O <sub>3</sub>      | 8                            | P10-P30/K10-K20         |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                                  |        |                                                |                              |                         |
|------------------------------------------------------|----------------------------------|--------|------------------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name                     | Grade  | Layer Composition                              | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Mitsubishi<br>(continued)                            | Mitsubishi Materials Corporation | U88    | TiC+Al <sub>2</sub> O <sub>3</sub>             | 8                            | P20-P40                 |
|                                                      |                                  | U505   | Composite + TiC+Al <sub>2</sub> O <sub>3</sub> | 8                            | P01-P10/K01-K10         |
|                                                      |                                  | U510   | Composite + TiC+Al <sub>2</sub> O <sub>3</sub> | 8                            | K01-K20                 |
|                                                      |                                  | U610   | Composite + TiC+Al <sub>2</sub> O <sub>3</sub> | 8                            | P01-P20/K01-K20         |
|                                                      |                                  | U625   | Composite + TiC+Al <sub>2</sub> O <sub>3</sub> | 8                            | P10-P30                 |
| Newpro                                               | Newcomer Products Inc            | NA02   | TiC+Al <sub>2</sub> O <sub>3</sub>             | 10                           | P10-P25/M10-M25/K01-K20 |
|                                                      |                                  | NN55   | TiC+TiN                                        | 10                           | P10-P30/M10-M30         |
|                                                      |                                  | NN60   | TiC+TiN                                        | 10                           | P10-P25/M10-M30         |
|                                                      |                                  | NP92   | TiC+TiN                                        | 10                           | P15-P45/M20-M40/K15-K40 |
|                                                      |                                  | NP94   | TiC+TiN+TiC+Al <sub>2</sub> O <sub>3</sub>     | 20                           | P10-P45/M20-M40/K10-K40 |
|                                                      |                                  | NP1000 | TiC+TiN                                        | 10                           | P10-P35/M10-M30/K05-K20 |
|                                                      |                                  | NP2000 | TiC+Al <sub>2</sub> O <sub>3</sub>             | 10                           | P05-P20/M05-M20/K01-K20 |
|                                                      |                                  | NP4000 | TiC+TiN+Al <sub>2</sub> O <sub>3</sub>         | 20                           | P01-P25/M05-M25/K01-K25 |
|                                                      |                                  | NT56   | TiC                                            | 7                            | P05-P15/M10-M20         |
| North American                                       | North American Carbide           | PV52   | TiN                                            | 3                            | P20-P40/M10-M35         |
|                                                      |                                  | 111-5  | TiC+TiN                                        | 6-8                          | P10-P30/K10-K30         |
|                                                      |                                  | 111-54 | TiC+TiN                                        | 6-8                          | P30-P40/K30-K40         |
|                                                      |                                  | 111-N  | TiC+TiN                                        | 6-8                          | P20-P40/K20-K40         |
|                                                      |                                  | 112    | TiC                                            | 6-8                          | ---                     |
|                                                      |                                  | 113-5  | TiC+Al <sub>2</sub> O <sub>3</sub>             | 6-8                          | P10-P30/K20-K40         |
|                                                      |                                  | 113-N  | TiC+Al <sub>2</sub> O <sub>3</sub>             | 6-8                          | P20-P40/K20-K40         |
|                                                      |                                  | 114    | TiN                                            | 2-4                          | P25/K25                 |
|                                                      |                                  | 115-N  | TiC+TiN+Al <sub>2</sub> O <sub>3</sub>         | 6-8                          | P20-P40/K20-K40         |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                   |       |                                                 |                              |                         |
|------------------------------------------------------|-------------------|-------|-------------------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name      | Grade | Layer Composition                               | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Poldi Diadur                                         | Pramet Sumperk    | 015P  | Ti(C,N)                                         | 4-8                          | P10-P20                 |
|                                                      |                   | 020P  | Ti(C,N)                                         | 4-8                          | P20-P30                 |
|                                                      |                   | 210K  | Ti(C,N)+TiC+Al <sub>2</sub> O <sub>3</sub>      | 4-8                          | K10-K20                 |
|                                                      |                   | 320P  | Ti(C,N)+TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | 4-8                          | P10-P30/M10-M20         |
|                                                      |                   | 515P  | Ti(C,N)+TiC+Ti(C,N)+TiN                         | 4-8                          | P15-P20/M10-M15         |
|                                                      |                   | 520P  | Ti(C,N)+TiC+Ti(C,N)+TiN                         | 4-8                          | P15-P30                 |
|                                                      |                   | 525P  | Ti(C,N)+TiC+Ti(C,N)+TiN                         | 4-8                          | P25-P35/M15-M20/K10-K20 |
|                                                      |                   | 530P  | Ti(C,N)+TiC+Ti(C,N)+TiN                         | 4-8                          | P15-P35/M10-M30/K15-K30 |
|                                                      |                   | 535P  | Ti(C,N)+TiC+Ti(C,N)+TiN                         | 4-8                          | P30-P40                 |
| RTW                                                  | Rogers Tool Works | 027   | TiN+Ti(C,N)+TiC+TiN                             | 8                            | M05-M20/K05-K20         |
|                                                      |                   | 714   | TiN+Ti(C,N)+TiC+TiN                             | 8                            | P05-P25                 |
|                                                      |                   | 716   | TiN+Ti(C,N)+TiC+TiN                             | 8                            | P10-P30                 |
|                                                      |                   | 718   | TiN+Ti(C,N)+TiC+TiN                             | 8                            | P10-P25                 |
|                                                      |                   | 725   | TiN+Ti(C,N)+TiC+TiN                             | 8                            | P10-P30                 |
|                                                      |                   | 731   | TiN+Ti(C,N)+TiC+TiN                             | 8                            | P01-P10                 |
|                                                      |                   | 755   | TiN+Ti(C,N)+TiC+TiN                             | 8                            | P20-P45                 |
|                                                      |                   | 914   | TiN+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub>      | 8                            | P05-P25/M05-M20/K05-K20 |
|                                                      |                   | 916   | TiN+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub>      | 8                            | P10-P30/M10-M30/K10-K30 |
|                                                      |                   | 918   | TiN+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub>      | 8                            | P05-P25/M10-M30/K10-K30 |
|                                                      |                   | 925   | TiN+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub>      | 8                            | P10-P30/M15-M35/K15-K35 |
|                                                      |                   | 931   | TiN+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub>      | 8                            | P01-P10/M05-M15/K05-K20 |
|                                                      |                   | 955   | TiN+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub>      | 8                            | P20-P45/M30-M40/K30-K40 |
|                                                      |                   | CX37  | TiN+Ti(C,N)+TiC+TiN                             | 8                            | P40-P50                 |
|                                                      |                   | CX47  | TiN+Ti(C,N)+TiC+TiN                             | 8                            | P40-P50                 |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                     |          |                                                 |                              |                         |
|------------------------------------------------------|---------------------|----------|-------------------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name        | Grade    | Layer Composition                               | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Sandvik<br>Coromant                                  | AB Sandvik Coromant | Coronite | TiN                                             | 3                            | ---                     |
|                                                      |                     | GC015    | TiC+Al <sub>2</sub> O <sub>3</sub>              | 7                            | P05-P35/K05-K20         |
|                                                      |                     | GC135    | TiC                                             | 5                            | P25-P45/M15-M20         |
|                                                      |                     | GC215    | Ti(C,N)                                         | 8                            | P10-P40/M10-M25         |
|                                                      |                     | GC225    | TiN+TiC+TiN                                     | 3                            | P10-P30                 |
|                                                      |                     | GC235    | TiN+TiC+TiN                                     | 3                            | P30-P50/M20-M40         |
|                                                      |                     | GC315    | TiC                                             | 5                            | M15-M20/K05-K25         |
|                                                      |                     | GC320    | TiC+Al <sub>2</sub> O <sub>3</sub>              | 4                            | K10-K25                 |
|                                                      |                     | GC415    | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN         | 8                            | P05-P30/K05-K20         |
|                                                      |                     | GC425    | TiC+TiN                                         | 8                            | P10-P35/M10-M20         |
|                                                      |                     | GC435    | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN         | 8                            | P25-P45/M15-M25         |
|                                                      |                     | GC1020   | TiN                                             | 3                            | M10-M30                 |
|                                                      |                     | GC1025   | TiC                                             | 6                            | P10-P35/K05-K20         |
|                                                      |                     | GC3015   | TiC+Al <sub>2</sub> O <sub>3</sub>              | 11                           | K05-K20                 |
|                                                      |                     | GCA      | Ti(C,N)+TiN                                     | 5                            | P10-P35                 |
| Seco                                                 | Seco Tools AB       | 550      | TiN+TiC+TiN                                     | 9                            | P20-P45                 |
|                                                      |                     | 560      | TiN+TiC+Al <sub>2</sub> O <sub>3</sub> +TiN     | 10                           | P10-P35/K10-K20         |
|                                                      |                     | 570      | Al <sub>2</sub> O <sub>3</sub>                  | 6                            | P05-P25/M10-M20/K05-K20 |
|                                                      |                     | CP30     | Ti(C,N)+TiC+TiN                                 | 4                            | P10-P20                 |
|                                                      |                     | T15M     | TiC+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub> +TiN | 7                            | K05-K15                 |
|                                                      |                     | T25M     | Ti(C,N)+TiC+TiN                                 | 5                            | P05-P40/M30-M40/K30-K40 |
|                                                      |                     | TP05     | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN         | 9                            | P05/K10                 |
|                                                      |                     | TP10     | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN         | 11                           | P10/K15                 |
|                                                      |                     | TP15     | TiC+Ti(C,N)+Al <sub>2</sub> O <sub>3</sub> +TiN | 7                            | P05-P25/M05-M20/K05-K20 |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                                  |       |                                             |                              |                         |
|------------------------------------------------------|----------------------------------|-------|---------------------------------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name                     | Grade | Layer Composition                           | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Seco<br>(continued)                                  | Seco Tools AB                    | TP20  | TiC=Al <sub>2</sub> O <sub>3</sub> +TiN     | 7                            | P10-P35/M20             |
|                                                      |                                  | TP30  | TiC+Ti(C,N)+TiN                             | 12                           | P30/M30                 |
|                                                      |                                  | TP35  | TiC                                         | 5                            | P20-P35/M15-M30         |
|                                                      |                                  | TP40  | Ti(C,N)+TiC+TiN                             | 5                            | P40/M40                 |
|                                                      |                                  | TP45  | TiC                                         | 4                            | P35-P50/M30-M40/K40     |
|                                                      |                                  | TP301 | Ti(C,N)+TiC+TiN                             | 4                            | P30/M40                 |
|                                                      |                                  | TP401 | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN     | 7                            | P40/M40                 |
|                                                      |                                  | TX10  | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN     | 7                            | P05-P15/M05-M15/K05-K15 |
| SKF                                                  | SKF Tools AB                     | QM15  | TiN                                         | ---                          | M05-M20/K01-K25         |
|                                                      |                                  | QM25  | TiN                                         | ---                          | P10-P35                 |
|                                                      |                                  | QT09  | TiC                                         | 5                            | M10-M15/K05-K20         |
|                                                      |                                  | QT11  | Al <sub>2</sub> O <sub>3</sub>              | ---                          | K05-K20                 |
|                                                      |                                  | QT15  | TiN                                         | ---                          | P05-P30/M10-M25/K05-K20 |
|                                                      |                                  | QT25  | TiC+TiN                                     | 7-8                          | P05-P35/M10-M40/K05-K20 |
|                                                      |                                  | QT27  | TiC-TiN                                     | 5-7                          | P25-P40/M10-M40         |
|                                                      |                                  | QT35  | TiC                                         | 5                            | P25-P40/M15-M30         |
| Sumitomo                                             | Sumitomo Electric Industries Ltd | AC05  | TiC+Al <sub>2</sub> O <sub>3</sub>          | 8                            | P01-P10/K01-K15         |
|                                                      |                                  | AC10  | TiC+Al <sub>2</sub> O <sub>3</sub>          | 8                            | P05-P25                 |
|                                                      |                                  | AC10G | TiC+Al <sub>2</sub> O <sub>3</sub>          | 8                            | K05-K20                 |
|                                                      |                                  | AC15  | Special+Al <sub>2</sub> O <sub>3</sub> +TiN | 8                            | P10-P30                 |
|                                                      |                                  | AC25  | Special+Al <sub>2</sub> O <sub>3</sub> +TiN | 8                            | P15-P45                 |
|                                                      |                                  | AC105 | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN     | 10                           | P01-P05/K01-K10         |
|                                                      |                                  | AC211 | Special+Al <sub>2</sub> O <sub>3</sub> +TiN | 4                            | K10-K20                 |
|                                                      |                                  | AC225 | Special+Al <sub>2</sub> O <sub>3</sub> +TiN | 4                            | P15-P45                 |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                                  |       |                                                 |                              |                 |
|------------------------------------------------------|----------------------------------|-------|-------------------------------------------------|------------------------------|-----------------|
| Trade Name                                           | Company Name                     | Grade | Layer Composition                               | Coating Depth, $\mu\text{m}$ | ISO Code(s)     |
| Sumitomo<br>(continued)                              | Sumitomo Electric Industries Ltd | AC305 | TiN+TiC+TiN                                     | 4                            | K05-K15         |
|                                                      |                                  | AC325 | TiN+TiC+TiN                                     | 4                            | P10-P30         |
|                                                      |                                  | AC330 | TiN+TiC+TiN                                     | 4                            | P20-P30         |
|                                                      |                                  | AC720 | TiC                                             | 8                            | P20-P30         |
|                                                      |                                  | AC815 | TiN+TiC+TiN                                     | 8                            | P15-P25         |
|                                                      |                                  | T12Z  | TiN+TiC+TiN                                     | 4                            | P05-P15         |
|                                                      |                                  | T110Z | TiN+TiC+TiN                                     | 4                            | P01-P15/K01-K10 |
|                                                      |                                  | T130Z | TiN+TiC+TiN                                     | 4                            | P05-P25         |
| Teledyne                                             | Teledyne Firth Sterling          | CC44  | Al <sub>2</sub> O <sub>3</sub>                  | 8                            | P15-P35         |
|                                                      |                                  | CC46  | Al <sub>2</sub> O <sub>3</sub>                  | 8                            | K05-K30         |
|                                                      |                                  | HN+   | HfN                                             | 8                            | P05-P20         |
|                                                      |                                  | MP21  | TiN+Al <sub>2</sub> O <sub>3</sub> +TiN+Ti(C,N) | 10                           | K05-K20         |
|                                                      |                                  | MP26  | ---                                             | 10                           | P10-P25/K20-K30 |
|                                                      |                                  | MP51  | TiN+Al <sub>2</sub> O <sub>3</sub> +TiN+Ti(C,N) | 10                           | P20-P40/K30-K40 |
|                                                      |                                  | MP62  | TiN+Al <sub>2</sub> O <sub>3</sub> +TiN+Ti(C,N) | ---                          | P10-P35/M15-M30 |
|                                                      |                                  | TP21  | TiN                                             | 3                            | P10-P20/K05-K20 |
|                                                      |                                  | TC41M | ---                                             | 5                            | P30-P40/K40     |
| Tizit<br>Goldmaster                                  | Plansee Tizit GmbH               | Gm15  | TiC+Ti(C,N)+TiN                                 | 10-12                        | P05-P20/K05-K20 |
|                                                      |                                  | Gm25  | TiC+Ti(C,N)+TiN                                 | 10-12                        | P10-P30/K10-K30 |
|                                                      |                                  | Gm26  | TiC+Ti(C,N)+TiN                                 | 5                            | P10-P30/K10-K30 |
|                                                      |                                  | Gm35  | TiC+Ti(C,N)+TiN                                 | 10-12                        | P20-P40         |
|                                                      |                                  | Gm36  | TiC+Ti(C,N)+TiN                                 | 5                            | P20-P40         |
|                                                      |                                  | Gm40  | TiC+Ti(C,N)+TiN                                 | 5                            | P25-P40         |
|                                                      |                                  | Gm43  | TiC+Ti(C,N)+TiN                                 | 3                            | P25-P40         |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                         |       |                                         |                              |                 |
|------------------------------------------------------|-------------------------|-------|-----------------------------------------|------------------------------|-----------------|
| Trade Name                                           | Company Name            | Grade | Layer Composition                       | Coating Depth, $\mu\text{m}$ | ISO Code(s)     |
| Tizit<br>Starmaster<br>(continued)                   | Plansee Tizit GmbH      | Gm176 | TiC+Ti(C,N)+TiN                         | 5                            | P15             |
|                                                      |                         | Gm306 | TiC+Ti(C,N)+TiN                         | 5-6                          | P40-P50/M40     |
|                                                      |                         | Sr16  | TiC+Ti(C,N)+KS+ZS                       | 7                            | K10             |
|                                                      |                         | Sr17  | TiC+Ti(C,N)+KS+ZS                       | 8                            | P05-P25/K05-K20 |
|                                                      |                         | Sr117 | TiC+Ti(C,N)+TiN+KS+ZS                   | 10-12                        | P10-P20         |
|                                                      |                         | Sr127 | TiC+Ti(C,N)+TiN+KS+ZS                   | 10-12                        | P15-P35/K10-K30 |
|                                                      |                         | Sr137 | TiC+Ti(C,N)+TiN+KS+ZS                   | 10-12                        | P30-P40         |
| Tool-Flo                                             | Tool-Flo Manufacturing  | A53   | TiC+Al <sub>2</sub> O <sub>3</sub>      | ---                          | P10-P20         |
|                                                      |                         | AG53  | TiC+Al <sub>2</sub> O <sub>3</sub> +TiN | ---                          | P10-P20         |
|                                                      |                         | G2    | TiN+TiC+TiN                             | ---                          | K20             |
|                                                      |                         | G4    | TiN+TiC+TiN                             | ---                          | K30-K40         |
|                                                      |                         | G5    | TiN+TiC+TiN                             | ---                          | P25-P30         |
|                                                      |                         | G6    | TiN+TiC+TiN                             | ---                          | P15-P20         |
|                                                      |                         | G7    | TiN+TiC+TiN                             | ---                          | P10             |
|                                                      |                         | G25   | TiN+TiC+TiN                             | ---                          | K05-K15         |
|                                                      |                         | G44   | TiN+TiC+TiN                             | ---                          | P35-P45         |
|                                                      |                         | G50   | TiN+TiC+TiN                             | ---                          | P25-P30         |
|                                                      |                         | G53   | TiN+TiC+TiN                             | ---                          | P25-P30         |
|                                                      |                         | G54   | TiN+TiC+TiN                             | ---                          | P35-P40         |
|                                                      |                         | GP2   | TiN                                     | ---                          | K20             |
|                                                      |                         | GP4   | TiN                                     | ---                          | P35-P45         |
|                                                      |                         | GP6   | TiN                                     | ---                          | P15-P20         |
|                                                      |                         | GP7   | TiN                                     | ---                          | P10             |
|                                                      |                         | GP25  | TiN                                     | ---                          | K05-K15         |
|                                                      |                         | N5    | TiN                                     | ---                          | P25-P30         |
| Tungaloy                                             | Toshiba Tungaloy Co Ltd | PEM   | TiN                                     | 3                            | (drills)        |



| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                         |       |                   |                              |                         |
|------------------------------------------------------|-------------------------|-------|-------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name            | Grade | Layer Composition | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Tungaloy<br>(continued)                              | Toshiba Tungaloy Co Ltd | PG2   | TiN               | 3                            | K10-K20                 |
|                                                      |                         | PK56  | TiN               | 3                            | P30-P40                 |
|                                                      |                         | T221  | (Ti,Ta)(N,O)      | 3                            | K01-K20                 |
|                                                      |                         | T260  | (Ti,Ta)(N,O)      | 3                            | P20-P30/M20-M40         |
|                                                      |                         | T313V | ---               | 2                            | P20-P30                 |
|                                                      |                         | T370  | TiC               | 2                            | P20-P30/M20-M30/K01-K30 |
|                                                      |                         | T530  | TiC+Ti(C,N)+TiN   | 10                           | K10-K20                 |
|                                                      |                         | T553  | TiC               | 7                            | P10-P30                 |
|                                                      |                         | T801  | TiC+Al(O,N)       | 8                            | K01-K10                 |
|                                                      |                         | T802  | TiC+Al(O,N)       | 8                            | P10-P20/M10-M20/K01-K20 |
|                                                      |                         | T803  | TiC+Al(O,N)       | 8                            | P10-P30/M10-M30/K10-K20 |
|                                                      |                         | T813  | Ti(C,N,O)+Al(O,N) | 8                            | P10-P40/M10-M30/K10-K30 |
|                                                      |                         | T821  | Ti(C,N,O)+Al(O,N) | 8                            | K01-K10                 |
|                                                      |                         | T822  | Ti(C,N,O)+Al(O,N) | 8                            | P01-P20/M10             |
|                                                      |                         | T823  | Ti(C,N,O)+Al(O,N) | 8                            | P10-P30/M10-M30/K10-K20 |
|                                                      |                         | T841  | TiC+Al(O,N)       | 12                           | M10-M20/K01-K10         |
|                                                      |                         | T842  | TiC+Al(O,N)       | 12                           | M10-M30/K01-K20         |
| Ultra-Met                                            | Ultra-Met Manufacturing | ZCB   | TiN               | 8                            | P25-P40/M20-M40         |
|                                                      |                         | ZCC   | TiN               | 8                            | P10-P15                 |
|                                                      |                         | ZCK   | TiN               | 8                            | K30                     |
|                                                      |                         | ZCJ   | TiN               | 8                            | P10-P30/M15-M30/K15-K30 |
|                                                      |                         | ZCS   | TiN               | 8                            | K15-K30                 |
|                                                      |                         | ZCU   | TiN               | 8                            | P25-P40/M20-M40         |
|                                                      |                         | ZDC   | ---               | 8                            | P05-P15/K05-K10         |
|                                                      |                         | ZDF   | ---               | 8                            | K20-K30                 |
|                                                      |                         | ZDI   | ---               | 8                            | P05-P20/M10-M20/K10-K20 |
|                                                      |                         | ZDS   | ---               | 8                            | K05-K20                 |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                          |       |                   |                              |                         |
|------------------------------------------------------|--------------------------|-------|-------------------|------------------------------|-------------------------|
| Trade Name                                           | Company Name             | Grade | Layer Composition | Coating Depth, $\mu\text{m}$ | ISO Code(s)             |
| Ultra-Met<br>(continued)                             | Ultra-Met Manufacturing  | ZFY   | TiN               | 3                            | P20-P30/K20-K30         |
|                                                      |                          | ZSF   | TiN               | 8                            | K20-K30                 |
| Valenite                                             | Valenite Inc             | 902   | TiN               | ---                          | K05-K20                 |
|                                                      |                          | 905   | TiN               | ---                          | P20-P30                 |
|                                                      |                          | 907   | TiN               | ---                          | P05-P15                 |
|                                                      |                          | SV3   | ---               | ---                          | P01-P30/M10-M30/K05-K20 |
|                                                      |                          | SV4   | TiN               | ---                          | P10-P40/M20-M40/K10-K40 |
|                                                      |                          | SV200 | TiC+TiN           | ---                          | P20-P50/K20-K40         |
|                                                      |                          | V01   | ---               | ---                          | P05-P20/M10-M20/K05-K15 |
|                                                      |                          | V1N   | TiN               | ---                          | P30-P40/M30-M40/K20-K40 |
|                                                      |                          | VN8   | TiN               | ---                          | P10-P30/M15-M20/K10-K20 |
|                                                      |                          | VX8   | TiC+TiN           | ---                          | P15-P30/M15-M30/K10-K20 |
|                                                      |                          | V88   | TiC               | ---                          | P01-P30/M10-M30/K01-K30 |
|                                                      |                          | V05   | ---               | ---                          | P01-P30/M05-M20/K01-K30 |
| Vandurit                                             | Metalloceramica Vanxetti | V111  | ---               | 4+4                          | P05-P25/M05-M25/K05-K25 |
|                                                      |                          | V134  | TiC+Ti(C,N)+TiN   | 8-10                         | P25-P40/M25-M40/K25-K40 |
|                                                      |                          | V635F | Ti(C,N)+TiN       | 3+1                          | P10-P30                 |
|                                                      |                          | VMT   | TiC+Ti(C,N)+TiN   | 8-10                         | P20-P35/M20-M35         |
|                                                      |                          | VOR   | TiC+Ti(C,N)+TiN   | 8-10                         | P15-P30/M15-M30         |
|                                                      |                          | VRC   | TiC               | 6                            | K15-K30                 |
| Walter                                               | Walter Hartmetall GmbH   | WTA21 | ---               | 5                            | P05-P20/M10-M25/K05-K20 |
|                                                      |                          | WTA31 | ---               | 5                            | P05-P20/M10-M25/K05-K20 |
|                                                      |                          | WTA33 | ---               | 12                           | P05-P20/M10-M25/K05-K20 |
|                                                      |                          | WTA41 | ---               | 5                            | P15-P30/M20-M35/K15-K30 |
|                                                      |                          | WTA43 | ---               | 12                           | P15-P30/M20-M35/K15-K30 |
|                                                      |                          | WTL14 | Ti(C,N)+TiN       | 5                            | P15-P35/K15-K35         |
|                                                      |                          | WTL41 | Ti(C,N)+TiN       | 5                            | P15-P35/M15-M20         |

| COATED CEMENTED CARBIDES CROSS REFERENCE (Continued) |                        |                 |                                        |                              |                 |
|------------------------------------------------------|------------------------|-----------------|----------------------------------------|------------------------------|-----------------|
| Trade Name                                           | Company Name           | Grade           | Layer Composition                      | Coating Depth, $\mu\text{m}$ | ISO Code(s)     |
| Walter<br>(continued)                                | Walter Hartmetall GmbH | WTL71           | Ti(C,N)+TiN                            | 5                            | P35-P40/K30-K40 |
|                                                      |                        | WTL74           | Ti(C,N)+TiN                            | 5                            | P35-P40/K30-K40 |
|                                                      |                        | WTL82           | Ti(C,N)+TiN                            | 5                            | M10-M15/K10-K30 |
|                                                      |                        | WTN33           | Ti(C,N)+TiN                            | 12                           | P05-P20         |
|                                                      |                        | WTN41           | Ti(C,N)+TiN                            | 5                            | P15-P30         |
|                                                      |                        | WTN43           | Ti(C,N)+TiN                            | 12                           | P15-P30         |
|                                                      |                        | WTN53           | Ti(C,N)+TiN                            | 12                           | P25-P40         |
| Widia                                                | Krupp Widia GmbH       | Widadur TN25    | TiC+Ti(C,N)+TiN                        | 10                           | P25             |
|                                                      |                        | Widadur TN25M   | TiC+Ti(C,N)+TiN                        | 4                            | P25             |
|                                                      |                        | Widadur TN35    | TiC+Ti(C,N)+TiN                        | 10                           | P30             |
|                                                      |                        | Widadur TN35M   | TiC+Ti(C,N)+TiN                        | 4                            | P30             |
|                                                      |                        | Widadur TN250   | TiC+Ti(C,N)+TiN                        | 10                           | P25             |
|                                                      |                        | Widadur TN450   | TiC+Ti(C,N)+TiN                        | 8                            | P30             |
|                                                      |                        | Widalon HK15    | multilayer Al(O,N)                     | 8                            | K15             |
|                                                      |                        | Widalon HK15M   | multilayer Al(O,N)                     | 5                            | K15             |
|                                                      |                        | Widalon HK35    | multilayer Al(O,N)                     | 8                            | M25             |
|                                                      |                        | Widalon HK150   | Ti(C,N)+Al <sub>2</sub> O <sub>3</sub> | 8                            | K15             |
|                                                      |                        | Widalon TK15    | multilayer Al(O,N)                     | 8                            | P15             |
|                                                      |                        | Widaplas TPC15  | TiN                                    | 3                            | P15             |
|                                                      |                        | Widaplas TPC25  | TiN                                    | 3                            | P25             |
|                                                      |                        | Widaplas TPC35  | TiN                                    | 3                            | P30             |
|                                                      |                        | Widianit CN1000 | Al <sub>2</sub> O <sub>3</sub>         | 1-2                          | K20             |
|                                                      |                        | Widianit CN2000 | Al <sub>2</sub> O <sub>3</sub>         | 1-2                          | K20             |
| Wolframcarb                                          | Wolframcarb SpA        | 333X            | TiC+Ti(C,N)+TiN                        | 5                            | P10-P30         |
|                                                      |                        | 666/S           | TiC+TiN                                | 2                            | P30-P45         |
|                                                      |                        | 666X            | TiC+Ti(C,N)+TiN                        | 5                            | P30-P45         |

| <b>COATED CEMENTED CARBIDES CROSS REFERENCE (Continued)</b> |                     |              |                                             |                                                |                    |
|-------------------------------------------------------------|---------------------|--------------|---------------------------------------------|------------------------------------------------|--------------------|
| <b>Trade Name</b>                                           | <b>Company Name</b> | <b>Grade</b> | <b>Layer Composition</b>                    | <b>Coating Depth, <math>\mu\text{m}</math></b> | <b>ISO Code(s)</b> |
| Wolframcarb<br>(continued)                                  | Wolframcarb SpA     | A55          | TiC+TiN+Al <sub>2</sub> O <sub>3</sub> +TiN | 5-6                                            | P01-P20/K01-K10    |
|                                                             |                     | A66          | TiC+Al <sub>2</sub> O <sub>3</sub>          | 5                                              | P30-P45/K30-K35    |
|                                                             |                     | A99          | TiC+Al <sub>2</sub> O <sub>3</sub>          | 5                                              | P20-P30/K20-K30    |
|                                                             |                     | A355         | TiC+TiN+Al <sub>2</sub> O <sub>3</sub> +TiN | 5-6                                            | P10-P30/K20-K30    |
|                                                             |                     | AK33         | TiC+Al <sub>2</sub> O <sub>3</sub>          | 5                                              | K01-K10            |
|                                                             |                     | AK44         | TiC+Al <sub>2</sub> O <sub>3</sub>          | 5                                              | K10-K20            |
|                                                             |                     | G166X        | TiC+Ti(C,N)+TiN                             | 5                                              | P30-P45            |
|                                                             |                     | T125         | TiC+TiN                                     | 2                                              | P20-P25            |
|                                                             |                     | T140         | TiC+TiN                                     | 2                                              | P30-P40            |
|                                                             |                     | W30X         | TiC+TiN                                     | 2                                              | P10-P30            |

a. This cross-reference table lists the ISO Code and company-related information; since this information is constantly being revised, it should be kept in mind that it is presented herein as a guide and may not reflect the latest revisions.

# Chapter 6

## ***LEAD, TIN & ZINC ALLOYS***

### **LEAD**

The origins of metallic lead lie in the far distant past. Lead ores are relatively easy to reduce, and hence the metal has been known and used for both ornamental and structural purposes probably since before 5000 B.C. Today the uses of lead and its alloys are based on its unique combination of properties, among which are high density, castability, formability, conductivity, thermal expansion, and corrosion resistance combined with low tensile and creep strength, hardness, elastic stiffness, and melting point. The low creep strength is a serious limitation to the structural applications of lead, but this can be overcome by design or by the use of inserts or supports. Battery applications represent the most important uses of lead and its alloys, but they are also used as shielding, bearing materials, type metal, cable sheathing, and solders. These applications are discussed in more detail below.

Primary lead production comes from the smelting of the mineral galena (lead sulphide, PbS). The ore is concentrated, using flotation to separate the galena from associated minerals. The concentrate is sintered and roasted, then smelted in a blast furnace to produce an impure lead bullion which is purified in a sequence of processes to remove most of the residual copper, antimony, tin, arsenic, precious metals, and zinc. The final step is often an electrolytic refining. Purities as high as 99.99% are readily obtainable.

Lead is also extensively recycled. Scrap processing accounts for more than half of lead production, giving it the highest recycling rate of all the metals.

Pure lead has a face-centered cubic crystal structure, and this combined with its low melting temperature (327°C, 621°F) account for its high

ductility. Compared to most of the common metals, it has a high density, its specific gravity being 11.3.

## Categories

The commercial grades of lead and its alloys are shown in Table 1 along with the corresponding UNS designations. The initial letter in the UNS designations, "L", refers to low melting metals and alloys (as such, the L category also includes cadmium, lithium, tin, and their alloys). Cast and wrought lead alloys are available but the UNS categories do not distinguish between these.

| <b>Table 1 Commercial Grades of Lead With UNS No.</b> |                   |
|-------------------------------------------------------|-------------------|
| Commercial purity lead                                | UNS L50000-L50099 |
| Lead-silver alloys                                    | UNS L50100-L50199 |
| Lead-arsenic alloys                                   | UNS L50300-L50399 |
| Lead-barium alloys                                    | UNS L50500-L50599 |
| Lead-calcium alloys                                   | UNS L50700-L50899 |
| Lead-cadmium alloys                                   | UNS L50900-L50999 |
| Lead-copper alloys                                    | UNS L51100-L51199 |
| Lead-indium alloys                                    | UNS L51500-L51599 |
| Lead-lithium alloys                                   | UNS L51700-L51799 |
| Lead-antimony alloys                                  | UNS L52500-L53799 |
| Lead-tin alloys                                       | UNS L54000-L55099 |
| Lead-strontium alloys                                 | UNS L55200-L55299 |

## Commercial Purity Lead

The four grades of commercial purity lead are "chemical lead" (UNS L51120) and "acid-copper" lead (UNS L51121), both of which contain a minimum of 99.9% lead, along with "pure lead" also called "corroding lead" (UNS L50042) and "common lead" (UNS L50045) which contain a minimum of 99.94% lead. Corroding lead is named not for its corrosion resistance but rather for a process to which it was subjected in order to produce products such as oxides, pigments, and other chemicals. Chemical lead contains copper and silver impurities which confer on it an improved corrosion resistance and strength, so that it is particularly appropriate for use in the chemical industries.

## Lead Alloys

The most common alloying elements in lead are antimony, tin, arsenic, and calcium. Antimony is added in amounts ranging up to 25%, but most commonly 2-5%, in order to improve the strength for applications such as

storage battery grids, pipe, and sheet. Calcium in amounts below 0.2% has a similar hardening effect on lead, and is sometimes added along with small amounts of tin and/or aluminum. Tin not only strengthens lead but also improves its casting and wetting properties, for uses as solders and as type metal for printing. Arsenic is also a strengthening addition to lead, both alone and in combination with antimony. Some lead alloys, including antimonial lead and lead-calcium alloys, exhibit pronounced precipitation hardening and can be considered heat treatable.

### **Battery Applications**

The primary applications of lead and its alloys are as grid plates, posts, and connector straps in lead-acid storage batteries. Grid plates function in a sulphuric acid environment under repeated cycles of charging and discharging, hence corrosion resistance is important. Both cast and wrought plates are used, typically lead-calcium, lead-calcium-tin, or antimonial lead alloys. For example, positive plates for automotive batteries may be made from antimonial lead (1.5-4%Sb plus minor amounts of tin, arsenic, etc.) including alloys UNS L52760, L52765, L52770, and L52840) while negative plates may be cast calcium-lead alloys (up to 0.1%Ca) with minor amounts of tin and/or aluminum (UNS L50775, L50780, and L50790) or without the tin/aluminum addition (UNS L50760 and L50770). Grids for industrial batteries usually are lead containing 5-8%Sb (e.g., UNS L53135). Other alloys for battery applications include the lead-strontium alloys (e.g., UNS L55260).

### **Type Metal**

Lead-based materials are also used for type in the printing industry. These are generally lead-antimony alloys, often with tin and copper as well. Here the good castability and low melting temperature of lead are further improved by the antimony and tin. Furthermore, the antimony and copper increase the hardness, while the tin reduces brittleness and improves the ability to reproduce fine detail. The different printing processes (electrotype, stereotype, linotype, monotype, foundry type) require different type characteristics, and hence different alloys are used. For example electrotype has relatively low alloy content (2-4%Sn, 2-3%Sb, e.g., UNS L52730 and L52830), since it is not required to resist wear, while linotype (3-5%Sn, 11-12%Sb, e.g., UNS L53425 and L53455), stereotype (6-8%Sn, 13-15%Sb; e.g., UNS L53530 and L53575), and monotype (7-12%Sn, 15-24%Sb; e.g., UNS L53685 and L53750) are increasingly highly alloyed for increased hardness and wear resistance. Foundry type, which is repeatedly reused without remelting and can be subjected to high pressures in forming molds, has up to 2% copper added for even greater hardness (e.g., UNS L53710 and L53780).

## **Cable Sheathing**

Lead sheathing is often extruded around electrical power and communication cables for protection against moisture, corrosion, and mechanical damage. Alloys used include chemical lead, antimonial lead, arsenical lead, and lead-calcium alloys, some with additions of copper or tellurium. In all cases, the total amount of alloying element remains small (less than 1%) so that the sheathing can be readily extruded around the cable. Examples include the arsenical lead alloy UNS L50310, the antimonial leads UNS L52520 and L52535, and the calcium leads UNS L50710, L50712, and L50725.

## **Shielding and Damping**

Lead and its alloys find many applications as shielding materials. Its high density provides it with good radiation shielding properties against x-rays and gamma rays, and it is frequently used for this purpose as a lining in concrete structures. The combination of high density, low stiffness, and high damping capacity gives lead excellent vibration and sound absorbing properties. It is widely used to isolate equipment and structures from vibration, for example as lead-steel composite pads under column footings in buildings. For sound absorption it is used either alone or in composites with polymer foams or sheets. Lead foils, either alone or as a sandwich rolled between thin layers of tin, are used as moisture barriers in the construction industry and as oxygen barriers on wine bottles.

## **Corrosion Resistant Sheet and Pipe**

In addition, lead and its alloys are used in sheet form in corrosion-resistant applications, for example in the construction industry for roofing and flashing, in pans below shower and bath stalls, and in flooring. Sheet and piping made from chemical lead (UNS L51120) and alloys such as antimonial lead (e.g., the 6%Sb alloy UNS L53125) are also used in the chemical industry as well as in plumbing and water distribution and waste systems, with the more highly alloyed material used where resistance to creep and erosion is important.

Corrosion resistance can be imparted to mild steel sheet or plate by coating it with a lead-tin (3-15%Sn) alloy. This is known as a terne coating and the product is called terne sheet or terne plate.



## **Solders**

Lead-tin alloys are very widely used as solders, since their low melting temperatures allow joining without damage to heat-sensitive materials. Depending on the composition, melting temperatures between 182° and 315°C (360 and 599°F) are possible, and commercial solders are available across the full range from pure tin to pure lead. The very low-tin solders (e.g., 5%Sn or 5/95 solder, UNS L54320) are used for coating, sealing and joining and at service temperatures as high as 120°C (248°F). Solders with higher amounts of tin (e.g., 10/90, UNS L54520; 15/85, L54560; 20/80, L54710) are used in the automotive industry, both for radiator joining applications and for body damage repairs. Solders 40/60 (UNS L54915) and 50/50 (UNS L55030) are general purpose solders used in the automotive, electrical and electronic, and construction industries, in the latter case for roofing seams. Some lead-tin based solders also contain additional alloying elements, notably antimony and silver for improved fatigue and creep resistance and improved performance at high and low temperatures. Examples include the lead-tin-silver alloys UNS L54525, L54750, and L54855, and the lead-tin-antimony alloys UNS L54211, L54321, and L54905.

## **Bearing Materials**

Many bearing materials are lead-based alloys; these are often referred to as lead-base babbitt metals. There are two basic groups of these alloys, one being lead-tin-antimony often with arsenic as well, the other being lead-calcium-tin often with other alkaline earth metals. The first group is the most common and includes four arsenical alloys covered by ASTM B23 (Alloy 7, UNS L53585; Alloy 8, UNS L53565; Alloy 13, UNS L53346, and the most common, Alloy 15, UNS L53620). Alloy 15 is used in automotive engines, often as a continuously cast bimetallic strip (steel and babbitt metal). For service in applications such as rolling mill bearings, a higher (3%) arsenic alloy is used. Another lead-tin-antimony alloy, known as SAE 16 (UNS L52860), is used for automotive applications as an overlay, cast onto a porous sintered non-ferrous matrix which is bonded to steel. Alloys in the second group of babbitt metals, the lead-calcium-tin alloys, are used for railway applications and some diesel engine bearings.

## **Miscellaneous Applications**

In addition to the applications discussed above, there are a number of miscellaneous uses for which the properties of lead alloys make them suitable materials. For example, the high density and excellent castability of lead make it a useful material for counterweights. Lead-

silver and lead-calcium-tin alloys in the form of rolled sheet find uses as anodes for electroplating and electrowinning (e.g., UNS L50110, L50120, L50730, and L53120). Unalloyed lead and alloys with tin, silver (e.g., UNS L50140), or antimony are used as anodes for cathodic protection, for example on ships and offshore rigs; these are used in cast or extruded bar form or as supported sheet. Fusible alloys, i.e., alloys with especially low melting points, in some cases below 100°C (212°F), are used in automatic sprinkler systems, as electrical fuses, and as boiler plugs. These are often lead-based alloys containing tin and bismuth, including UNS L54755, L54830, and L54930.

## **TIN**

Tin has been used as an alloying element in bronze for at least 6000 years and has been known as a metal in its own right for at least 3500 years. It is characterized by a low melting point (232°C, 450°F), an attractive appearance, softness, and corrosion resistance. The major applications of tin are in coatings, mainly tinplated steel sheet, and as a component of solders, but other uses include bearing materials and pewter. Tin and its alloys are used in cast and wrought forms and as a powder.

Tin is obtained primarily from the smelting of the mineral cassiterite ( $\text{SnO}_2$ ) mined from low-grade placer deposits or veins in Brazil, Southeast Asia, Bolivia, and Australia. The high density of cassiterite permits it to be readily beneficiated, and the concentrate is then smelted in a reverberatory furnace, refined by a remelting step, and further refined if necessary by liquating or electrolytic refining.

Tin exists normally as *beta* tin or "white tin" with a body-centered tetragonal crystal structure. Below 13°C (56°F) the equilibrium structure is *alpha* tin or "grey tin" which is a nonmetallic cubic phase. The transformation from white tin to grey tin is usually associated with disintegration or blistering problems which result from the volume increase; however, grey tin does not normally form. The transformation is difficult to initiate and impurities inhibit it further, so this factor does not usually have to be taken into consideration.

Tin is a reasonably dense metal with a specific gravity of 7.28, very slightly greater than zinc, but much less than lead. As is the case for lead, the tensile strength of tin is not as important a design criterion as its creep strength, since it can readily undergo creep at room temperature.

## **Unalloyed Tin**

Commercially pure tin is available in several grades, but the most important is Grade A tin (UNS L13008) which contains a minimum of 99.8%Sn. Uses include pewter and tinplate foil. It is also used as a lining material in contact with high purity water, for example in distillation plants. The corrosion resistance of tin is excellent in near-neutral solutions, for example dilute solutions of weak alkalis, but tin does corrode in strong acids and bases and in aerated aqueous solutions.

## **Tinplate**

Tinplate was originally produced by dipping iron or steel sheet into a bath of molten tin, but this process has been largely replaced by electroplating techniques. Coatings on steel sheet include pure tin, as well as alloys including tin-zinc (brass), tin-cadmium, and tin-copper (bronze). Coating thicknesses are almost always less than 2 micrometers (80 microinches) with overall tinplate thickness of 0.15 to 0.60 mm (0.006 to 0.024 in.). Electrolytic tinplate is used mainly for containers for food products, motor oil, and many other materials. Hot dip tin coatings are used for component leads, bonding layers in bearings, and in the food handling and processing industries.

## **Solders**

Solder materials cover the entire composition range of the lead-tin system from pure tin to pure lead. Alloys containing up to 50%Sn have been discussed above in the Lead section. These include the widely used general purpose solders 40/60 and 50/50 which contain 40% and 50%Sn respectively. The roles of tin in solder include lowering the melting temperature range as well as increasing the wetting and adhesion of the solder to a wide range of base materials. Relatively high tin solders are used in the electrical and electronics industries because of their higher strength and electrical conductivity. These include the 60%Sn solders UNS L13600 and L13601 and the eutectic (63%Sn) solders UNS L13630 and L13631. Tin alloy solders often contain zinc, antimony, or silver for higher strength or higher temperature applications. These typically contain more than 95%Sn, for example the tin-antimony solders UNS L13940 and L13950 and the tin-silver solders UNS L13960 and L13961. Unalloyed tin and very high tin alloys with a maximum of 0.2%Pb (UNS L13940, L13950, and L13960) are used for soldering side seams of some food product containers and in numerous other applications where the presence of lead could be a hazard.

## **Pewter**

The material known as pewter is traditionally a lead-tin based alloy; however, modern pewters are tin alloys containing up to 8%Sb and up to 3%Cu in order to avoid the toxicity and surface brightness problems of the older lead-bearing pewters. Pewter is used in both cast (e.g., UNS L13911) and wrought (e.g., UNS L13912) forms. Its high formability permits the use of a wide range of shaping processes including spinning, rolling, hammering, and drawing, often without the necessity for annealing steps during fabrication. Pewter is used for such products as trays, dishes, vases, and candlesticks.

## **Bearing Alloys**

Bearing alloys which are rich in lead (lead-base babbitt metals) have been discussed above in the Lead section. However, many bearing alloys are tin-rich; these are usually alloyed with antimony and copper for increased hardness, tensile strength, and fatigue resistance. Examples include UNS L13840, L13870, and L13910. Other tin-base bearing alloys include intermediate lead-tin babbitt alloys and aluminum-tin bearing alloys. The latter find applications in contact with hardened steel or ductile iron crankshafts, where they are capable of withstanding higher loading and provide better fatigue resistance than tin-base or lead-base bearing alloys. These are used in high-duty engine applications including connecting rod bearings, crosshead bearings, and thrust bearings.

## **Miscellaneous Applications**

"Spotted metals," tin-lead alloys in the form of cast strip, are used for organ pipes; these contain 20% to 90% tin depending on the tone desired. Tin-based die casting alloys, some of which are also used for sleeve bearings, contain antimony and copper (UNS L13913 and L13820) and sometimes lead (UNS L13650). A tin-antimony alloy (8%Sb), known as white metal, is used for jewelry applications. Collapsible tubes made of tin containing 0.4%Cu are used for packaging (e.g., artist paint tubes), and tin foil containing 8%Zn is used for food packaging.

Tin in powder form is used in sintered components whose primary constituent is bronze or iron powder. The role of the tin is to create a liquid which can function as a carrier phase for liquid-phase sintering. Tin-lead solder powders are also used in powder compacts which are to be bonded by warm compression. Tin powder also finds applications as spray-deposited coatings for corrosion resistance, bearing repairs, and metallizing of non-conducting components.

## **ZINC**

Zinc has been used since before Roman times as a component of brass, but this early brass was produced not from metallic zinc but from zinc oxide, which in turn was obtained from calamine (zinc carbonate) or roasted sphalerite (zinc sulphide). Metallic zinc was known in Europe and in China by about 1600 A.D., but was clearly known in India at least a few hundred years earlier.

The production of metallic zinc is complicated by the fact that the temperatures necessary to reduce zinc from its ores are higher than the boiling point of zinc, so that zinc is produced as a vapour which readily oxidizes during cooling unless a reducing environment is maintained during cooling. Hence, zinc smelting traditionally involved distillation processes, but now is carried out by hydrometallurgy, with leaching of zinc concentrate being followed by electrowinning. The cathode zinc is then remelted and cast into ingots or slabs. There are also pyrometallurgical processes for zinc extraction, notably the Imperial Smelting process which involves a blast furnace and a lead splash condenser for recovering zinc from the blast furnace gas stream.

Pure zinc has a hexagonal close-packed (hcp) crystal structure, a melting temperature of 420°C (788°F), and a specific gravity of 7.14 at room temperature.

The major use of zinc is as a coating on steel, the process being known as galvanizing and the product as galvanized steel. Zinc and zinc alloys are also widely used as casting alloys, especially for die casting, and to a lesser extent in wrought form as sheet, extrusions, drawn wire, and forgings.

### **Nomenclature**

Zinc and its alloys are categorized under the UNS system using the prefix letter Z. Other designations follow various ASTM standards in utilizing simpler nomenclatures (e.g., die casting alloy no. 2). These are described in more detail below in connection with various applications of zinc and its alloys.

Zinc is available in several grades in slab form, intended for remelting especially for galvanizing. These grades include, in order of decreasing purity, Special High Grade zinc (min. 99.99%Zn, UNS Z13001), High Grade zinc (min. 99.90%Zn, UNS Z15001), and Prime Western zinc (min. 98.0%Zn, UNS Z19001). The higher purity grades are used for continuous and electrolytic galvanizing and for alloy production, both in

brassmaking and in zinc die casting alloys, where control of impurity levels is critical. For after-fabrication hot dip galvanizing, zinc purity is not as important and the Prime Western grade is satisfactory or even advantageous as its lead content (1%Pb) has benefits in the galvanizing process.

## **Galvanizing**

Zinc has the ability to cathodically protect steel against corrosion by acting as a sacrificial anode, so that the zinc corrodes itself in preference to the steel and thereby protects it. Galvanized steel has good resistance to corrosion in many environments, and galvanized products cover a wide range, from small fasteners to large structures. Zinc is readily applied to steel as a surface coating, the most common techniques being hot dip galvanizing (dipping into a molten zinc bath), electroplating, metallizing (spraying molten zinc onto the surface), and mechanical galvanizing (forcing zinc powder onto the surface under pressure). Of these, hot dip galvanizing remains the most common. Typically, continuously hot dip galvanized steel strip with a 25 micron (0.001 in.) thick layer of Zn containing 0.2%Al finds applications in the automotive, appliance, and building industries. Variations on this process include the galvannealing process where a post-galvanizing heat treatment converts the zinc layer to a layer of iron-zinc alloy, and the galvalume process which creates a zinc-aluminum alloy coating for improved corrosion resistance.

Fabricated components or structures are hot dip galvanized in a bath of Prime Western or other lead-bearing zinc, the resultant coating having a thickness typically of 85-100 microns (0.0034-0.004 in.). Galvanized structural components include electricity and microwave transmission towers, highway signs and guard rails, pipe, and reinforcing bar.

Electrogalvanizing is carried out by a continuous high speed process, creating a smooth thin coating. This is finding applications in the automotive industry.

Application of a zinc coating by thermal spraying (metallizing) is utilized when a heavy coating of zinc is desired, typically in field application and for repair of existing coatings. Pure zinc (UNS Z13001) or zinc-15%Al alloy are typical sprayed coatings. Mechanical galvanizing, by tumbling the components in a drum with zinc dust, chemicals, and glass beads, finds applications where high temperatures, such as those encountered in hot dipping cannot be tolerated, for example fasteners manufactured from high strength steels.

## **Sacrificial Anodes**

Zinc plates are used as sacrificial anodes, especially for ships hulls, ballast tanks, and underwater structures where the surface area is too large for galvanizing to be appropriate. Alloys used include a relatively high purity zinc (Type II Anodes, UNS Z13000) and alloys containing small amounts of aluminum (Type I, UNS Z32120 and Type III, UNS Z32121).

## **Zinc Alloy Castings**

Zinc and its alloys have low melting points, high fluidity in the liquid state, and do not require fluxing or protective atmospheres, thus making them excellent casting alloys. They are utilized for all forms of castings including pressure die castings, permanent mold castings, sand castings, investment castings, and centrifugal castings. Of these, pressure die castings are the most important. Most zinc casting alloys are based on the zinc-aluminum system, which exhibits a eutectic point at about 5%Al and 382°C (720°F). Many of the die casting alloys are hypoeutectic, solidifying with a microstructure consisting of proeutectic dendrites of zinc-rich *eta* phase in a eutectic matrix. The hypereutectic alloys have aluminum-rich *beta* or *alpha* dendrites in the eutectic matrix. Because of the high cooling rates associated with die casting, stabilization heat treatments, e.g., 70°-100°C (158°-212°F) for 3-20 hours, are sometimes necessary to prevent small changes in dimensions and properties which result from long-term aging.

Zinc alloy castings are readily machinable, can be joined by soldering or brazing, have good sound and vibration damping properties, especially at high temperatures, and are used also as bearings and bushings under low speed high load conditions. They have good corrosion resistance, which can be improved by surface treatments such as chromating and anodizing; they can also be painted or plated for improved appearance. Zinc alloy castings are extensively used in the automotive industry, for example for carburetor and fuel pump bodies and various frames, levers, brackets, and moldings. They are also used for hardware components in computers, business machines, vending machines, and hand tools, as well as for components of domestic appliances, motor housings, locks, and clocks.

Each of the common die casting alloys is available with two similar specifications, differing slightly in composition; one is a specification for castings, the other with slightly lower impurity limits is a specification for ingots to be remelted for casting. The four common hypoeutectic casting alloys, all of which contain about 4%Al, are referred to as Alloys

2, 3, 5, and 7, or ASTM designations AC43A, AG40A, AC41A, and AG40B respectively. Alloy No. 3 (UNS Z33520 castings, UNS Z33521 ingots) is a very widely used alloy, with an excellent combination of strength and castability at a low cost. Alloy No. 7 (UNS Z33523 castings, UNS Z33522 ingots) is a high purity version of No. 3, with improved castability and ductility. Alloy No. 5 (UNS Z33531 castings, UNS Z33530 ingots) contains about 1%Cu for improved strength and creep resistance but decreased ductility, so that more care is necessary in any post-casting operations. Alloy No. 2 (UNS Z33541 castings, UNS Z33540 ingots) contains close to 3%Cu, giving it the highest strength and creep resistance of the hypoeutectoid alloys. It also has good bearing properties, but suffers from reduced ductility and some dimensional instability.

The hypereutectoid alloys include alloys ZA-8, ZA-12, and ZA-27 which contain approximately 8, 12, and 27%Al respectively. ZA-8 (UNS Z35636 castings, UNS Z35635 ingots) has properties similar to those of alloy No. 2, but with improved dimensional stability and higher strength. It is the only hypereutectoid alloy which can be cast using hot chamber die casting machines, as the hypoeutectoid alloys can. ZA-12 (UNS Z35631 castings, UNS Z35630 ingots) has good castability and a low density, along with excellent bearing and wear properties. ZA-27 (UNS Z35841 castings, UNS Z35840 ingots) has the highest strength, lowest density, and best sound, and vibration damping properties; however, it is not as easily castable. The ZA alloys can also be gravity cast, using sand or permanent molds. The coarser microstructures of the gravity cast alloys give them properties which are slightly different from those of the equivalent pressure die cast alloys. For example, strength is lower and creep resistance higher. Of the three ZA alloys, ZA-8 is most used with ferrous permanent molds, ZA-12 with graphite molds, and ZA-27 with sand molds.

Also included among the gravity cast alloys are the Kirksite alloys which are used for cast two-piece dies for sheet metal forming and polymer injection molding. These alloys, which are similar in composition to die casting alloy No. 2, are referred to as Kirksite I or forming die alloy A (UNS Z35543) and Kirksite II or forming die alloy B (UNS Z35542).

Slush casting is used for the production of hollow castings where interior surface quality is unimportant (e.g., hollow lamp bases). Zinc alloys used for this purpose include the slush casting alloys A (UNS Z34510) and B (UNS Z30500).



## **Wrought Zinc Alloys**

Zinc alloys are rolled to strip, sheet, and foil which can be subsequently formed by deep drawing, spinning, roll forming, coining, and impact extrusion. A number of zinc alloys are applied in wrought form, including alloys containing small amounts of copper (UNS Z40330 and Z44330), copper plus titanium (UNS Z41320), or lead and cadmium (UNS Z21210, Z21220, and Z21540). Wrought zinc is used in roofing and flashing, and after forming as dry cell battery cans, cups, cases, gaskets, and other electrical and hardware components. An alloy of zinc containing approximately 22%Al has superplastic forming properties, which can be removed by a subsequent heat treatment, permitting complex forming operations followed by strengthening.

Zinc can be formed into rod and then drawn into wire, for example for use in thermal spray applications (metallizing). Forged zinc alloys include Korloy 2573, which contains 15%Al, and a zinc-copper-titanium alloy (Korloy 3130).

| <b>SAE/AMS SPECIFICATIONS - SOLDER, BABBITT &amp; LEAD ALLOYS</b> |                                                                                                              |
|-------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                        | <b>Title</b>                                                                                                 |
| 4750                                                              | Solder, Tin-Lead, UNS L54950                                                                                 |
| 4751                                                              | Solder, Tin-Lead, Eutectic, 63Sn - 37Pb, UNS L13630                                                          |
| 4755                                                              | Solder, Lead-Silver, 94Pb - 5.5Ag, UNS L50180                                                                |
| 4756                                                              | Solder, 97.5Pb - 1.5Ag - 1Sn, UNS L50131                                                                     |
| 4800                                                              | Bearings, Babbitt, 91Sn - 4.5Sb - 4.5Cu, UNS L13910                                                          |
| 7721                                                              | Lead Alloy, Sheet and Extrusions, Special Property Material, 93Pb - 6.5Sb - 0.5Sn, As Fabricated, UNS L53131 |

| <b>ASTM SPECIFICATIONS - LEAD, TIN &amp; ZINC ALLOYS</b> |                                                                  |
|----------------------------------------------------------|------------------------------------------------------------------|
| <b>ASTM</b>                                              | <b>Title</b>                                                     |
| <b>Lead &amp; Tin Alloys</b>                             |                                                                  |
| B 23                                                     | White Metal Bearing Alloys (Known Commercially as Babbitt Metal) |
| B 29                                                     | Pig Lead                                                         |
| B 32                                                     | Solder Metal                                                     |
| B 102                                                    | Lead- and Tin-Alloy Die Castings                                 |
| B 339                                                    | Pig Tin                                                          |
| B 560                                                    | Modern Pewter Alloys                                             |
| B 749                                                    | Lead and Lead Alloy Strip, Sheet, and Plate Products             |
| B 774                                                    | Low Melting Point Alloys                                         |
| <b>Zinc &amp; Zinc Alloys</b>                            |                                                                  |
| B 6                                                      | Zinc                                                             |
| B 69                                                     | Rolled Zinc                                                      |
| B 86                                                     | Zinc-Alloy Die Castings                                          |
| B 240                                                    | Zinc Alloys in Ingot Form for Die Castings                       |
| B 327                                                    | Aluminum-Alloy Hardeners Used in Making Zinc Die-Casting Alloys  |
| B 418                                                    | Cast and Wrought Galvanic Zinc Anodes                            |
| B 669                                                    | Zinc-Aluminum Alloys in Ingot Form for Foundry and Die Castings  |

| <b>ASTM SPECIFICATIONS - LEAD, TIN &amp; ZINC ALLOYS (Continued)</b> |                                                                                   |
|----------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| <b>ASTM</b>                                                          | <b>Title</b>                                                                      |
| <b>Zinc &amp; Zinc Alloys (Continued)</b>                            |                                                                                   |
| B 750                                                                | Zinc-5% Aluminum-Mischmetal Alloy (UNS Z38510) in Ingot Form for Hot-Dip Coatings |
| B 791                                                                | Zinc-Aluminum Alloy Foundry and Die Castings                                      |
| B 792                                                                | Zinc Alloys in Ingot Form for Slush Casting                                       |
| B 793                                                                | Zinc Casting Alloy Ingot for Sheet Metal Forming Dies                             |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - LEAD, TIN &amp; ZINC ALLOYS</b> |            |                 |                 |            |                 |
|-------------------------------------------------------------------------------|------------|-----------------|-----------------|------------|-----------------|
| <b>UNS</b>                                                                    | <b>AMS</b> | <b>ASTM</b>     | <b>FED</b>      | <b>SAE</b> | <b>MIL SPEC</b> |
| <b>Lead &amp; Tin Alloys</b>                                                  |            |                 |                 |            |                 |
| L01900                                                                        | ---        | B 440           | ---             | ---        | ---             |
| L05120                                                                        | ---        | ---             | QQ-T-390        | ---        | ---             |
| L13008                                                                        | ---        | B 339 (A)       | ---             | ---        | ---             |
| L13600                                                                        | ---        | ---             | QQ-S-571 (Sn60) | ---        | ---             |
| L13630                                                                        | 4751       | B 32 (Sn63)     | QQ-S-571 (Sn63) | ---        | ---             |
| L13650                                                                        | ---        | B 102 (PY1815A) | ---             | ---        | ---             |
| L13700                                                                        | ---        | B 32 (Sn70)     | QQ-S-571 (Sn70) | ---        | ---             |
| L13820                                                                        | ---        | B 102 (YC135A)  | ---             | ---        | ---             |
| L13840                                                                        | ---        | B 23 (3)        | QQ-T-390        | ---        | ---             |
| L13870                                                                        | ---        | B 23 (11)       | ---             | ---        | ---             |
| L13890                                                                        | ---        | B 23 (2)        | QQ-T-390        | ---        | ---             |
| L13910                                                                        | 4800       | B 23 (1)        | QQ-T-390        | ---        | ---             |
| L13911                                                                        | ---        | B 560 (1)       | ---             | ---        | ---             |
| L13912                                                                        | ---        | B 560 (2)       | ---             | ---        | ---             |
| L13913                                                                        | ---        | B 102 (CY44A)   | ---             | ---        | ---             |
| L13940                                                                        | ---        | ---             | QQ-S-571 (Sb5)  | ---        | ---             |
| L13950                                                                        | ---        | B 32 (Sb5)      | ---             | ---        | ---             |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - LEAD, TIN & ZINC ALLOYS (Continued) |      |                                   |                            |               |          |
|--------------------------------------------------------------------------------|------|-----------------------------------|----------------------------|---------------|----------|
| UNS                                                                            | AMS  | ASTM                              | FED                        | SAE           | MIL SPEC |
| <b>Lead &amp; Tin Alloys (Continued)</b>                                       |      |                                   |                            |               |          |
| L13961                                                                         | ---  | ---                               | QQ-S-571 (Sn96)            | ---           | ---      |
| L13963                                                                         | ---  | B 560 (3)                         | ---                        | ---           | ---      |
| L50042                                                                         | ---  | B 29 (Corroding Lead); B 749      | ---                        | ---           | ---      |
| L50045                                                                         | ---  | B 29 (Common Lead)                | ---                        | ---           | ---      |
| L50050                                                                         | ---  | ---                               | QQ-L-171                   | ---           | ---      |
| L50065                                                                         | ---  | ---                               | QQ-C-40 (AA, C)            | ---           | ---      |
| L50070                                                                         | ---  | ---                               | QQ-L-201                   | ---           | ---      |
| L50080                                                                         | ---  | ---                               | QQ-L-171                   | ---           | ---      |
| L50132                                                                         | ---  | B 32 (Ag1.5)                      | QQ-S-571 (Ag 1.5)          | ---           | ---      |
| L50151                                                                         | ---  | B 32 (Ag2.5)                      | QQ-S-571 (Ag2.5)           | ---           | ---      |
| L51120                                                                         | ---  | B 29 (Chemical lead); B749        | ---                        | ---           | ---      |
| L51121                                                                         | ---  | B 29 (Copper Bearing Lead); B 749 | QQ-L-171 (C); QQ-L-201 (C) | ---           | ---      |
| L51123                                                                         | ---  | B 749                             | QQ-L-201 (D)               | ---           | ---      |
| L51124                                                                         | ---  | ---                               | QQ-C-40 (D)                | ---           | ---      |
| L51180                                                                         | ---  | ---                               | ---                        | J460, No. 485 | ---      |
| L53131                                                                         | 7721 | ---                               | ---                        | ---           | ---      |
| L53340                                                                         | ---  | B 102 (Y10A)                      | ---                        | ---           | ---      |
| L53345                                                                         | ---  | ---                               | ---                        | J460 (13)     | ---      |
| L53346                                                                         | ---  | B 23 (13)                         | ---                        | ---           | ---      |
| L53560                                                                         | ---  | B 102 (YT155A)                    | ---                        | ---           | ---      |
| L53565                                                                         | ---  | B 23 (8)                          | ---                        | ---           | ---      |
| L53585                                                                         | ---  | B 23 (7)                          | ---                        | ---           | ---      |
| L53620                                                                         | ---  | B 23 (15)                         | ---                        | ---           | ---      |
| L54210                                                                         | ---  | B 32 (Sn2)                        | ---                        | ---           | ---      |
| L54250                                                                         | ---  | ---                               | ---                        | J473 (No. 9B) | ---      |
| L54322                                                                         | ---  | B 32 (Sn5)                        | QQ-S-571 (Sn5)             | ---           | ---      |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - LEAD, TIN &amp; ZINC ALLOYS (Continued)</b> |            |                 |                 |               |                 |
|-------------------------------------------------------------------------------------------|------------|-----------------|-----------------|---------------|-----------------|
| <b>UNS</b>                                                                                | <b>AMS</b> | <b>ASTM</b>     | <b>FED</b>      | <b>SAE</b>    | <b>MIL SPEC</b> |
| <b>Lead &amp; Tin Alloys (Continued)</b>                                                  |            |                 |                 |               |                 |
| L54370                                                                                    | ---        | ---             | ---             | J460, No. 190 | ---             |
| L54510                                                                                    | ---        | ---             | ---             | J460, No. 19  | ---             |
| L54520                                                                                    | ---        | B 32 (Sn10A)    | ---             | ---           | ---             |
| L54525                                                                                    | ---        | B 32 (Sn10B)    | QQ-S-571 (Sn10) | ---           | ---             |
| L54555                                                                                    | ---        | ---             | ---             | J473 (No. 6B) | ---             |
| L54560                                                                                    | ---        | B 32 (Sn15)     | ---             | ---           | ---             |
| L54610                                                                                    | ---        | ---             | ---             | J473 (No. 5B) | ---             |
| L54711                                                                                    | ---        | B 32 (Sn20A)    | QQ-S-571 (Pb80) | ---           | ---             |
| L54712                                                                                    | ---        | B 32 (Sn20B)    | QQ-S-571 (Sn20) | ---           | ---             |
| L54721                                                                                    | ---        | B 32 (Sn25A)    | ---             | ---           | ---             |
| L54722                                                                                    | ---        | B 32 (Sn 25B)   | ---             | ---           | ---             |
| L54815                                                                                    | ---        | ---             | ---             | J473 (No. 3B) | ---             |
| L54821                                                                                    | ---        | B 32 (Sn30A)    | QQ-S-571 (Pb70) | ---           | ---             |
| L54822                                                                                    | ---        | B 32 (Sn30B)    | QQ-S-571 (Sn30) | ---           | ---             |
| L54851                                                                                    | ---        | B 32 (Sn35A)    | QQ-S-571 (Pb65) | ---           | ---             |
| L54852                                                                                    | ---        | B 32 (Sn35B)    | QQ-S-571 (Sn35) | ---           | ---             |
| L54905                                                                                    | ---        | ---             | ---             | J473 (No. 2B) | ---             |
| L54915                                                                                    | ---        | B 32 (Sn40A)    | ---             | ---           | ---             |
| L54916                                                                                    | ---        | ---             | QQ-S-571 (Sn40) | ---           | ---             |
| L54918                                                                                    | ---        | B 32 (Sn40B)    | ---             | ---           | ---             |
| L54935                                                                                    | ---        | B 774 (291-325) | ---             | ---           | ---             |
| L54940                                                                                    | ---        | ---             | ---             | J473 (No. 1B) | ---             |
| L54950                                                                                    | 4750       | ---             | ---             | ---           | ---             |
| L54951                                                                                    | ---        | B 32 (Sn45)     | ---             | ---           | ---             |
| L55031                                                                                    | ---        | B 32 (Sn50)     | QQ-S-571 (Sn50) | ---           | ---             |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - LEAD, TIN &amp; ZINC ALLOYS (Continued)</b> |            |                              |            |              |                 |
|-------------------------------------------------------------------------------------------|------------|------------------------------|------------|--------------|-----------------|
| <b>UNS</b>                                                                                | <b>AMS</b> | <b>ASTM</b>                  | <b>FED</b> | <b>SAE</b>   | <b>MIL SPEC</b> |
| <b>Zinc &amp; Zinc Alloys</b>                                                             |            |                              |            |              |                 |
| Z13000                                                                                    | ---        | B 418 (Zinc Anodes Type II)  | ---        | ---          | ---             |
| Z13001                                                                                    | ---        | B 6 (Special High Grade)     | ---        | ---          | ---             |
| Z15001                                                                                    | ---        | B 6 (High Grade)             | ---        | ---          | ---             |
| Z19001                                                                                    | ---        | B 6 (Prime Western)          | ---        | ---          | ---             |
| Z21210                                                                                    | ---        | B 69 (Zn-0.08Pb)             | ---        | ---          | ---             |
| Z21220                                                                                    | ---        | B 69 (Zn-0.06Pb-0.06Cd)      | ---        | ---          | ---             |
| Z21540                                                                                    | ---        | B 69 (Zn-0.3Pb-0.3Cd)        | ---        | ---          | ---             |
| Z30500                                                                                    | ---        | B 792                        | ---        | ---          | ---             |
| Z32120                                                                                    | ---        | B 418 (Zinc Anodes - Type I) | ---        | ---          | ---             |
| Z32121                                                                                    | ---        | ---                          | ---        | ---          | MIL-A-18001     |
| Z33520                                                                                    | 4803       | B 86 (AG40A)                 | QQ-Z-363   | J468 (903) ( | ---             |
| Z33521                                                                                    | ---        | B 240 (AG40A)                | ---        | J468 (903)   | ---             |
| Z33522                                                                                    | ---        | B 240                        | ---        | ---          | ---             |
| Z33523                                                                                    | ---        | B 86                         | ---        | ---          | ---             |
| Z34510                                                                                    | ---        | B 792                        | ---        | ---          | ---             |
| Z35530                                                                                    | ---        | B 240                        | ---        | J468 (925)   | ---             |
| Z35531                                                                                    | ---        | B 86                         | QQ-Z-363   | J468 (925)   | ---             |
| Z35540                                                                                    | ---        | B 240                        | ---        | ---          | ---             |
| Z35541                                                                                    | ---        | B 86 (AC43A)                 | ---        | ---          | ---             |
| Z35542                                                                                    | ---        | B 793                        | ---        | J469 (921)   | MIL-I-7068 (II) |
| Z35543                                                                                    | ---        | B 793                        | ---        | ---          | MIL-I-7068 (I)  |
| Z35630                                                                                    | ---        | B 669 (ZA-12)                | ---        | ---          | ---             |
| Z35631                                                                                    | ---        | B 791                        | ---        | ---          | ---             |
| Z35635                                                                                    | ---        | B 669 (ZA-8)                 | ---        | ---          | ---             |
| Z35636                                                                                    | ---        | B 791                        | ---        | ---          | ---             |
| Z35840                                                                                    | ---        | B 669 (ZA-27)                | ---        | ---          | ---             |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - LEAD, TIN &amp; ZINC ALLOYS (Continued)</b> |            |                        |            |            |                 |
|-------------------------------------------------------------------------------------------|------------|------------------------|------------|------------|-----------------|
| <b>UNS</b>                                                                                | <b>AMS</b> | <b>ASTM</b>            | <b>FED</b> | <b>SAE</b> | <b>MIL SPEC</b> |
| <b>Zinc &amp; Zinc Alloys (Continued)</b>                                                 |            |                        |            |            |                 |
| Z35841                                                                                    | ---        | B 791                  | ---        | ---        | ---             |
| Z38510                                                                                    | ---        | B 750                  | ---        | ---        | ---             |
| Z40330                                                                                    | ---        | B 69 (Zn-0.8Cu)        | ---        | ---        | ---             |
| Z41320                                                                                    | ---        | B 69 (Zn-0.8Cu-0.15Ti) | ---        | ---        | ---             |
| Z44330                                                                                    | ---        | B 69 (Zn-1Cu)          | ---        | ---        | ---             |
| Z45330                                                                                    | ---        | B 69 (Zn-1Cu-0.01Mg)   | ---        | ---        | ---             |

a. This cross-reference table lists the basic specification or standard number, and since these standards are constantly being revised, it should be kept in mind that they are presented herein as a guide and may not reflect the latest revision.

| <b>COMMON NAMES OF LEAD &amp; TIN ALLOYS WITH UNS No.</b> |                                            |            |                               |
|-----------------------------------------------------------|--------------------------------------------|------------|-------------------------------|
| <b>UNS</b>                                                | <b>Common Name</b>                         | <b>UNS</b> | <b>Common Name</b>            |
| L05120                                                    | Bearing Alloy White Metal (Babbitt Metal)  | L53131     | Lead Alloy                    |
| L13840                                                    | Bearing Alloy White Metal (Babbitt Metal)  | L51123     | Lead Alloy Grade D            |
| L13870                                                    | Bearing Alloy White Metal (Babbitt Metal)  | L51124     | Lead Alloy Grade D            |
| L13910                                                    | Bearing Alloy, White Metal (Babbitt Metal) | L13963     | Pewter, Modern                |
| L13890                                                    | Bearing Alloy, White Metal (Babbitt Metal) | L13911     | Pewter Casting Alloys, Modern |
| L53345                                                    | Bearing Alloy, Lead-Base                   | L13912     | Pewter Sheet Alloy, Modern    |
| L53346                                                    | Bearing Alloy, Lead-Base                   | L13008     | Pig Tin                       |
| L53565                                                    | Bearing Alloy, White Metal , Lead-Base     | L54905     | Solder Alloy, Antimonial      |
| L53585                                                    | Bearing Alloy, White Metal , Lead-Base     | L54250     | Solder Alloy                  |
| L53620                                                    | Bearing Alloy, Lead-Base                   | L54555     | Solder Alloy                  |
| L51180                                                    | Bearing Alloy, Copper-Lead                 | L54610     | Solder Alloy                  |
| L54370                                                    | Bearings, Plated Overlay for               | L54815     | Solder Alloy                  |
| L54510                                                    | Bearings, Plated Overlay for               | L54821     | Solder Alloy                  |
| L53340                                                    | Die Casting Alloy, Lead-Base               | L54822     | Solder Alloy                  |

| COMMON NAMES OF LEAD & TIN ALLOYS WITH UNS No. (Continued) |                              |        |                       |
|------------------------------------------------------------|------------------------------|--------|-----------------------|
| UNS                                                        | Common Name                  | UNS    | Common Name           |
| L53560                                                     | Die Casting Alloy, Lead-Base | L54851 | Solder Alloy          |
| L54935                                                     | Fusible Alloy                | L54852 | Solder Alloy          |
| L50042                                                     | Lead, Corroding              | L54916 | Solder Alloy          |
| L50045                                                     | Lead, Common                 | L54918 | Solder Alloy          |
| L50050                                                     | Lead, Grade A                | L54940 | Solder Alloy          |
| L50065                                                     | Lead, Grade AA, or Grade C   | L54951 | Solder Alloy          |
| L50070                                                     | Lead, Remelted, Grade B      | L55031 | Solder Alloy          |
| L50080                                                     | Lead, Grade B                | L54711 | Solder Alloy 20B      |
| L51120                                                     | Lead, Chemical               | L54712 | Solder Alloy 20C      |
| L51121                                                     | Lead, Copper Bearing         | L54721 | Solder Alloy 25B      |
| L54722                                                     | Solder Alloy 25C             | L54915 | Solder, 40/60         |
| L50131                                                     | Solder Alloy-Grade 1.5S      | L54950 | Solder, 45/55         |
| L50150                                                     | Solder Alloy-Grade 2.5S      | L55030 | Solder, 50/50         |
| L50132                                                     | Solder Alloy-Grade Ag1.5     | L13600 | Solder, Tin-Lead      |
| L50151                                                     | Solder Alloy-Grade Ag2.5     | L13601 | Solder, Tin-Lead      |
| L50180                                                     | Solder Alloy-Grade Ag5.5     | L13630 | Solder, Tin-Lead      |
| L54210                                                     | Solder, 2% Tin               | L13631 | Solder, Tin-Lead      |
| L54211                                                     | Solder, 2% Tin Antimonial    | L13700 | Solder, Tin-Lead      |
| L54320                                                     | Solder, 5/95                 | L13701 | Solder, Tin-Lead      |
| L54321                                                     | Solder, 5% Tin Antimonial    | L13940 | Solder, Tin-Antimony  |
| L54322                                                     | Solder, SN5                  | L13950 | Solder, Tin-Antimony  |
| L54520                                                     | Solder, 10/90                | L13960 | Solder, Tin-Silver    |
| L54525                                                     | Solder, 88-10-2              | L13961 | Solder, Tin-Silver    |
| L54560                                                     | Solder, 15/85                | L13965 | Solder, Tin-Silver    |
| L54720                                                     | Solder, 25/75                | L13650 | Tin Die Casting Alloy |
| L54820                                                     | Solder, 30/70                | L13820 | Tin Die Casting Alloy |
| L54850                                                     | Solder, 35/65                | L13913 | Tin Die-Casting Alloy |



| <b>COMMON NAMES OF ZINC &amp; ZINC ALLOYS WITH UNS No.</b> |                                |            |                                           |
|------------------------------------------------------------|--------------------------------|------------|-------------------------------------------|
| <b>UNS</b>                                                 | <b>Common Name</b>             | <b>UNS</b> | <b>Common Name</b>                        |
| Z13000                                                     | Zinc Anodes (Type II)          | Z35531     | Zinc Alloy (AC41A) Die Casting            |
| Z13001                                                     | Zinc Metal                     | Z35540     | Zinc Alloy (AC43A) Ingot Form             |
| Z15001                                                     | Zinc Metal                     | Z35541     | Zinc Alloy (AC43A) Die Casting            |
| Z19001                                                     | Zinc Metal                     | Z35542     | Zinc Alloy (Kirkcote II or B) Forming Die |
| Z21210                                                     | Zinc Rolled                    | Z35543     | Zinc Alloy (Kirkcote I or A) Forming Die  |
| Z21220                                                     | Zinc Alloy Rolled              | Z35630     | Zinc-Aluminum Alloy (ZA-12) Ingot Form    |
| Z21540                                                     | Zinc Alloy Rolled              | Z35631     | Zinc-Aluminum Alloy (ZA-12) Casting       |
| Z30500                                                     | Zinc Alloy (B) Slush Casting   | Z35635     | Zinc-Aluminum Alloy (ZA-8) Ingot Form     |
| Z32120                                                     | Zinc Anodes (Type I)           | Z35636     | Zinc-Aluminum Alloy (ZA-8) Casting        |
| Z32121                                                     | Zinc Anodes (Type III)         | Z35840     | Zinc-Aluminum Alloy (ZA-27) Ingot Form    |
| Z33520                                                     | Zinc Alloy (AG40A) Die Casting | Z35841     | Zinc-Aluminum Alloy (ZA-27) Casting       |
| Z33521                                                     | Zinc Alloy (AG40A) Ingot Form  | Z38510     | Zinc Alloy Ingot Form                     |
| Z33522                                                     | Zinc Alloy (AG40B) Ingot Form  | Z40330     | Zinc Alloy, Rolled                        |
| Z33523                                                     | Zinc Alloy (AG40B) Die Casting | Z41320     | Zinc Alloy, Rolled                        |
| Z34510                                                     | Zinc Alloy (A) Slush Casting   | Z44330     | Zinc Alloy, Rolled                        |
| Z35530                                                     | Zinc Alloy (AC41A) Ingot Form  | Z45330     | Zinc Alloy, Rolled                        |

| <b>CHEMICAL COMPOSITION OF LEAD &amp; TIN ALLOYS</b> |                                                                                                                                                               |
|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                           | <b>Chemical Composition</b>                                                                                                                                   |
| L01900                                               | Cd 99.90 min Ag 0.01 max As 0.003 max Cu 0.015 max Pb 0.025 max Sb 0.001 max Sn 0.01 max Zn 0.035 max Other Ti 0.003 max                                      |
| L05120                                               | Pb 83.0-88.0 Al 0.005 max As 0.20 max Cu 0.50 max Fe 0.10 max Sb 8.0-10.0 Sn 4.0-6.0 Zn 0.005 max Other total 0.75 max                                        |
| L13008                                               | Sn 99.80 min As 0.05 max Bi 0.015 max Cd 0.001 max Cu 0.04 max Fe 0.015 max Fe 0.015 max Pb 0.05 max S 0.01 max Sb 0.04 max Zn 0.005 max Other Ni+Co 0.01 max |
| L13600                                               | Sn 60 nom Pb 40 nom Al 0.005 max As 0.03 max Bi 0.25 max Co 0.08 max Fe 0.02 max Sb 0.12 max Zn 0.005 max                                                     |
| L13601                                               | Sn 60 nom Pb 40 nom Al 0.005 max As 0.03 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20-0.50 Zn 0.005 max                                                    |
| L13630                                               | Sn 63 nom Pb 37 nom Al 0.005 max As 0.03 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.12 max Zn 0.005 max                                                     |

| CHEMICAL COMPOSITION OF LEAD & TIN ALLOYS (Continued) |                                                                                                                                                                         |
|-------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                   | Chemical Composition                                                                                                                                                    |
| L13631                                                | Sn 63 nom Pb 37 nom Al 0.005 max As 0.03 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20-0.50 Zn 0.005 max                                                              |
| L13650                                                | Sn 64-66 Pb 17-19 Al 0.01 max As 0.15 max Cu 1.5-2.5 Fe 0.08 max Sb 14-16 Zn 0.01 max                                                                                   |
| L13700                                                | Sn 70 nom Pb 30 nom Al 0.005 max As 0.003 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20 nom Zn 0.005 max                                                              |
| L13701                                                | Sn 70 nom Pb 30 nom Al 0.005 max As 0.03 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20-0.50 Zn 0.005 max                                                              |
| L13820                                                | Sn 80-84 Sb 12-14 Al 0.01 max As 0.08 max Cu 4-6 Fe 0.08 max Pb 0.35 max Zn 0.01 max                                                                                    |
| L13840                                                | Sn 83.0-85.0 Sb 7.5-8.5 Al 0.005 max As 0.10 max Bi 0.08 max Cd 0.05 max Cu 7.5-8.5 Fe 0.08 max Pb 0.35 max Zn 0.005 max                                                |
| L13870                                                | Sn 86.0-89.0 Sb 6.0-7.5 Al 0.005 max As 0.10 max Bi 0.08 max Cd 0.05 max Cu 5.0-6.5 Fe 0.08 max Pb 0.50 max Zn 0.005 max                                                |
| L13890                                                | Sn 88.0-90.0 Sb 7.0-8.0 Al 0.005 max As 0.10 max Bi 0.08 max Cd 0.05 max Cu 3.0-4.0 Fe 0.08 max Pb 0.35 max Zn 0.005 max                                                |
| L13910                                                | Sn 90.0-92.0 Sb 4.0-5.0 Al 0.005 max As 0.10 max Bi 0.08 max Cd 0.05 max Cu 4.0-5.0 Fe 0.08 max Pb 0.35 max Zn 0.005 max                                                |
| L13911                                                | Sn 90-93 Sb 6-8 As 0.05 max Cu 0.25-2.0 Fe 0.015 max Pb 0.05 max Zn 0.005 max                                                                                           |
| L13912                                                | Sn 90-93 Sb 5-7.5 As 0.05 max Cu 1.5-3.0 Fe 0.015 max Pb 0.05 max Zn 0.005 max                                                                                          |
| L13913                                                | Sn 90-92 Sb 4-5 Al 0.01 max As 0.08 max Cu 4-5 Fe 0.08 max Pb 0.35 max Zn 0.01 max                                                                                      |
| L13940                                                | Sn 94 min Sb 4.0-6.0 Al 0.03 max As 0.06 max Cd 0.03 max Cu 0.08 max Fe 0.08 max Pb 0.20 max Zn 0.03 max Other total 0.03 max                                           |
| L13950                                                | Sn 95 nom Sb 4.5-5.5 Al 0.005 max As 0.05 max Bi 0.15 max Cu 0.08 max Fe 0.04 max Pb 0.20 max Zn 0.005 max                                                              |
| L13960                                                | Sn 96 nom Ag 3.6-4.4 Al 0.005 max As 0.05 max Bi 0.15 max Cu 0.08 max Fe 0.02 max Pb 0.20 max Sb 0.20-0.50 Zn 0.005 max                                                 |
| L13961                                                | Sn rem Ag 3.6-4.4 As 0.05 max Cd 0.005 max Cu 0.20 max Pb 0.10 max Zn 0.005 max                                                                                         |
| L13963                                                | Sn 95-98 As 0.05 max Cu 1.0-2.0 Fe 0.015 max Pb 0.05 max Sb 1.0-3.0 Zn 0.005 max                                                                                        |
| L13965                                                | Sn 96.5 nom Ag 3.3-3.7 Al 0.005 max As 0.05 max Bi 0.15 max Cu 0.08 max Fe 0.02 max Pb 0.20 max Sb 0.20-0.50 Zn 0.005 max                                               |
| L50042                                                | Pb 99.94 min Ag 0.0015 max Bi 0.050 max Cu 0.0015 max Fe 0.002 max Zn 0.001 max Other Cu+Ag 0.0025 max, As+Sb+Sn 0.002 max                                              |
| L50045                                                | Pb 99.94 min Ag 0.005 max Bi 0.050 max Cu 0.0015 max Fe 0.002 max Zn 0.001 max Other As+Sb+Sn 0.002 max                                                                 |
| L50050                                                | Pb 99.90 min Other total other elements 0.10 max                                                                                                                        |
| L50065                                                | Pb 99.7 min Sb 0.02 max                                                                                                                                                 |
| L50070                                                | Pb 39.5 min Bi 0.025 max (Optional)                                                                                                                                     |
| L50080                                                | Pb 95.0 min Other total other elements 5.0 max                                                                                                                          |
| L50131                                                | Pb 97.5 nom As 1.3-1.7 Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sn 0.75-1.25 Zn 0.005 max                                                           |
| L50132                                                | Pb rem Ag 1.3-1.7 Al 0.005 max As 0.02 max Bi 0.25 max Cd 0.001 max Cu 0.30 max Fe 0.02 max Sb 0.40 max Sn 0.75-1.25 Zn 0.005 max<br>Other total of all others 0.08 max |

| <b>CHEMICAL COMPOSITION OF LEAD &amp; TIN ALLOYS (Continued)</b> |                                                                                                                                                                                                               |
|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                       | <b>Chemical Composition</b>                                                                                                                                                                                   |
| L50150                                                           | Pb 97.5 nom Ag 2.3-2.7 Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sn 0.25 max Zn 0.005 max                                                                                                  |
| L50151                                                           | Pb rem Ag 2.3-2.7 Al 0.005 max As 0.02 max Bi 0.25 max Cd 0.001 max Cu 0.30 max Fe 0.02 max Sb 0.40 max Sn 0.25 max Zn 0.005 max<br>Other total of all others 0.03 max                                        |
| L50180                                                           | Pb rem Ag 5.0-6.0 Al 0.005 max As 0.02 max Bi 0.25 max Cd 0.001 max Cu 0.30 max Fe 0.002 max Cd 0.001 max Cu 0.30 max Fe 0.002 max<br>Sb 0.40 max Sn 0.25 max Zn 0.005 max Other total of all others 0.03 max |
| L51120                                                           | Pb 99.90 min Ag 0.002-0.02 Bi 0.005 max Cu 0.04-0.08 Fe 0.002 max Zn 0.001 max Other As+Sb+Sn 0.002 max                                                                                                       |
| L51121                                                           | Pb 99.90 min Ag 0.020 max Bi 0.025 max Cu 0.04 -0.08 Fe 0.002 max Zn 0.001 max Other As+Sb+Sn 0.002 max                                                                                                       |
| L51123                                                           | Pb 99.85 min Ag 0.020 max Bi 0.025 max Cu 0.04-0.08 Fe 0.002 max Te 0.035-0.060 Zn 0.001 max Other As+Sb+Sn 0.002 max                                                                                         |
| L51124                                                           | Pb 99.82 min Ag 0.020 max Bi 0.025 max Cu 0.04-0.08 Fe 0.002 max Sn 0.016 max Te 0.035-0.055 Zn 0.001 max Other Sb+As 0.002 max                                                                               |
| L51180                                                           | Cu rem Fe 0.35 max Pb 44.0-58.0 Sn 1.0-5.0 Other total of others 0.45 max, others, each 0.15 max                                                                                                              |
| L53131                                                           | Pb rem Sb 6.0-7.0 Sn 0.25-0.75                                                                                                                                                                                |
| L53340                                                           | Pb 89-91 Sb 9.25-10.75 As 0.15 max Cu 0.50 max Zn 0.01 max                                                                                                                                                    |
| L53345                                                           | Pb rem Sb 9.0-11.0 Sn 5.0-7.0 Al 0.005 max As 0.25 max Bi 0.10 max Cd 0.05 max Cu 0.50 max Zn 0.005 max Other total of others 0.20 max                                                                        |
| L53346                                                           | Pb rem Sb 9.5-10.5 Sn 5.5-6.5 Al 0.005 max As 0.25 max Bi 0.10 max Cd 0.05 max Cu 0.50 max Fe 0.10 max Zn 0.005 max                                                                                           |
| L53560                                                           | Pb 79-81 Sb 14-16 Sn 4-6 Al 0.01 max As 0.15 max Cu 0.50 max Zn 0.01 max                                                                                                                                      |
| L53565                                                           | Pb rem Sb 14.0-16.0 Sn 4.5-5.5 Al 0.005 max As 0.30-0.60 Bi 0.10 max Cd 0.05 max Cu 0.50 max Fe 0.10 max Zn 0.005 max                                                                                         |
| L53585                                                           | Pb rem Sb 14.0-16.0 Sn 9.3-10.7 Al 0.005 max As 0.30-0.60 Bi 0.10 max Cd 0.05 max Cu 0.50 max Fe 0.10 max Zn 0.005 max                                                                                        |
| L53620                                                           | Pb rem Sb 14.5-17.5 Sn 0.8-1.2 Al 0.005 max As 0.8-1.4 Bi 0.10 max Cd 0.05 max Cu 0.6 max Fe 0.10 max Zn 0.005 max                                                                                            |
| L54210                                                           | Pb 98 nom Sb 0.12 max Sn 1.5-2.5 Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Zn 0.005 max                                                                                                    |
| L54211                                                           | Pb 98 nom Sb 0.20-0.50 Sn 1.5-2.5 Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Zn 0.005 max                                                                                                   |
| L54250                                                           | Pb rem Sb 4.90-5.40 Sn 2.50-2.75 Al 0.005 max As 0.40-0.60 Bi 0.25 max Cu 0.08 max Fe 0.02 max Zn 0.005 max<br>Other other elements, total 0.08 max                                                           |
| L54320                                                           | Pb 95 nom Sn 4.5-5.5 Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.12 max Zn 0.005 max                                                                                                    |
| L54321                                                           | Pb 95 nom Sn 4.5-5.5 Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20-0.50 Zn 0.005 max                                                                                                   |
| L54322                                                           | Pb rem Sn 4.5-5.5 Ag 0.015 max Al 0.005 max As 0.02 max Bi 0.25 max Cd 0.001 max Cu 0.08 max Fe 0.02 max Sb 0.50 max Zn 0.005 max<br>Other total of all others 0.08 max                                       |
| L54370                                                           | Pb rem Sn 5.0-9.0 Other other elements, total 3.5 max                                                                                                                                                         |

| CHEMICAL COMPOSITION OF LEAD & TIN ALLOYS (Continued) |                                                                                                                                                            |
|-------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| UNS                                                   | Chemical Composition                                                                                                                                       |
| L54510                                                | Pb rem Sn 8.0-12.0 Other other elements, total 3.5 max                                                                                                     |
| L54520                                                | Pb 90 nom Sn 10 nom Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20-0.50 Zn 0.005 max                                                 |
| L54525                                                | Pb rem Sn 9.0-11.0 Ag 1.7-2.4 Al 0.005 max As 0.02 max Bi 0.03 max Cd 0.001 max Cu 0.08 max Sb 0.20 max Zn 0.005 max<br>Other total of all others 0.10 max |
| L54555                                                | Pb rem Sn 14.0-15.0 Sb as specified 2.75 max Al 0.005 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Zn 0.005 max<br>Other other elements, total 0.08 max         |
| L54560                                                | Pb 85 nom Sn 15 desired Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20-0.50 Zn 0.005 max                                             |
| L54610                                                | Pb rem Sn 19.0-20.0 Sb 1.25-1.75 Al 0.005 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Zn 0.005 max Other elements, total 0.08 max                              |
| L54711                                                | Pb 80 nom Sn 20 desired Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20-0.50 Zn 0.005 max                                             |
| L54712                                                | Pb 79 nom Sn 20 desired Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.8-1.2 Zn 0.005 max                                               |
| L54720                                                | Pb 75 nom Sn 25 nom Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.25 max Zn 0.005 max                                                  |
| L54721                                                | Pb 75 nom Sn 25 desired Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20-0.50 Zn 0.005 max                                             |
| L54722                                                | Pb 73.7 nom Sn 25 desired Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 1.1-1.5 Zn 0.005 max                                             |
| L54815                                                | Pb rem Sn 29.0-30.0 Al 0.005 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.75-1.25 Zn 0.005 max Other other elements, total 0.08 max                        |
| L54820                                                | Pb 70 nom Sn 30 desired Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.25 max Zn 0.005 max                                              |
| L54821                                                | Pb 70 nom Sn 30 desired Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20-0.50 Zn 0.005 max                                             |
| L54822                                                | Pb 68.4 nom Sn 30 desired Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 1.4-1.8 Zn 0.005 max                                             |
| L54850                                                | Pb 65 nom Sn 35 nom Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.25 max Zn 0.005 max                                                  |
| L54851                                                | Pb 65 nom Sn 35 nom Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20-0.50 Zn 0.005 max                                                 |
| L54852                                                | Pb 63.2 nom Sn 35 nom Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 1.6-2.0 Zn 0.005 max                                                 |
| L54905                                                | Pb rem Sn 38.0-38.5 Al 0.005 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 1.5-2.00 Zn 0.005 max Other other elements, total 0.08 max                         |
| L54915                                                | Pb 60 nom Sn 40 nom Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.12 max Zn 0.005 max                                                  |
| L54916                                                | Pb 60 nom Sn 40 nom Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 0.20-0.50 Zn 0.005 max                                                 |
| L54918                                                | Pb 58 nom Sn 40 nom Al 0.005 max As 0.02 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Sb 1.8-2.4 Zn 0.005 max                                                   |
| L54935                                                | Pb 43 nom Sn 43 nom Bi 14 nom                                                                                                                              |
| L54940                                                | Pb rem Sn 43.0-43.5 Sb 1.5-2.00 Al 0.005 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Zn 0.005 max Other other elements, total 0.08 max                         |
| L54950                                                | Pb 55 nom Sn 45 nom Sb 0.12 max Al 0.005 max As 0.03 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Zn 0.005 max                                                  |

| <b>CHEMICAL COMPOSITION OF LEAD &amp; TIN ALLOYS (Continued)</b> |                                                                                                            |
|------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                       | <b>Chemical Composition</b>                                                                                |
| L54951                                                           | Pb 55 nom Sn 45 nom Sb 0.20-0.50 Al 0.005 max As 0.03 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Zn 0.005 max |
| L55030                                                           | Pb 50 nom Sn 50 nom Sb 0.12 max Al 0.005 max As 0.03 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Zn 0.005 max  |
| L55031                                                           | Pb 50 nom Sn 50 nom Sb 0.20-0.50 Al 0.005 max As 0.03 max Bi 0.25 max Cu 0.08 max Fe 0.02 max Zn 0.005 max |

| <b>CHEMICAL COMPOSITION OF ZINC ALLOYS</b> |                                                                                                                                                         |
|--------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                 | <b>Chemical Composition</b>                                                                                                                             |
| Z13000                                     | Zn rem Al 0.005 max Cd 0.003 max Cu 0.002 max Fe 0.0014 max Pb 0.003 max                                                                                |
| Z13001                                     | Zn 99.99 min Al 0.002 max Cd 0.003 max Cu 0.002 max Fe 0.003 max Pb 0.003 max Sn 0.001 max                                                              |
| Z15001                                     | Zn 99.90 min Al 0.01 max Cd 0.02 max Fe 0.02 max Pb 0.03 max                                                                                            |
| Z19001                                     | Zn 98.0 min Al 0.01 max Cd 0.20 max Cu 0.20 max Fe 0.05 max Pb 0.5-1.4                                                                                  |
| Z21210                                     | Zn rem Al 0.001 max Cd 0.005 max Cu 0.001 max Fe 0.012 max Pb 0.10 max Sn 0.001 max                                                                     |
| Z21220                                     | Zn rem Al 0.001 max Cd 0.05-0.08 Cu 0.005 max Fe 0.012 max Pb 0.05-0.10 Sn 0.001 max                                                                    |
| Z21540                                     | Zn rem Al 0.001 max Cd 0.25-0.45 Cu 0.005 max Fe 0.002 max Pb 0.25-0.50                                                                                 |
| Z30500                                     | Zn rem Al 5.25-5.75 Cd 0.005 max Cu 0.1 max Fe 0.10 max Pb 0.007 max Sn 0.005 max                                                                       |
| Z32120                                     | Zn rem Al 0.10-0.5 Cd 0.025-0.07 Cu 0.005 max Fe 0.005 max Pb 0.006 max Other 0.1 max                                                                   |
| Z32121                                     | Zn rem Al 0.1-0.5 Cd 0.025-0.15 Cu 0.005 max Fe 0.005 max Pb 0.006 max Si 0.125 max                                                                     |
| Z33520                                     | Zn rem Al 3.5-4.3 Cd 0.004 max Cu 0.25 max Fe 0.100 max Mg 0.02-0.05 Pb 0.005 max Sn 0.003 max                                                          |
| Z33521                                     | Zn rem Al 3.9-4.3 Cd 0.003 max Cu 0.10 max Fe 0.075 max Pb 0.004 max Mg 0.025-0.05 Sn 0.002 max                                                         |
| Z33522                                     | Zn rem Al 3.9-4.3 Cd 0.0020 max Cr 0.02 max Cu 0.10 max Fe 0.075 max Mg 0.010-0.020 Mn 0.05 max Ni 0.005-0.020 Pb 0.0020 max Si 0.035 max Sn 0.0010 max |
| Z33523                                     | Zn rem Al 3.5-4.3 Cd 0.0020 max Cr 0.02 max Cu 0.25 max Fe 0.075 max Mg 0.005-0.020 Mn 0.5 max Ni 0.005-0.020 Pb 0.0030 max Si 0.035 max Sn 0.0010 max  |
| Z34510                                     | Zn rem Al 4.5-5.0 Cd 0.005 max Cu 0.2-0.3 Fe 0.100 max Pb 0.007 max Sn 0.005 max                                                                        |
| Z35530                                     | Zn rem Al 3.9-4.3 Cd 0.003 max Cu 0.75-1.25 Fe 0.075 max Pb 0.004 max Mg 0.03-0.06 Sn 0.002 max                                                         |
| Z35531                                     | Zn rem Al 3.5-4.3 Cd 0.004 max Cu 0.75-1.25 Fe 0.100 max Mg 0.03-0.08 Pb 0.005 max Sn 0.003 max                                                         |

| <b>CHEMICAL COMPOSITION OF ZINC ALLOYS (Continued)</b> |                                                                                                                                                                                                              |
|--------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                             | <b>Chemical Composition</b>                                                                                                                                                                                  |
| Z35540                                                 | Zn rem Al 3.9-4.3 Cd 0.003 max Cu 2.6-2.9 Fe 0.075 max Pb 0.004 max Mg 0.025-0.050 Sn 0.002 max                                                                                                              |
| Z35541                                                 | Zn rem Al 3.5-4.3 Cd 0.004 max Cu 2.5-3.0 Fe 0.100 max Mg 0.020-0.050 Pb 0.005 max Sn 0.003 max                                                                                                              |
| Z35542                                                 | Zn rem Al 3.9-4.3 Cd 0.003 max Cu 2.5-2.9 Fe 0.075 max Mg 0.02-0.05 Pb 0.003 max Sn 0.001 max                                                                                                                |
| Z35543                                                 | Zn rem Al 3.5-4.5 Cd 0.005 max Cu 2.5-3.5 Fe 0.100 max Mg 0.02-0.10 Pb 0.007 max Sn 0.005 max                                                                                                                |
| Z35630                                                 | Zn rem Al 10.8-11.5 Cd 0.005 max Cu 0.50-1.2 Fe 0.065 max Mg 0.020-0.030 Pb 0.005 max Sn 0.002 max                                                                                                           |
| Z35631                                                 | Zn rem Al 10.5-11.5 Cd 0.004 max Cu 0.5-1.2 Fe 0.075 max Pb 0.006 max Mg 0.015-0.030 Sn 0.003 max                                                                                                            |
| Z35635                                                 | Zn rem Al 8.2-8.8 Cd 0.005 max Cu 0.8-1.3 Fe 0.10 max Mg 0.020-0.030 Pb 0.005 max Sn 0.002 max                                                                                                               |
| Z35636                                                 | Zn rem Al 8.0-8.8 Cd 0.006 max Cu 0.8-1.3 Fe 0.075 max Pb 0.006 max Mg 0.015-0.030 Sn 0.003 max                                                                                                              |
| Z35840                                                 | Zn rem Al 25.5-28.0 Cd 0.005 max Cu 2.0-2.5 Fe 0.072 max Mg 0.012-0.020 Pb 0.005 max Sn 0.002 max                                                                                                            |
| Z35841                                                 | Zn rem Al 25.0-28.0 Cd 0.006 max Cu 2.0-2.5 Fe 0.075 max Pb 0.006 max Mg 0.010-0.020 Sn 0.003 max                                                                                                            |
| Z38510                                                 | Zn rem Al 4.2-6.2 Cd 0.005 max Cu 0.1 max Fe 0.075 max Mg 0.05 max Pb 0.005 max Sb 0.002 max Si 0.015 max Sn 0.002 max Ti 0.02 max<br>Zr 0.02 max Other Ce+La 0.03-0.10 Other reach 0.02 max, total 0.04 max |
| Z40330                                                 | Zn rem Al 0.005 max Cd 0.02 max Cu 0.70-0.90 Fe 0.01 max Pb 0.02 max Ti 0.02 max                                                                                                                             |
| Z41320                                                 | Zn rem Al 0.001 max Cd 0.05 max Cu 0.50-1.50 Fe 0.012 max Pb 0.10 max Sn 0.001 max Ti 0.12-0.50                                                                                                              |
| Z44330                                                 | Zn rem Al 0.001 max Cd 0.005 max Cu 0.85-1.25 Fe 0.012 max Pb 0.10 max Sn 0.001 max                                                                                                                          |
| Z45330                                                 | Zn rem Al 0.001 max Cd 0.04 max Cu 0.85-1.25 Fe 0.015 max Mg 0.006-0.016 Pb 0.15 max Sn 0.001 max                                                                                                            |

| <b>PHYSICAL PROPERTIES OF WHITE METAL BEARING ALLOYS - ASTM B 23</b> |                                                     |                     |                     |                     |                                                             |                     |                      |                      |                                     |                        |
|----------------------------------------------------------------------|-----------------------------------------------------|---------------------|---------------------|---------------------|-------------------------------------------------------------|---------------------|----------------------|----------------------|-------------------------------------|------------------------|
| <b>Alloy No.</b>                                                     | <b>Johnson's Apparent Elastic Limit<sup>a</sup></b> |                     |                     |                     | <b>Ultimate Tensile Strength in Compression<sup>b</sup></b> |                     |                      |                      | <b>Brinell Hardness<sup>c</sup></b> |                        |
|                                                                      | <b>psi<br/>68°F</b>                                 | <b>MPa<br/>20°C</b> | <b>psi<br/>68°F</b> | <b>MPa<br/>20°C</b> | <b>psi<br/>68°F</b>                                         | <b>MPa<br/>20°C</b> | <b>psi<br/>212°F</b> | <b>MPa<br/>100°C</b> | <b>68°F<br/>20°C</b>                | <b>212°F<br/>100°C</b> |
| 1                                                                    | 2450                                                | 16.9                | 1050                | 7.2                 | 12 850                                                      | 88.6                | 6950                 | 47.9                 | 17.0                                | 8.0                    |
| 2                                                                    | 3350                                                | 23.1                | 1100                | 7.6                 | 14 900                                                      | 102.7               | 8700                 | 60.0                 | 24.5                                | 12.0                   |
| 3                                                                    | 5350                                                | 36.9                | 1300                | 9.0                 | 17 600                                                      | 121.3               | 9900                 | 68.3                 | 27.0                                | 14.5                   |
| 7                                                                    | 2500                                                | 17.2                | 1350                | 9.3                 | 15 650                                                      | 107.9               | 6150                 | 42.4                 | 22.5                                | 10.5                   |
| 8                                                                    | 2650                                                | 18.3                | 1200                | 8.3                 | 15 600                                                      | 107.6               | 6150                 | 42.4                 | 20.0                                | 9.5                    |
| 15                                                                   | ---                                                 | ---                 | ---                 | ---                 | ---                                                         | ---                 | ---                  | ---                  | 21.0                                | 13.0                   |

- a. Johnson's apparent elastic limit is taken as the unit stress at the point where the slope of the tangent to the curve is 2/3 times its slope at the origin.
- b. The ultimate strength values were taken as the unit load necessary to produce a deformation of 25% of the length of the specimen.
- c. These values are the average Brinell number of three impressions on each alloy using a 10-mm ball and 500-kg load applied for 30 s.

| <b>PHYSICAL PROPERTIES OF WHITE METAL BEARING ALLOYS - ASTM B 23</b> |                      |           |                                             |           |                                   |           |
|----------------------------------------------------------------------|----------------------|-----------|---------------------------------------------|-----------|-----------------------------------|-----------|
| <b>Alloy No.</b>                                                     | <b>Melting Point</b> |           | <b>Temperature of Complete Liquefaction</b> |           | <b>Proper Pouring Temperature</b> |           |
|                                                                      | <b>°F</b>            | <b>°C</b> | <b>°F</b>                                   | <b>°C</b> | <b>°F</b>                         | <b>°C</b> |
| 1                                                                    | 433                  | 223       | 700                                         | 371       | 825                               | 441       |
| 2                                                                    | 466                  | 241       | 669                                         | 354       | 795                               | 424       |
| 3                                                                    | 464                  | 240       | 792                                         | 422       | 915                               | 491       |
| 7                                                                    | 464                  | 240       | 514                                         | 268       | 640                               | 338       |
| 8                                                                    | 459                  | 237       | 522                                         | 272       | 645                               | 341       |
| 15                                                                   | 479                  | 248       | 538                                         | 281       | 662                               | 350       |

| PHYSICAL PROPERTIES OF BULK SOLDERS |                        |                        |                         |                            |                                                                            |          |
|-------------------------------------|------------------------|------------------------|-------------------------|----------------------------|----------------------------------------------------------------------------|----------|
| Alloy Composition <sup>a</sup>      | Melting Temperature °C | Solidus Temperature °C | Liquidus Temperature °C | Density Mg m <sup>-3</sup> | Coefficient of Linear Thermal Expansion x 10 <sup>-6</sup> K <sup>-1</sup> | Hardness |
| 100Sn                               | 231.9                  | ---                    | ---                     | 7.29                       | 23.5                                                                       | 3.9 HB   |
| 99Sn-1Cu                            | ---                    | 227                    | 255                     | 7.31                       | ---                                                                        | 9 HB     |
| 98Sn-2Ag                            | ---                    | 221 <sup>b</sup>       | 230 <sup>b</sup>        | ---                        | ---                                                                        | ---      |
| 97Sn-3Cu                            | ---                    | 227 <sup>b</sup>       | 310                     | 7.34                       | ---                                                                        | 11 HB    |
| 96.5Sn-3.5Ag                        | 221                    | ---                    | ---                     | 10.38                      | ---                                                                        | 14.8 HV  |
| 95Sn-5Sb                            | ---                    | 234                    | 240                     | 7.250                      | ---                                                                        | 15 HB    |
| 60Sn-40Pb                           | ---                    | 183                    | 188                     | 8.520                      | 23.9                                                                       | 16 HV    |
| 50Sn-50Pb                           | ---                    | 183                    | 216                     | 8.89                       | 23.4                                                                       | 14 HV    |
| 42Sn-58Bi                           | 138                    | ---                    | ---                     | 8.72                       | 13.78                                                                      | 22 HB    |
| 40Sn-60Pb                           | ---                    | 183                    | 234                     | 9.280                      | 24.58                                                                      | 12 HV    |
| 10Sn-90Pb                           | ---                    | 268                    | 301                     | 10.50                      | 27.98                                                                      | 10 HV    |
| 62Sn-36Pb-2Ag                       | ---                    | 177                    | 189                     | 8.50                       | 27.0                                                                       | ---      |
| 50Sn-32Pb-18Cd                      | 145                    | ---                    | ---                     | 8.5                        | 13.2                                                                       | 14 HB    |
| 40Sn-58Pb-2Sb                       | ---                    | 185                    | 231                     | 9.23                       | 24.3                                                                       | ---      |
| 34Sn-42Pb-24Bi                      | ---                    | 99.5                   | 146                     | ---                        | ---                                                                        | ---      |
| 5Sn-93.5Pb-1.5Ag                    | ---                    | 296                    | 301                     | 11.10                      | ---                                                                        | ---      |
| 1Sn-97.5Pb-1.5Ag                    | 309                    | ---                    | ---                     | 11.28                      | ---                                                                        | 13 HB    |
| 95Pb-5Ag                            | ---                    | 304                    | 365                     | ---                        | ---                                                                        | ---      |

a. By weight. b. Estimated.



# Chapter 7

## ***PRECIOUS METALS***

The term precious metals is taken to include silver, gold, and the six platinum group metals - platinum, palladium, ruthenium, rhodium, osmium, and iridium. Gold and silver have been known and used for many millennia, as has platinum to a lesser extent. The others are recent discoveries. These metals and their alloys are used in the electronics, jewelry, dentistry, coinage, textile, automotive, aerospace, ceramic, and chemical industries. They all have high densities (specific gravities ranging from silver at 10.5 to iridium at 22.6), relatively good corrosion resistance, good electrical conductivity and light reflectivity, and relatively high cost. Despite the latter factor, they are often economically acceptable because of their properties and performance in service. Scrap values are high and recycling is common.

Products available include rod and wire drawn as fine as 7.5 microns (0.0003 in) diameter for some alloys, and rolled products such as sheet, strip, ribbon, and foil (in some cases as thin as 2.5 microns (0.0001 in). Tubing of various cross-sections is also available for various precious metal alloys in the form of seamless tube for small sizes down to 0.4 mm (0.16 in) outside diameter, and as seamed tubing for larger sizes up to 75 mm (3 in) inside diameter and in less ductile alloys. Powder products are produced for applications in the electronic industry, including inks and films, and for applications as protective coatings.

Base metal alloys clad with precious metals (via mechanical and thermal bonding) are available in a range of product forms including sheet, wire, and tubing. Precious metal coatings can be applied using such techniques as vacuum metallizing and sputtering, electroplating, and thermal decomposition (firing).

The purities of silver and gold are designated in terms of several systems which do not apply to other metals. Fineness is used to designate purity in parts per thousand by weight; hence, 995 fine gold is 99.5% gold, and 925 fine silver (sterling silver) is 92.5% silver. Gold bullion, as traded, is

at least 995 fine and silver bullion at least 999 fine. Gold purity for jewelry applications is specified in karats, where 1 karat is 1/24th part of gold; hence, for example, 18 karat gold is 75% gold.

## **SILVER**

Silver is characterized by its bright appearance, high thermal and electrical conductivities, reflectivity, and very high malleability. It is resistant to corrosion in many organic acids and in sodium and potassium hydroxide, but it is susceptible to corrosion in mineral acids. It resists oxidation at room temperature but is susceptible to attack by sulphur. Although its major use is in photographic emulsions, it finds wide applications as brazing filler metal alloys ("silver solder"), as well as in electrical contacts, bearings, jewelry, and tableware, batteries, mirror backings, dental alloys, catalysts, and coinage. Silver-clad base metals (copper, brass, nickel, iron) are also used, in particular in the electrical and chemical industries.

Silver and the other precious metals are described by the UNS system in a single category with the prefix letter P. Other than for unalloyed silver, the designation given is P07xxy, where xx gives the approximate silver content of the alloy in percent; hence, P07650 contains about 65%Ag. Refined silver is available at several levels of purity from 99.99% (UNS P07010) to 99.90% (UNS P07020).

## **Brazing Alloys**

A very wide range of silver based brazing filler metal alloys is described by various standards, notably ASME SFA5.8 and AWS A5.8, which give alloy designations in the form BAg-x. These alloys are characterized by low melting temperatures and the ability to wet the solid base metals; hence, they are suitable filler metals for brazing steel, cast iron, stainless steel, and copper alloys to themselves and each other. They are also used in the brazing of some reactive and refractory metals, although the latter are restricted to low temperature use.

These brazing alloys are generally silver-copper-zinc alloys, some with additions of cadmium, manganese, nickel, or tin. The most widely used are the alloys BAg-1 (UNS P07450 which contains 45%Ag, 15%Cu, 16%Zn, 24%Cd) and BAg-1a (UNS P07500 containing 50%Ag, 15%Cu, 16%Zn, 18%Cd). The cadmium additions give these alloys particularly low melting temperatures, narrow melting temperature ranges, and high fluidities. Other brazing alloys include BAg-2 (UNS P07350 with 35%Ag, 26%Cu, 21%Zn, 18%Cd) and BAg-2a (UNS P07300 with 30%Ag, 27%Cu, 23%Zn, 20%Cd) which contain less silver and are therefore cheaper but

have higher melting temperatures and are less fluid. For food processing applications, where toxicity must be considered, it is necessary to utilize brazing alloys which are free of cadmium; these alloys include BAg-4 (UNS P07400 with 40%Ag, 30%Cu, 28%Zn, 2%Ni), BAg-5 (UNS P07453 with 45%Ag, 30%Cu, 25%Zn), BAg-20 (UNS P07301 with 30%Ag, 38%Cu, 32%Zn), and BAg-28 (UNS P07401 with 40%Ag, 30%Cu, 28%Zn, 2%Sn). For the brazing of stainless steel, the nickel-bearing alloy BAg-3 (UNS P07501 with 50%Ag, 15%Cu, 16%Zn, 16%Cd, 3%Ni) is most commonly used, but many other silver-based brazing alloys are applicable as well.

The vacuum brazing grades have maximum contents specified for a number of impurities, notably cadmium, phosphorus, and zinc which have high vapour pressures. Typical examples include BVAg-0 (UNS P07017 with 99.95% Ag) and BVAg-8 (UNS P07727 with 72%Ag, 28%Cu). A few brazing alloys contain lithium in amounts less than 0.5%; brazing with these alloys, such as BAg-8a (UNS P07723 with 72%Ag, 27%Cu, 0.4%Li) and BAg-19 (UNS P07925 with 92%Ag, 8%Cu, 0.2%Li), can be performed without the use of a flux, since the alloys are self-fluxing in dry, non-oxidizing protective atmospheres.

### **Electrical Contacts**

Silver is a useful material for medium- and heavy-duty electrical contacts, particularly when alloyed with a dispersion of cadmium oxide. Here, advantage is taken of the high thermal and electrical conductivity and low surface contact resistance of silver, and the ability of the particles of cadmium oxide to prevent sticking and welding and to minimize arc erosion. Under light-duty conditions (low voltage, low current) these materials are not suitable because of the tendency of silver to react with sulphur in the atmosphere to form a sulphide surface layer. The cadmium oxide dispersion can be formed either by powder metallurgical processing or by internal oxidation (e.g., the Ag-15%Cd alloy). Silver alloys containing approximately 0.25% each of magnesium, nickel, and in some cases copper, can also be dispersion strengthened by internal oxidation for use as electrical contact materials. Other silver-based alloys used for electrical contact purposes include fine silver, for low current applications, and alloys of silver with copper, palladium, platinum, or gold. These alloying elements increase the hardness, but decrease the electrical conductivity. Silver is also used in the form of an electroplated coating on electrical connection plugs and sockets.

### **Jewelry and Tableware Alloys, Coinage**

The high reflectivity of silver makes it particularly attractive for applications in jewelry and tableware. Strength, hardness, and wear

resistance are obtained through the use of alloys, in particular sterling silver, which contains 92.5%Ag and 7.5%Cu. There are two grades of sterling silver - the standard grade (UNS P07931) and silversmiths grade (P07932), which has closer limits on the allowable silver and copper contents. Sterling silver is heat treatable by precipitation hardening, for example by solution treatment at 720°C (1328°F) followed by aging for 1 hr at 300°C (572°F) but this is not a normal operation.

Silver alloys containing copper (e.g., Ag-10%Cu) are traditional coinage alloys.

### **Dental Alloys**

Silver-tin-mercury and silver-tin-copper-mercury alloys (amalgams) find wide use in dentistry because of their attractive mechanical properties and the small dimensional changes which occur during their "setting." Typically, particles containing 65%Ag min, 29%Sn max, and 6%Cu max are mixed with a similar weight of mercury to form the amalgam. The setting process occurs as mercury diffuses in the alloy and reacts with the constituents so as to transform from the liquid state into solid intermetallic compounds such as  $\text{Ag}_2\text{Hg}_3$  or  $\text{Sn}_7\text{Hg}$ . These, along with compounds such as  $\text{Ag}_3\text{Sn}$  and  $\text{Cu}_6\text{Sn}_5$ , make up the final filling material.

### **Miscellaneous Applications**

Silver also finds use as a catalyst in chemical reactions such as the oxidation of ethylene and the production of formaldehyde from methanol, and as a crucible material for molten NaOH. It is used in engine bearings where advantage is taken of its lubricating properties, its high thermal conductivity, and its low solubility in iron. It makes an excellent reflector for visible and infrared light, and can be applied to glass or ceramics by a vacuum sublimation metallizing process. In the form of a silver-silver oxide composite, it finds specialized application as a battery plate material.

## **GOLD**

Gold is a metal with a bright, pleasing yellow colour which can be substantially modified by alloy addition. It has very high malleability, thermal and electrical conductivity, and excellent corrosion resistance, including resistance to oxidation and sulphidation (i.e., to tarnish). This combination of properties has given gold and its alloys traditional applications in the jewelry, dental, electrical, and electronics industries and as brazing filler metals. Gold and gold alloys are used in the form of

bulk materials, and also as surface coatings applied by a wide range of techniques.

Gold and its alloys are given UNS designations in the precious metals and alloys group, specifically designations of the form P00xxx where xxx refers to specific alloys. Thus gold with a minimum purity of 99.99% is categorized as UNS P00010, P00015, or P00016 depending on impurities and their limits, while UNS P00020 and P00025 are refined golds with minimum gold contents of 99.95% and 99.5% respectively.

## **Jewelry**

Gold and its alloys are the most popular of the jewelry metals, as they have been for thousands of years. Jewelry alloys are classified by their karat ratings and described by their colours. The most widely used alloys are 14 k gold (58%Au), 18 k gold (75%Au) and 10 k gold (42%Au). The elements which make up the balance of these alloys are silver and the base metals copper, zinc, and nickel, with the colour of the alloy being determined by which elements are present and their proportions. Thus, increasing silver content changes the colour of gold from yellow to greenish yellow to white, copper increases the redness, nickel increases whiteness, and zinc acts as a decolourizer. The jewelry alloys which result from these additions include the green, yellow, red, and white golds. At the 18 k level, the green golds are gold-silver alloys (e.g., UNS P00280) and red golds are gold-copper alloys (UNS P00285), while the gold-silver-copper alloys are yellow (UNS P00250, P00255, P00260). The red 18 k gold alloy is difficult to work because it undergoes an ordering transformation in the solid state which increases its strength and lowers its ductility. The 10 k and 14 k gold alloys are based on the gold-silver-copper system (e.g., 14 k yellow golds UNS P00180, P00190, P00200, P00220); the properties of these alloys are dependent mainly on the ratios of silver to copper, and not on the gold contents. The white golds are either gold-silver-copper alloys to which 5-12% zinc is added (e.g., 10 k alloy UNS P00125) or else alloys in the gold-nickel-copper system, also containing zinc (e.g., 14 k alloys UNS P00150, P00160). The gold-nickel-copper white golds are harder but are susceptible to cracking when annealed after light working ("firecracking").

In addition, there are several ways of producing jewelry with a gold surface and a base metal interior. The expression "gold filled" applies to situations in which the weight of the coating (minimum 10 k gold) is at least 5% of the total weight. If the coating weight is less than this, the expression "rolled gold plate" is used. These coatings are applied by soldering, brazing, welding, or are applied mechanically. Gold and gold alloy electrodeposits are also used; in some cases alloying is accomplished

by electrodeposition of successive layers of different materials followed by heating to permit alloying by diffusion.

### **Electronic Applications**

Gold finds applications in the electronic industry in printed circuit boards, connectors, keyboard contacts, and miniaturized circuitry, applications where high conductivity and chemical and metallurgical stability are required. Gold and gold alloys are used in sliding electrical contacts for low current service; typical alloys include those containing about 25%Ag and 6-8%Pt (UNS P00691 and P00692). Other electrical contact gold alloys include UNS P00710 (15%Cu, 8%Pt, 5%Ag), UNS P00750 (22%Ag, 3%Ni), and UNS P00901 (Au-10%Cu). Gold in the form of a surface electrodeposit finds electronic uses include surfacing of plug-type electrical connectors and of high frequency conductors for use in environments where silver corrodes.

### **Brazing Alloys**

Gold brazing alloys are used for joining jet and rocket engine components made from nickel- or cobalt-based superalloys or stainless steel. Here, joint ductility is high since alloying with the base metal is minimized. They are also used for joining hermetically sealed vacuum tube components where the low vapour pressure is advantageous. The common brazing alloys include gold-copper alloys such as BAu-1 (UNS P00375 with 38%Au, 62%Cu), BAu-2 (UNS P00800 with 80%Au and 20%Cu), and BAu-3 (UNS P00350 with 35%Au, 62%Cu and 3%Ni), gold-nickel alloys like BAu-4 (UNS P00820 with 82%Au, 18%Ni), and gold-nickel-palladium alloys like BAu-5 (UNS P00300 with 30%Au, 36%Ni and 34%Pd) and BAu-6 (UNS P00700 with 70%Au, 22%Ni and 8%Pd). As in the case of silver-base brazing alloys, some of these have BVAu equivalents designed specifically for vacuum brazing applications with restricted contents of volatile impurities. Examples include BVAu-2 (UNS P00807), BVAu-4 (UNS P00827), the gold-nickel-palladium alloy BVAu-7 (UNS P00507), and the gold-palladium alloy BVAu-8 (UNS P00927) with 92%Au and 8%Pd).

### **Miscellaneous Applications**

Gold is a good reflector of radiation in the red and infrared part of the spectrum, and thus finds applications as coatings for infrared reflectors and in heating and drying devices including thermal barrier windows, space vehicle components, and space suits. Gold alloys are also used extensively in dentistry for crown and bridge alloys, inlays, and porcelain fused to metal alloys. Many compositions are used, typically gold-silver

alloys with additions of copper, zinc, and palladium. The gold alloy 70%Au-30%Pt is used for spinnerettes in rayon production in severe corrosion service. This is also a high melting point solder for platinum.

## **PLATINUM**

Platinum is the most abundant of the platinum group metals, and it is also the most widely used. Applications are based on the corrosion resistance, high melting point, ductility, electronic properties, and overall appearance. Platinum remains bright when heated in air at all temperatures up to the melting point and is soluble only in acids which generate free chlorine, such as aqua regia. Unalloyed platinum is available at two purity levels, UNS P04980 (min. 99.80%Pt) and P04995 (min. 99.95%Pt). Purity better than 99.9%Pt is required for laboratory ware and for electrical contacts. Even higher purity platinum is used for thermocouples and resistance thermometers. Platinum and its alloys are used for jewelry, as a brazing alloy for tungsten, as sensing elements for gas analyzers, as containers for various chemicals at high temperatures, and as various types of electrodes. Platinum alloys are excellent catalysts for oxidation and hydrogenation reactions and in petroleum reforming. Catalysts, in the form of platinum-palladium alloys for the automotive industry, account for the largest use of platinum.

Platinum-palladium alloys are also used in jewelry and for electrodes and electrical contacts. Platinum-iridium alloys up to 30%Ir are used for laboratory ware, jewelry, electrical contacts and electrodes, and as fine tubing. Platinum-rhodium alloys (up to 40%Rh, with Pt-10%Rh being the most popular) are used for applications at high temperatures in oxidizing conditions, in addition to being used as a catalyst, as a furnace element material (at 10%, 20% or 40%Rh), and as standard thermocouple alloys (at 10%, 13%, and 30%Rh). Platinum-rhodium alloys are also used for crucibles and dies in the glass industry, and as spinnerettes for synthetic fibers and bushings in the extrusion of fiberglass. Platinum-ruthenium alloys (5-11%Ru) are used for electrical contacts, for jewelry, and for hypodermic needles. The very strong alloy Pt-15%Rh-6%Ru is used in wire form in many applications including wire-wound electrical instruments. Pt-8%W wire is used widely in electrical, electronic, and biochemical applications. Pt-10%Ni has outstanding high temperature strength. Pt-23%Co (i.e., 50 atomic %Co) is a permanent magnet material with an unusually high coercive force. The creep resistance of platinum and its alloys at high temperatures can be much improved by using alloys containing a dispersion of zirconia; hence, the term ZGS (Zirconia-Grain-Stabilized) platinum and platinum alloys. These find applications in such areas as the glass industry where it is used for bushings, stirrers, and carrying apparatus.

## **PALLADIUM**

Palladium is similar to platinum in its appearance, ductility, and strength but it is lower in melting point and in corrosion/tarnish resistance and much lower in density. Overall, it is the second most widely used of the platinum group elements with wide applications as a material for electrical contacts. In the automotive industry palladium is employed as a component of catalyst alloys, and palladium alloy catalysts also have applications in the chemical and pharmaceutical industries. Other uses of palladium alloys are found in medical and dental materials, in jewelry, and in brazing alloys. It can be electroplated, electroformed, and deposited by electroless methods.

Commercial purity palladium with a minimum 99.8%Pd (UNS P03980) is used in electrical contacts for such light duty purposes as relays in telephone systems. Palladium-silver alloys also find applications as electrical contact materials, and the Pd-40%Ag alloy is used as well for precision resistance wires, and as a diffusion membrane for separation of hydrogen from other gases. Electrical contacts are also made from palladium-copper (40%Cu) alloy and from palladium-silver-copper alloys such as UNS P03440 (38%Ag, 16%Cu, 1%Pt) and UNS P03350 (30%Ag, 14%Cu, 10%Pt, 10%Au). The latter alloys can be precipitation hardened, making them useful in contact applications where sliding wear resistance or spring properties are required. Some palladium-silver-gold alloys are solution strengthened but there are others which are precipitation hardened. These are used in dental applications and in the form of cladding for severe corrosion service, particularly in halogen acids. Alloys used for brazing include palladium-cobalt alloys, such as the vacuum brazing alloy BVPd-1 (UNS P03657 with 65%Pd-35%Co). Pd-4.5%Ru is a standard jewelry alloy, in both cast and wrought forms, and palladium-ruthenium alloys up to 12%Ru are also used for electrical contacts.

## **RHODIUM, IRIDIUM, RUTHENIUM, OSMIUM**

These platinum group metals are all hard white metals which have little ductility at room temperature, but all except osmium can be worked at elevated temperatures. They are all used primarily as alloying elements in other precious metals, usually platinum or palladium, but some have applications in their own right. In general, they have excellent corrosion resistance, accompanied by high melting temperature and high density.

Rhodium is available in unalloyed form (e.g., UNS P05980, P05981 and P05982) and finds commercial applications, many of which are based on its very bright appearance (high specular reflectivity). For example, it is used as a plating on other white jewelry metals for whiteness and wear



resistance. It remains bright under all atmospheric conditions at ordinary temperatures and is resistant to high temperature oxidation and to corrosion by aqua regia.

Iridium has a combination of excellent corrosion resistance and high temperature strength, giving it applications as a crucible material for melting nonmetallic materials up to 2100°C (3812°F). It is also used as a neutron absorber and as a gamma ray source. Iridium has the highest density of any metal (22.65 g/cm<sup>3</sup>) and is the only metal which can be used for short periods at 2000°C (3632°F) in air.

Ruthenium and osmium are mainly used as alloying elements in other precious metals, where they provide hardness and corrosion resistance. Osmium-ruthenium alloys are used in specialized instrument applications such as galvanometer pivots.

| <b>COMMON NAMES OF PRECIOUS METALS WITH UNS No.</b> |                                    |            |                                                    |
|-----------------------------------------------------|------------------------------------|------------|----------------------------------------------------|
| <b>UNS</b>                                          | <b>Common Name</b>                 | <b>UNS</b> | <b>Common Name</b>                                 |
| P00140                                              | 10-Karat Green Gold Jewelry Alloy  | P00225     | 14-Karat Yellow Gold Jewelry Alloy                 |
| P00145                                              | 10-Karat Red Gold Jewelry Alloy    | P00280     | 18-Karat Green Gold Jewelry Alloy                  |
| P00125                                              | 10-Karat White Gold Jewelry Alloy  | P00285     | 18-Karat Red Gold Jewelry Alloy                    |
| P00130                                              | 10-Karat White Gold Jewelry Alloy  | P00270     | 18-Karat White Gold Jewelry Alloy                  |
| P00135                                              | 10-Karat White Gold Jewelry Alloy  | P00275     | 18-Karat White Gold Jewelry Alloy                  |
| P00105                                              | 10-Karat Yellow Gold Jewelry Alloy | P00250     | 18-Karat Yellow Gold Jewelry Alloy                 |
| P00110                                              | 10-Karat Yellow Gold Jewelry Alloy | P00255     | 18-Karat Yellow Gold Jewelry Alloy                 |
| P00115                                              | 10-Karat Yellow Gold Jewelry Alloy | P00260     | 18-Karat Yellow Gold Jewelry Alloy                 |
| P00120                                              | 10-Karat Yellow Gold Jewelry Alloy | P00016     | Gold                                               |
| P00230                                              | 14-Karat Green Gold Jewelry Alloy  | P00100     | Gold Alloy (990) Gold                              |
| P00235                                              | 14-Karat Green Gold Jewelry Alloy  | P00350     | Gold Brazing Alloy                                 |
| P00170                                              | 14-Karat Red Gold Jewelry Alloy    | P00375     | Gold Brazing Alloy                                 |
| P00150                                              | 14-Karat White Gold Jewelry Alloy  | P00500     | Gold Brazing Alloy                                 |
| P00155                                              | 14-Karat White Gold Jewelry Alloy  | P00700     | Gold Brazing Alloy                                 |
| P00160                                              | 14-Karat White Gold Jewelry Alloy  | P00800     | Gold Brazing Alloy                                 |
| P00165                                              | 14-Karat White Gold Jewelry Alloy  | P00820     | Gold Brazing Alloy                                 |
| P00032                                              | 14-Karat Yellow Gold Jewelry Alloy | P00807     | Gold Brazing Alloy (Vacuum Grade)                  |
| P00175                                              | 14-Karat Yellow Gold Jewelry Alloy | P00827     | Gold Brazing Alloy (Vacuum Grade)                  |
| P00180                                              | 14-Karat Yellow Gold Jewelry Alloy | P00691     | Gold Electrical Contact Alloy                      |
| P00185                                              | 14-Karat Yellow Gold Jewelry Alloy | P00692     | Gold Electrical Contact Alloy                      |
| P00190                                              | 14-Karat Yellow Gold Jewelry Alloy | P00710     | Gold Electrical Contact Alloy                      |
| P00195                                              | 14-Karat Yellow Gold Jewelry Alloy | P00750     | Gold Electrical Contact Alloy                      |
| P00200                                              | 14-Karat Yellow Gold Jewelry Alloy | P00901     | Gold Electrical Contact Alloy                      |
| P00205                                              | 14-Karat Yellow Gold Jewelry Alloy | P00927     | Gold-Palladium Brazing Alloy (Vacuum Grade)        |
| P00210                                              | 14-Karat Yellow Gold Jewelry Alloy | P00300     | Gold-Palladium-Nickel Brazing Alloy                |
| P00215                                              | 14-Karat Yellow Gold Jewelry Alloy | P00507     | Gold-Palladium-Nickel Brazing Alloy (Vacuum Grade) |
| P00220                                              | 14-Karat Yellow Gold Jewelry Alloy | P00900     | Gold-Silver Alloy                                  |

| <b>COMMON NAMES OF PRECIOUS METALS WITH UNS No. (Continued)</b> |                                                                |            |                               |
|-----------------------------------------------------------------|----------------------------------------------------------------|------------|-------------------------------|
| <b>UNS</b>                                                      | <b>Common Name</b>                                             | <b>UNS</b> | <b>Common Name</b>            |
| P00580                                                          | Gold: 14 Karat Yellow Gold - New U.S. (After September 1981)   | P07560     | Silver Brazing Alloy          |
| P00560                                                          | Gold: 14 Karat Yellow Gold - Old U.S. (Prior to October 1981)  | P07563     | Silver Brazing Alloy          |
| P03300                                                          | Palladium Alloy (Paliney No. 7, "W" Alloy 3350, No. 226 Alloy) | P07600     | Silver Brazing Alloy          |
| P03350                                                          | Palladium Electrical Contact Alloy                             | P07650     | Silver Brazing Alloy          |
| P03440                                                          | Palladium Electrical Contact Alloy                             | P07700     | Silver Brazing Alloy          |
| P03657                                                          | Palladium-Cobalt Brazing Alloy (Vacuum Grade)                  | P07720     | Silver Brazing Alloy          |
| P00010                                                          | Refined Gold                                                   | P07723     | Silver Brazing Alloy          |
| P00015                                                          | Refined Gold                                                   | P07925     | Silver Brazing Alloy          |
| P00020                                                          | Refined Gold                                                   | P07450     | Silver Brazing Alloy (BAg-1)  |
| P00025                                                          | Refined Gold                                                   | P07540     | Silver Brazing Alloy (BAg-13) |
| P06100                                                          | Refined Iridium                                                | P07500     | Silver Brazing Alloy (BAg-1a) |
| P03980                                                          | Refined Palladium                                              | P07350     | Silver Brazing Alloy (BAg-2)  |
| P03995                                                          | Refined Palladium                                              | P07301     | Silver Brazing Alloy (BAg-20) |
| P04980                                                          | Refined Platinum                                               | P07630     | Silver Brazing Alloy (BAg-21) |
| P04995                                                          | Refined Platinum                                               | P07490     | Silver Brazing Alloy (BAg-22) |
| P05981                                                          | Refined Rhodium                                                | P07850     | Silver Brazing Alloy (BAg-23) |
| P05982                                                          | Refined Rhodium                                                | P07505     | Silver Brazing Alloy (BAg-24) |
| P07015                                                          | Refined Silver                                                 | P07200     | Silver Brazing Alloy (BAg-25) |
| P07020                                                          | Refined Silver                                                 | P07250     | Silver Brazing Alloy (BAg-26) |
| P07010                                                          | Refined Silver                                                 | P07251     | Silver Brazing Alloy (BAg-27) |
| P05980                                                          | Rhodium                                                        | P07401     | Silver Brazing Alloy (BAg-28) |
| P07016                                                          | Silver                                                         | P07300     | Silver Brazing Alloy (BAg-2a) |
| P07253                                                          | Silver Brazing Alloy                                           | P07501     | Silver Brazing Alloy (BAg-3)  |
| P07351                                                          | Silver Brazing Alloy                                           | P07252     | Silver Brazing Alloy (BAg-33) |
| P07402                                                          | Silver Brazing Alloy                                           | P07380     | Silver Brazing Alloy (BAg-34) |
| P07454                                                          | Silver Brazing Alloy                                           | P07400     | Silver Brazing Alloy (BAg-4)  |
| P07502                                                          | Silver Brazing Alloy                                           | P07453     | Silver Brazing Alloy (BAg-5)  |

| <b>COMMON NAMES OF PRECIOUS METALS WITH UNS No. (Continued)</b> |                                     |            |                                               |
|-----------------------------------------------------------------|-------------------------------------|------------|-----------------------------------------------|
| <b>UNS</b>                                                      | <b>Common Name</b>                  | <b>UNS</b> | <b>Common Name</b>                            |
| P07503                                                          | Silver Brazing Alloy (BAg-6)        | P07728     | Silver Brazing Alloy (Vacuum Grade)           |
| P07507                                                          | Silver Brazing Alloy (Vacuum Grade) | P07017     | Silver Brazing Alloy (Vacuum Grade) (BVAg-0)  |
| P07587                                                          | Silver Brazing Alloy (Vacuum Grade) | P07900     | Silver Electrical Contact Alloy               |
| P07607                                                          | Silver Brazing Alloy (Vacuum Grade) | P07932     | Silver, Sterling Silver (Silversmiths Grade)  |
| P07627                                                          | Silver Brazing Alloy (Vacuum Grade) | P07931     | Silver, Sterling Silver (Standard Grade)      |
| P07687                                                          | Silver Brazing Alloy (Vacuum Grade) | P07547     | Silver-Palladium Brazing Alloy (Vacuum Grade) |
| P07727                                                          | Silver Brazing Alloy (Vacuum Grade) |            |                                               |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - PRECIOUS METALS</b> |            |                 |               |               |                 |
|-------------------------------------------------------------------|------------|-----------------|---------------|---------------|-----------------|
| <b>UNS</b>                                                        | <b>AMS</b> | <b>ASME</b>     | <b>AWS</b>    | <b>ASTM</b>   | <b>MIL SPEC</b> |
| P00010                                                            | ---        | ---             | ---           | B562 (99.995) | ---             |
| P00015                                                            | ---        | ---             | ---           | B562 (99.99)  | ---             |
| P00016                                                            | ---        | ---             | ---           | F72           | ---             |
| P00020                                                            | 7731       | ---             | ---           | B562 (99.95)  | ---             |
| P00025                                                            | ---        | ---             | ---           | B562 (99.5)   | ---             |
| P00300                                                            | 4785       | SFA5.8 (BAu-5)  | A5.8 (BAu-5)  | ---           | ---             |
| P00350                                                            | ---        | SFA5.8 (BAu-3)  | A5.8 (BAu-3)  | ---           | ---             |
| P00375                                                            | ---        | SFA5.8 (BAu-1)  | A5.8 (BAu-1)  | ---           | ---             |
| P00500                                                            | 4784       | ---             | ---           | ---           | ---             |
| P00507                                                            | ---        | SFA5.8 (BVAu-7) | A5.8 (BVAu-7) | ---           | ---             |
| P00691                                                            | ---        | ---             | ---           | B522 (I)      | ---             |
| P00692                                                            | ---        | ---             | ---           | B522 (II)     | ---             |
| P00700                                                            | 4786       | SFA5.8 (BAu-6)  | A5.8 (BAu-6)  | ---           | ---             |
| P00710                                                            | ---        | ---             | ---           | B541          | ---             |
| P00750                                                            | ---        | ---             | ---           | B477          | ---             |
| P00800                                                            | ---        | SFA5.8 (BAu-2)  | A5.8 (BAu-2)  | ---           | ---             |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - PRECIOUS METALS (Continued)</b> |            |                 |               |              |                 |
|-------------------------------------------------------------------------------|------------|-----------------|---------------|--------------|-----------------|
| <b>UNS</b>                                                                    | <b>AMS</b> | <b>ASME</b>     | <b>AWS</b>    | <b>ASTM</b>  | <b>MIL SPEC</b> |
| P00807                                                                        | ---        | SFA5.8 (BVAu-2) | A5.8 (BVAu-2) | ---          | ---             |
| P00820                                                                        | 4787       | SFA5.8 (BAu-4)  | A5.8 (BAu-4)  | ---          | ---             |
| P00827                                                                        | ---        | SFA5.8 (BVAu-4) | A5.8 (BVAu-4) | ---          | ---             |
| P00901                                                                        | ---        | ---             | ---           | B596         | ---             |
| P00927                                                                        | ---        | SFA5.8 (BVAu-8) | A5.8 (BVAu-8) | ---          | ---             |
| P03300                                                                        | 7735       | ---             | ---           | ---          | ---             |
| P03350                                                                        | ---        | ---             | ---           | B540         | ---             |
| P03440                                                                        | ---        | ---             | ---           | B563         | ---             |
| P03657                                                                        | ---        | SFA5.8 (BVPd-1) | A5.8 (BVPd-1) | ---          | ---             |
| P03980                                                                        | ---        | ---             | ---           | B589 (99.80) | ---             |
| P03995                                                                        | ---        | ---             | ---           | B589 (99.95) | ---             |
| P04980                                                                        | ---        | ---             | ---           | B561         | ---             |
| P04995                                                                        | ---        | ---             | ---           | B561 (99.95) | ---             |
| P05980                                                                        | ---        | ---             | ---           | B616 (99.80) | ---             |
| P05981                                                                        | ---        | ---             | ---           | B616 (99.90) | ---             |
| P05982                                                                        | ---        | ---             | ---           | B616 (99.95) | ---             |
| P06100                                                                        | ---        | ---             | ---           | B671         | ---             |
| P07010                                                                        | ---        | ---             | ---           | B413 (99.99) | ---             |
| P07015                                                                        | ---        | ---             | ---           | B413 (99.95) | MIL-S-13282     |
| P07016                                                                        | ---        | ---             | ---           | F106 (TB Ag) | ---             |
| P07017                                                                        | ---        | SFA5.8 (BVAg-0) | A5.8 (BVAg-0) | ---          | ---             |
| P07020                                                                        | ---        | ---             | ---           | B413 (99.90) | ---             |
| P07200                                                                        | ---        | SFA5.8 (BAG-25) | A5.8 (BAG-25) | ---          | ---             |
| P07250                                                                        | ---        | SFA5.8 (BAG-26) | A5.8 (BAG-26) | ---          | ---             |
| P07251                                                                        | ---        | SFA5.8 (BAG-27) | A5.8 (BAG-27) | ---          | ---             |
| P07252                                                                        | ---        | SFA5.8 (BAG-33) | A5.8 (BAG-33) | ---          | ---             |
| P07253                                                                        | ---        | SFA5.8 (BAG-37) | A5.8 (BAG-37) | ---          | ---             |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - PRECIOUS METALS (Continued)</b> |            |                  |                |             |                     |
|-------------------------------------------------------------------------------|------------|------------------|----------------|-------------|---------------------|
| <b>UNS</b>                                                                    | <b>AMS</b> | <b>ASME</b>      | <b>AWS</b>     | <b>ASTM</b> | <b>MIL SPEC</b>     |
| P07300                                                                        | ---        | SFA5.8 (BAg-2a)  | A5.8 (BAg-2a)  | ---         | ---                 |
| P07301                                                                        | ---        | SFA5.8 (BAg-20)  | A5.8 (BAg-20)  | ---         | ---                 |
| P07350                                                                        | 4768       | SFA5.8 (BAg-2)   | A5.8 (BAg-2)   | ---         | MIL-B-7883 (BAg-2)  |
| P07351                                                                        | ---        | SFA5.8 (BAg-35)  | A5.8 (BAg-35)  | ---         | ---                 |
| P07380                                                                        | ---        | SFA5.8 (BAg-34)  | A5.8 (BAg-34)  | ---         | ---                 |
| P07400                                                                        | ---        | SFA5.8 (BAg-4)   | A5.8 (BAg-4)   | ---         | ---                 |
| P07401                                                                        | ---        | SFA5.8 (BAg-28)  | A5.8 (BAg-28)  | ---         | ---                 |
| P07402                                                                        | 4762       | ---              | ---            | ---         | ---                 |
| P07450                                                                        | 4769       | SFA5.8 (BAg-1)   | A5.8 (BAg-1)   | ---         | MIL-B-7883 (BAg-1)  |
| P07453                                                                        | ---        | SFA5.8 (BAg-5)   | A5.8 (BAg-5)   | ---         | ---                 |
| P07454                                                                        | ---        | SFA5.8 (BAg-36)  | A5.8 (BAg-36)  | ---         | ---                 |
| P07490                                                                        | ---        | SFA5.8 (BAg-22)  | A5.8 (BAg-22)  | ---         | ---                 |
| P07500                                                                        | 4770       | SFA5.8 (BAg-1a)  | A5.8 (BAg-1a)  | ---         | MIL-B-7883 (BAg-1a) |
| P07501                                                                        | 4771       | SFA5.8 (BAg-3)   | A5.8 (BAg-3)   | ---         | MIL-B-7883 (BAg-3)  |
| P07502                                                                        | ---        | ---              | ---            | ---         | ---                 |
| P07503                                                                        | ---        | SFA5.8 (BAg-6)   | A5.8 (BAg-6)   | ---         | ---                 |
| P07505                                                                        | 4788       | SFA5.8 (BAg-24)  | A5.8 (BAg-24)  | ---         | ---                 |
| P07507                                                                        | ---        | SFA5.8 (BVAg-6c) | A5.8 (BVAg-6c) | ---         | ---                 |
| P07540                                                                        | 4772       | SFA5.8 (BAg-13)  | A5.8 (BAg-13)  | ---         | MIL-B-7883 (BAg-13) |
| P07547                                                                        | ---        | SFA5.8 (BVAg-32) | A5.8 (BVAg-32) | ---         | ---                 |
| P07560                                                                        | 4765       | SFA5.8 (BAg-13a) | A5.8 (BAg-13a) | ---         | ---                 |
| P07563                                                                        | ---        | SFA5.8 (BAg-7)   | A5.8 (BAg-7)   | ---         | ---                 |
| P07587                                                                        | ---        | SFA5.8 (BVAg-31) | A5.8 (BVAg-31) | ---         | ---                 |
| P07600                                                                        | 4773       | SFA5.8 (BAg-18)  | A5.8 (BAg-18)  | ---         | ---                 |
| P07607                                                                        | ---        | SFA5.8 (BVAg-18) | A5.8 (BVAg-18) | ---         | ---                 |
| P07627                                                                        | ---        | SFA5.8 (BVAg-29) | A5.8 (BVAg-29) | ---         | ---                 |
| P07630                                                                        | 4774       | SFA5.8 (BAg-21)  | A5.8 (BAg-21)  | ---         | ---                 |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - PRECIOUS METALS (Continued)</b> |            |                  |                |             |                     |
|-------------------------------------------------------------------------------|------------|------------------|----------------|-------------|---------------------|
| <b>UNS</b>                                                                    | <b>AMS</b> | <b>ASME</b>      | <b>AWS</b>     | <b>ASTM</b> | <b>MIL SPEC</b>     |
| P07650                                                                        | ---        | SFA5.8 (BAg-9)   | A5.8 (BAg-9)   | ---         | ---                 |
| P07687                                                                        | ---        | SFA5.8 (BVAg-30) | A5.8 (BVAg-30) | ---         | ---                 |
| P07700                                                                        | ---        | SFA5.8 (BAg-10)  | A5.8 (BAg-10)  | ---         | ---                 |
| P07720                                                                        | ---        | SFA5.8 (BAg-8)   | A5.8 (BAg-8)   | ---         | MIL-B-7883 (BAg-8)  |
| P07723                                                                        | ---        | SFA5.8 (BAg-8a)  | A5.8 (BAg-8a)  | ---         | MIL-B-7883 (BAg-8a) |
| P07727                                                                        | ---        | SFA5.8 (BVAg-8)  | A5.8 (BVAg-8)  | ---         | ---                 |
| P07728                                                                        | ---        | SFA5.8 (BVAg-8b) | A5.8 (BVAg-8b) | ---         | ---                 |
| P07850                                                                        | 4766       | SFA5.8 (BAg-23)  | A5.8 (BAg-23)  | ---         | MIL-B-7883 (BAg-23) |
| P07900                                                                        | ---        | ---              | ---            | B617        | ---                 |
| P07925                                                                        | 4767       | SFA5.8 (BAg-19)  | A5.8 (BAg-19)  | ---         | MIL-B-7883 (BAg-19) |

a. This cross-reference table lists the basic specification or standard number, and since these standards are constantly being revised, it should be kept in mind that they are presented herein as a guide and may not reflect the latest revision.

| <b>CHEMICAL COMPOSITIONS OF PRECIOUS METALS</b> |                                                                                                                                                                             |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                      | <b>Chemical Composition</b>                                                                                                                                                 |
| P00010                                          | Au 99.995 min Ag 0.001 max Bi 0.001 max Cr 0.0003 max Cu 0.001 max Fe 0.001 max Mg 0.001 max Mn 0.0003 max Pb 0.001 max Pd 0.001 max Si 0.001 max Sn 0.001 max              |
| P00015                                          | Au 99.99 min As 0.003 max Bi 0.002 max Cr 0.0003 max Cu 0.005 max Fe 0.002 max Mg 0.003 max Mn 0.0003 max Ni 0.0003 max Pb 0.002 max Pd 0.005 max Si 0.005 max Sn 0.001 max |
| P00016                                          | Au 99.99 min Other Ag+Cu 0.009 max, each, other impurity 0.003 max                                                                                                          |
| P00020                                          | Au 99.95 min Ag 0.035 max Cu 0.02 max Fe 0.005 max Pb 0.005 max Pd 0.02 max Other AG+Cu 0.04 max                                                                            |
| P00025                                          | Au 99.5 min                                                                                                                                                                 |
| P00032                                          | Au 58.33 (-0.3) Cu 31.08 (+/- 1.0) rem Ag 4.00 (+/- 0.5) Fe 0.05 (+/- 0.5) Ni 0.10 (+/- 0.5) Si 0.01 (+/- 0.5) Zn 6.43 (+/- 0.5)                                            |
| P00100                                          | Au 99.0 min Ti 1.0 (0.8 min)                                                                                                                                                |
| P00105                                          | Au 41.817 (-0.3) Cu 38.5 (rem) Zn 12.68 (+/- 1.0) Ag 5.85 (+/- 0.5) Ni 1.15 (+/- 0.5)                                                                                       |
| P00110                                          | Au 41.70 (-0.3) Ag 11.66 (+/- 1.0) Zn 5.83 (+/- 0.5) B 0.02 Cu 40.81 (rem) Si 0.03                                                                                          |

| <b>CHEMICAL COMPOSITIONS OF PRECIOUS METALS (Continued)</b> |                                                                                        |
|-------------------------------------------------------------|----------------------------------------------------------------------------------------|
| <b>UNS</b>                                                  | <b>Chemical Composition</b>                                                            |
| P00115                                                      | Au 41.70 (-0.3) Cu 43.8 (rem) Zn 9.00 (+/- 0.5) Ag 5.50 (+/- 0.5)                      |
| P00120                                                      | Au 41.70 (-0.3) Cu 48.00 (rem) Ag 6.60 (+/- 0.5) Zn 3.70 (+/- 0.5)                     |
| P00125                                                      | Au 41.817 (-0.3) Cu 46.683 (rem) Zn 10.35 (+/- 1.0) Ni 1.15 (+/- 0.5)                  |
| P00130                                                      | Au 41.70 (-0.3) Cu 32.82 (rem) Ni 17.08 (+/- 1.0) Zn 8.40 (+/- 0.5)                    |
| P00135                                                      | Au 41.66 (-0.3) Cu 29.20 (rem) Ni 15.05 (+/- 1.0) Zn 12.12 (+/- 0.5) Co 1.97 (+/- 0.5) |
| P00140                                                      | Ag 48.90 (+/- 1.0) Au 41.70 (-0.3) Cu 9.05 (rem) Zn 0.35                               |
| P00145                                                      | Au 41.70 (-0.3) Cu 55.48 (rem) Ag 2.82 (+/- 0.5)                                       |
| P00150                                                      | Au 58.484 (-0.3) Cu 24.00 (rem) Ni 8.00 (+/- 0.5) Zn 7.52 (+/- 0.5) Ag 2.00 (+/- 0.5)  |
| P00155                                                      | Au 58.33 (-0.3) Cu 22.10 (rem) Ni 10.80 (+/- 1.0) Zn 8.77 (+/- 0.5)                    |
| P00160                                                      | Au 58.33 (-0.3) Cu 23.47 (rem) Ni 12.21 (+/- 1.0) Zn 5.99 (+/- 0.5)                    |
| P00165                                                      | Au 58.33 (-0.3) Cu 28.32 (rem) Ni 8.55 (+/- 0.5) Zn 4.80 (+/- 0.5)                     |
| P00170                                                      | Au 58.33 (-0.3) Cu 39.59 (rem) Ag 2.08 (+/- 0.5)                                       |
| P00175                                                      | Au 58.33 (-0.3) Zn 6.63 (+/- 0.5) Ag 5.00 (+/- 0.5) B 0.02 Cu 30.00 (rem) Si 0.03      |
| P00180                                                      | Au 58.33 (-0.3) Cu 24.97 (rem) Ag 16.50 (+/- 1.0) Zn 0.20                              |
| P00185                                                      | Au 58.33 (-0.3) Cu 26.58 (rem) Ag 7.46 (+/- 0.5) Zn 6.63 (+/- 0.5) Ni 1.00             |
| P00195                                                      | Au 58.33 (-0.3) Cu 29.67 (rem) Ag 10.00 (+/- 1.0) Zn 2.00 (+/- 0.5)                    |
| P00200                                                      | Au 58.33 (-0.3) Cu 20.17 (rem) Ag 21.20 (+/- 1.0) Zn 0.30                              |
| P00205                                                      | Au 58.33 (-0.3) Cu 29.19 (rem) Ag 8.31 (+/- 0.5) Zn 4.17 (+/- 0.5)                     |
| P00210                                                      | Au 58.33 (-0.3) Cu 31.24 (rem) Ag 4.00 (+/- 0.5) Zn 6.43 (+/- 0.5)                     |
| P00215                                                      | Au 58.33 (-0.3) Ag 24.78 (+/- 1.0) Cu 16.75 (rem) Zn 0.14                              |
| P00220                                                      | Au 58.33 (-0.3) Ag 21.20 (+/- 1.0) Cu 20.17 (rem) Zn 0.30                              |
| P00225                                                      | Au 58.33 (-0.3) Cu 31.24 (rem) Zn 6.43 (+/- 0.5) Ag 4.00 (+/- 0.5)                     |
| P00230                                                      | Au 58.33 (-0.3) Ag 32.50 (+/- 1.0) Cu 8.97 (rem) Zn 0.20 (+/- 0.5)                     |
| P00235                                                      | Au 58.33 (-0.3) Ag 35.00 (+/- 1.0) Cu 6.47 (rem) Zn 0.20                               |
| P00250                                                      | Au 75.00 (-0.3) Ag 13.00 (+/- 1.0) Cu 12.00 (rem)                                      |
| P00255                                                      | Au 75.00 (-0.3) Ag 15.00 (+/- 1.0) Cu 10.00 (rem)                                      |
| P00260                                                      | Au 75.15 Ag 19.00 (+/- 1.0) (-0.3) Cu 2.85 (rem) Zn 3.00 (+/- 0.5)                     |



| <b>CHEMICAL COMPOSITIONS OF PRECIOUS METALS (Continued)</b> |                                                                                                                                                   |
|-------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                  | <b>Chemical Composition</b>                                                                                                                       |
| P00270                                                      | Au 75.15 (-0.3) Ni 12.00 (+/- 1.0) Cu 9.85 (rem) Zn 3.00 (+/- 0.5)                                                                                |
| P00275                                                      | Au 75.00 (-0.3) Ni 17.80 (+/- 1.0) Cu 1.73 (rem) Zn 5.47 (+/- 0.5)                                                                                |
| P00280                                                      | Au 75.00 (-0.3) Ag 22.50 (+/- 1.0) Cu 2.50 (rem)                                                                                                  |
| P00285                                                      | Au 75.00 (-0.3) Cu 20.00 (rem) Ag 5.00 (+/- 0.5)                                                                                                  |
| P00300                                                      | Au 29.5-30.5 Ni 35.5-36.5 Pd 33.5-34.5 Other 0.15 max                                                                                             |
| P00350                                                      | Au 34.5-35.5 Cu rem Ni 2.5-3.5 Other 0.15 max                                                                                                     |
| P00375                                                      | Au 37.0-38.0 Cu rem Other 0.15 max                                                                                                                |
| P00500                                                      | Au 49.5-50.5 Ni 24.5-25.5 Pd 24.5-25.5                                                                                                            |
| P00507                                                      | Au 49.5-50.5 C 0.005 max Cd 0.001 max Co 0.06 max Ni 24.5-25.5 P 0.002 max Pb 0.002 max Pd rem Zn 0.001 max                                       |
| P00560                                                      | Au 56.25-56.55 Cu 32.30-33.30 Ag 3.70-4.70 Fe 0.05 max Ni 0.10 max Si 0.01 max Zn 6.00-7.50<br>Other all elements except Au, Ag, Cu, Zn: max 0.15 |
| P00580                                                      | Ag 3.0-4.0 Au 58.03-58.63 Cu 30.74-31.74 Fe 0.05 max Ni 0.10 max Si 0.01 max Zn 5.68-7.18 Other all elements except Au, Ag, Cu, Zn: max 0.15      |
| P00691                                                      | Ag 23.5-26.5 Au 68.0-70.0 Pt 5.0-7.0                                                                                                              |
| P00692                                                      | Ag 24.5-25.5 Au 68.5-69.5 Pt 5.5-6.5 S 0.01 max                                                                                                   |
| P00700                                                      | Au 69.5-70.5 Ni 21.5-22.5 Pd 7.5-8.5 Other 0.15 max                                                                                               |
| P00710                                                      | Ag 4.0-5.0 Au 70.5-72.5 Cu 13.5-15.5 Pt 8.0-9.0 Zn 0.7-1.3                                                                                        |
| P00750                                                      | Ag 21.4-22.6 Au 74.2-75.8 Ni 2.6-3.4                                                                                                              |
| P00800                                                      | Au 79.5-80.5 Cu rem                                                                                                                               |
| P00807                                                      | Au 79.5-80.5 C 0.005 max Cd 0.001 max Cu rem P 0.002 max Pb 0.002 max Zn 0.001 max Other 0.15 max                                                 |
| P00820                                                      | Au 81.5-82.5 Ni rem Other 0.15 max                                                                                                                |
| P00827                                                      | Au 81.5-82.5 C 0.005 max Cd 0.001 max Ni rem P 0.002 max Pb 0.002 max Zn 0.001 max                                                                |
| P00900                                                      | Ag 3.0-10.0 Au 90.0 min                                                                                                                           |
| P00901                                                      | Au 89.0-91.0 Cu 9.0-11.0                                                                                                                          |
| P00927                                                      | Au 91.0-93.0 C 0.005 max Cd 0.001 max P 0.002 max Pb 0.002 max Pd rem Zn 0.001 max                                                                |
| P03300                                                      | Pd 34.0-36.0 Ag 29.0-31.0 Au 9.5-10.5 Cu 13.5-14.5 Pt 9.5-10.5 Other elements 0.01 max total                                                      |
| P03350                                                      | Pd 34.0-36.0 Ag 29-31 Au 9.5-10.5 Cu 13.5-14.5 Pt 9.5-10.5 Zn 0.6-1.2 Other total 0.1 max                                                         |
| P03440                                                      | Pd 43.0-45.0 Ag 37.0-39.0 Cu 15.5-16.5 Ni 0.8-1.2 Pt 0.8-1.2                                                                                      |

| <b>CHEMICAL COMPOSITIONS OF PRECIOUS METALS (Continued)</b> |                                                                                                                                                                                                                                                                                                                                                       |
|-------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                  | <b>Chemical Composition</b>                                                                                                                                                                                                                                                                                                                           |
| P03657                                                      | Pd 64.0-66.0 Co rem C 0.005 max Cd 0.001 max Ni 0.06 max P 0.002 max Pb 0.002 max Zn 0.001 max                                                                                                                                                                                                                                                        |
| P03980                                                      | Pd 99.80 min Ir 0.05 max Pt 0.15 max Rh 0.10 max Other Ru 0.05 max                                                                                                                                                                                                                                                                                    |
| P03995                                                      | Pd 99.95 min Ag 0.005 max Al 0.005 max Au 0.01 max Ca 0.005 max Co 0.001 max Cr 0.001 max Cu 0.005 max Fe 0.005 max Mg 0.005 max Mn 0.001 max Ni 0.005 max Pb 0.005 max Sb 0.002 max Si 0.005 max Sn 0.005 max Zn 0.0025 max Other Pt+Rh+Ru+Ir 0.03 max                                                                                               |
| P04980                                                      | Pt 99.80 min Ir 0.05 max Rh 0.10 max Other Pd 0.15 max Ru 0.05 max                                                                                                                                                                                                                                                                                    |
| P04995                                                      | Pt 99.5 min Ag 0.005 max Al 0.005 max As 0.005 max Au 0.01 max Bi 0.005 max Cd 0.005 max Cr 0.005 max Cu 0.01 max Ir 0.015 max Fe 0.01 max Mg 0.005 max Mn 0.005 max Mo 0.01 max Ni 0.005 max Pb 0.005 max Rh 0.03 max Sb 0.005 max Si 0.01 max Sn 0.005 max Te 0.005 max Zn 0.005 max Other Ca 0.005 max, Ru 0.01 max, Pd 0.02 max                   |
| P05980                                                      | Rh 99.8 min As 0.01 max Bi 0.01 max Cd 0.01 max Ir 0.01 max Fe 0.01 max Pb 0.01 max Pd 0.05 max Pt 0.01 max Ru 0.05 max Sn 0.01 max Zn 0.01 max                                                                                                                                                                                                       |
| P05981                                                      | Rh 99.90 min Ag 0.02 max Al 0.01 max As 0.005 max Au 0.01 max B 0.005 max Bi 0.005 max Cd 0.005 max Co 0.005 max Cr 0.01 max Cu 0.01 max Fe 0.01 max Ir 0.05 max Mg 0.01 max Mn 0.005 max Ni 0.01 max Pb 0.01 max Pt 0.05 max Sb 0.005 max Si 0.01 max Sn 0.01 max Te 0.01 max Zn 0.01 max Other Pd 0.05 max, Ru 0.05 max, Ca 0.01 max                |
| P05982                                                      | Rh 99.95 min Ag 0.005 max Al 0.005 max As 0.003 max Au 0.003 max B 0.001 max Bi 0.005 max Cd 0.005 max Co 0.001 max Cr 0.005 max Cu 0.005 max Fe 0.003 max Ir 0.02 max Mg 0.005 max Mn 0.005 max Ni 0.003 max Pb 0.005 max Pt 0.02 max Sb 0.003 max Si 0.005 max Sn 0.003 max Te 0.005 max Zn 0.003 max Other Pd 0.005 max, Ru 0.01 max, Ca 0.005 max |
| P06100                                                      | Ir 99.80 min As 0.01 max Bi 0.01 max Cd 0.01 max Fe 0.01 max Pb 0.02 max Pt 0.10 max Rh 0.15 max Si 0.02 max Sn 0.01 max Other Pd 0.05 max, Ru 0.05 max                                                                                                                                                                                               |
| P07010                                                      | Ag 99.99 min Bi 0.0005 max Cu 0.010 max Fe 0.001 max Pb 0.001 max Se 0.0005 max Te 0.0005 max Other Pd 0.001 max                                                                                                                                                                                                                                      |
| P07015                                                      | Ag 99.95 min Bi 0.001 max Cu 0.04 max Fe 0.002 max Pb 0.015 max                                                                                                                                                                                                                                                                                       |
| P07016                                                      | Ag 99.95 min Cu 0.05 max P 0.002 max Other total volatile impurities 0.010 max                                                                                                                                                                                                                                                                        |
| P07017                                                      | Ag 99.95 min C 0.005 max Cd 0.001 max Cu 0.05 max P 0.002 max Pb 0.002 max Zn 0.001 max                                                                                                                                                                                                                                                               |
| P07020                                                      | Ag 99.90 min Bi 0.001 max Cu 0.08 max Fe 0.002 max Pb 0.025 max Other Ag+Cu 99.95 min                                                                                                                                                                                                                                                                 |
| P07200                                                      | Ag 19.0-21.0 Cu 39.0-41.0 Mn 4.5-5.5 Zn 33.0-37.0                                                                                                                                                                                                                                                                                                     |
| P07250                                                      | Ag 24.0-26.0 Cu 37.0-39.0 Mn 1.5-2.5 Ni 1.5-2.5 Zn 31.0-35.0                                                                                                                                                                                                                                                                                          |
| P07251                                                      | Ag 24.0-26.0 Cd 12.5-14.5 Cu 34.0-36.0 Zn 24.5-28.5                                                                                                                                                                                                                                                                                                   |
| P07252                                                      | Ag 24.0-26.0 Cd 16.5-18.5 Cu 29.0-31.0 Zn 26.5-28.5                                                                                                                                                                                                                                                                                                   |

| <b>CHEMICAL COMPOSITIONS OF PRECIOUS METALS (Continued)</b> |                                                                                                 |
|-------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                  | <b>Chemical Composition</b>                                                                     |
| P07253                                                      | Ag 24.0-26.0 Cu 39.0-41.0 Sn 1.5-2.5 Zn 31.0-35.0                                               |
| P07300                                                      | Ag 29.0-31.0 Cd 19.0-21.0 Cu 26.0-28.0 Zn 21.0-25.0                                             |
| P07301                                                      | Ag 29.0-31.0 Cu 37.0-39.0 Zn 30.0-34.0                                                          |
| P07350                                                      | Ag 34.0-36.0 Cd 17.0-19.0 Cu 25.0-27.0 Zn 19.0-23.0                                             |
| P07351                                                      | Ag 34.0-36.0 Cu 31.0-33.0 Zn 31.0-35.0                                                          |
| P07380                                                      | Ag 37.0-39.0 Cu 31.0-33.0 Sn 1.5-2.5 Zn 26.0-30.0                                               |
| P07400                                                      | Ag 39.0-41.0 Cu 29.0-31.0 Ni 1.5-2.5 Zn 26.0-30.0                                               |
| P07401                                                      | Ag 39.0-41.0 Cu 29.0-31.0 Sn 1.5-2.5 Zn 26.0-30.0                                               |
| P07402                                                      | Ag 39.0-41.0 Cu 29.0-32.0 Zn 28.0-32.0 Other 0.15 max                                           |
| P07450                                                      | Ag 44.0-46.0 Cd 23.0-25.0 Cu 14.0-16.0 Zn 14.0-18.0                                             |
| P07453                                                      | Ag 44.0-46.0 Cu 29.0-31.0 Zn 23.0-27.0                                                          |
| P07454                                                      | Ag 44.0-46.0 Cu 26.0-28.0 Sn 2.5-3.5 Zn 23.0-27.0                                               |
| P07490                                                      | Ag 48.0-50.0 Cu 15.0-17.0 Mn 7.0-8.0 Ni 4.0-5.0 Zn 21.0-25.0                                    |
| P07500                                                      | Ag 49.0-51.0 Cd 17.0-19.0 Cu 14.5-16.5 Zn 14.5-18.5                                             |
| P07501                                                      | Ag 49.0-51.0 Cd 15.0-17.0 Cu 14.5-16.5 Ni 2.5-3.5 Zn 13.5-17.5                                  |
| P07502                                                      | Ag 49.0-51.0 Cd 9.0-11.0 Cu 17.0-19.0 Zn 20.0-24.0                                              |
| P07503                                                      | Ag 49.0-51.0 Cu 33.0-35.0 Zn 14.0-18.0                                                          |
| P07505                                                      | Ag 49.0-51.0 Cu 19.0-21.0 Ni 1.5-2.5 Zn 26.0-30.0                                               |
| P07507                                                      | Ag 49.0-51.0 Cu rem C 0.005 max Cd 0.001 max P 0.002 max Pb 0.002 max Zn 0.001 max              |
| P07540                                                      | Ag 53.0-55.0 Cu rem Ni 0.5-1.5 Zn 4.0-6.0                                                       |
| P07547                                                      | Ag 53.0-55.0 Pd rem C 0.005 max Cd 0.001 max Cu 20.0-22.0 P 0.002 max Pb 0.002 max Zn 0.001 max |
| P07560                                                      | Ag 55.0-57.0 Cu rem Ni 1.5-2.5                                                                  |
| P07563                                                      | Ag 55.0-57.0 Cu 21.0-23.0 Sn 4.5-5.5 Zn 15.0-19.0                                               |
| P07587                                                      | Ag 57.0-59.0 Pd rem C 0.005 max Cd 0.001 max Cu 31.0-33.0 P 0.002 max Pb 0.002 max Zn 0.001 max |
| P07600                                                      | Ag 59.0-61.0 Cr rem Sn 9.5-10.5                                                                 |
| P07607                                                      | Ag 59.0-61.0 Cu rem C 0.005 max Cd 0.001 max P 0.002 max Pb 0.002 max Sn 9.5-10.5 Zn 0.001 max  |
| P07627                                                      | Ag 60.5-62.5 Cu rem C 0.005 max Cd 0.001 max P 0.002 max Pb 0.002 max In 14.0-15.0 Zn 0.001 max |

| <b>CHEMICAL COMPOSITIONS OF PRECIOUS METALS (Continued)</b> |                                                                                                              |
|-------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                  | <b>Chemical Composition</b>                                                                                  |
| P07630                                                      | Ag 62.0-64.0 Cu 27.5-29.5 Ni 2.0-3.0 Sn 5.0-7.0                                                              |
| P07650                                                      | Ag 64.0-66.0 Cu 19.0-21.0 Zn 13.0-17.0                                                                       |
| P07687                                                      | Ag 67.0-69.0 Cu rem C 0.005 max Cd 0.001 max P 0.002 max Pb 0.002 max Pd 4.5-5.5 Zn 0.001 max                |
| P07700                                                      | Ag 69.0-71.0 Cu 19.0-21.0 Zn 8.0-12.0                                                                        |
| P07720                                                      | Ag 71.0-73.0 Cu rem                                                                                          |
| P07723                                                      | Ag 71.0-73.0 Cu rem Li 0.25-0.50                                                                             |
| P07727                                                      | Ag 71.0-73.0 Cu rem C 0.005 max Cd 0.001 max P 0.002 max Pb 0.002 max Zn 0.001 max                           |
| P07728                                                      | Ag 70.5-72.5 Cu rem C 0.005 max Cd 0.001 max P 0.002 max Pb 0.002 max Ni 0.3-0.7 Zn 0.001 max                |
| P07850                                                      | Ag 84.0-86.0 Mn rem                                                                                          |
| P07900                                                      | Ag 89.6-91.0 Cu 9.0-10.4 Al 0.005 max Cd 0.05 max Fe 0.05 max Ni 0.01 max P 0.02 max Pb 0.03 max Zn 0.06 max |
| P07925                                                      | Ag 92.0-93.0 Cu rem Li 0.15-0.30                                                                             |
| P07931                                                      | Ag 92.10-93.50 Cu 6.50-7.90 Cd 0.05 max Fe 0.05 max Pb 0.03 max Zn 0.06 max Other 0.06 max                   |
| P07932                                                      | Ag 92.50-93.50 Cu 6.50-7.50 Cd 0.05 max Fe 0.05 max Pb 0.03 max Zn 0.06 max Other 0.06 max                   |

# Chapter

# 8

## ***COPPER & COPPER ALLOYS***

Copper is one of the first metals used by humanity. Initially, the naturally occurring native copper was exploited but since at least 5000 BC copper has been produced as a smelted product. It was likely the first metal to be smelted from its ore as well as the first metal used in alloyed form. The copper-tin alloy bronze has been used since at least 3500 BC and the copper-zinc alloy brass since before Roman times. Copper and its alloys remain to this day among the most important engineering materials as a result of a combination of properties which include resistance to corrosion, outstanding electrical and thermal conductivity, attractive appearance, strength, ductility, and ease of fabrication and joining.

Copper is produced by the smelting of sulphide minerals. Since copper ores are generally low-grade, with copper contents well below 1%, they are first subjected to beneficiation to produce a concentrate. This concentrate is smelted, usually via pyrometallurgical processes, to impure "blister copper." Blister copper is fire refined to tough pitch copper, which contains at least 99.5%Cu with a significant content of copper oxide. Tough pitch copper is normally cast into anodes and refined electrolytically to produce electrolytic copper ( $\geq 99.95\%Cu$ ), also known as cathode copper, which is remelted and cast into shapes for further fabrication. Alloying can be carried out as desired during this final remelting. Some copper is extracted by hydrometallurgical methods, producing a copper-bearing aqueous solution from which refined copper is extracted by electrowinning. Processing of copper-bearing scrap is very common, with more than half of refined copper produced coming from recycled scrap.

About half of the copper consumption is processed in wire mills, for production of electrical conductors (wire and cable). Another 40% goes to brass mills where both unalloyed and alloyed copper products are produced. The unalloyed copper and high-copper alloys are typically produced as tube for plumbing and air conditioning, as well as bus bar and roofing sheet. The main copper alloy products are free-cutting brass



## **Corrosion Resistance**

Copper and its alloys are relatively resistant to general corrosion in most environments, but can be susceptible to stress corrosion cracking (e.g., brass in ammonia, amines, mercury compounds or cyanide). Some copper-based alloys in some environments suffer from hydrogen embrittlement by the steam reaction (e.g., tough pitch copper in reducing atmospheres). Brasses containing more than 15%Zn are also susceptible to dezincification, in which zinc is selectively removed by corrosion from the surface of the material, leaving a porous layer of copper and corrosion products.

## **Weldability**

Copper and its alloys are most frequently welded using GTAW (gas tungsten arc welding), or its pulsed variant, especially for thin sections, since high localized heat input is important in materials with high thermal conductivity. In thicker sections, GMAW (gas metal arc welding) is preferred. The weldability varies among the different alloys for a variety of reasons, including the occurrence of hot cracking in the leaded (free-machining) alloys and unsound welds in alloys containing copper oxide. Tin and zinc both reduce the weldability of copper alloys. The presence in the alloy of residual phosphorus is beneficial to weldability, since it combines with absorbed oxygen, thereby preventing the formation of copper oxide in the weld. Resistance welding is also widely used, particularly in alloys with low thermal conductivity. Most copper alloys can be brazed satisfactorily. Oxygen-bearing coppers can be subject to gassing and embrittlement, particularly in oxyacetylene welding.

## **Nomenclature**

Copper and its alloys were formerly given designations according to the Copper Development Association (CDA) system of three digits. This CDA system was used as the basis for the Unified Numbering System (UNS) designations, shown in Table 1. For copper and its alloys, the UNS system has come into common usage by all specification writing organizations.

The traditional system of temper designations referred to the amount of reduction in cold work, stated in Brown & Sharpe (B&S) gage numbers for rolled sheet and drawn wire. The current system defined in ASTM B 601 is more comprehensive; this assigns an alphanumeric code to each of the standard descriptive temper designations. Here cold worked tempers are defined by the letter H and 2 digits where the digits refer either to the amount of cold work or to the specific product. Other letter designations,

which are followed by digits used for many purposes, include: HR (cold worked and stress relieved), M (as manufactured), O and OS (annealed), TB (solution treated), TD (solution treated and cold worked), TF (solution treated and precipitation hardened), TM (mill hardened), TQ (quench hardened), and WH (welded and drawn).

| <b>Table 1 UNS Designations For Copper &amp; Copper Alloys</b> |                                                                   |
|----------------------------------------------------------------|-------------------------------------------------------------------|
| <b>UNS Designations - Wrought Alloys</b>                       |                                                                   |
| C10100-C15760                                                  | Coppers (>99%Cu)                                                  |
| C16200-C19600                                                  | High-copper alloys (>96%Cu)                                       |
| C21000-C28000                                                  | Brasses (Cu-Zn)                                                   |
| C31200-C38500                                                  | Leaded brasses (Cu-Zn-Pb)                                         |
| C40400-C48600                                                  | Tin brasses (Cu-Zn-Sn-Pb)                                         |
| C50100-C52400                                                  | Phosphor bronzes (Cu-Sn-P)                                        |
| C53400-C54400                                                  | Leaded phosphor bronzes (Cu-Sn-Pb-P)                              |
| C55180-C55284                                                  | Copper-phosphorus and copper-silver-phosphorus alloys (Cu-P-Ag)   |
| C60800-C64210                                                  | Aluminum bronzes and aluminum-silicon bronzes (Cu-Al-Ni-Fe-Si-Sn) |
| C64700-C66100                                                  | Silicon bronzes (Cu-Si-Sn)                                        |
| C66400-C69900                                                  | Other copper-zinc alloys                                          |
| C70100-C72950                                                  | Copper-nickels (Cu-Ni-Fe)                                         |
| C73500-C79800                                                  | Nickel silvers (Cu-Ni-Zn)                                         |
| <b>UNS Designations - Cast Alloys</b>                          |                                                                   |
| C80100-C81200                                                  | Coppers (>99%Cu)                                                  |
| C81400-C82800                                                  | High-copper alloys (>94%Cu)                                       |
| C83300-C84800                                                  | Red and leaded red brasses (Cu-Zn-Sn-Pb, 75-89%Cu)                |
| C85200-C85800                                                  | Yellow and leaded yellow brasses (Cu-Zn-Sn-Pb, 57-74%Cu)          |
| C86100-C86800                                                  | Manganese bronzes and leaded manganese bronzes (Cu-Zn-Mn-Fe-Pb)   |
| C87300-C87800                                                  | Silicon bronzes, silicon brasses (Cu-Zn-Si)                       |
| C90200-C94500                                                  | Tin bronzes and leaded tin bronzes (Cu-Sn-Zn-Pb)                  |
| C94700-C94900                                                  | Nickel-tin bronzes (Cu-Ni-Sn-Zn-Pb)                               |
| C95200-C95900                                                  | Aluminum bronzes (Cu-Al-Fe-Ni)                                    |
| C96200-C96800                                                  | Copper-nickels (Cu-Ni-Fe)                                         |
| C97300-C97800                                                  | Nickel silvers (Cu-Ni-Zn-Pb-Sn)                                   |
| C98200-C98800                                                  | Leaded coppers (Cu-Pb)                                            |
| C99300-C99750                                                  | Miscellaneous alloys                                              |



Copper and its alloys are discussed in this chapter in order of the UNS system general categories, i.e., wrought alloys first, beginning with coppers and high-copper alloys and moving through brasses, bronzes, copper-nickels and nickel silvers, followed by cast alloys in a similar order. It is important to note that although the terms brass and bronze can be clearly defined as copper-zinc and copper-tin alloys respectively, the common names are not always consistent with these definitions. In particular, the name "bronze" is applied to many different copper-based alloys. Hence, for example, Cu-10%Zn is called "commercial bronze" despite the fact that it is clearly a brass and is so categorized in the CDA and UNS designation systems.

### **Wrought Alloys - Coppers (UNS C10100-C15760)**

Unalloyed copper is widely used, mainly because of its high electrical conductivity, but also to take advantage of its attractive appearance, its corrosion resistance, ease of fabrication, and reasonable strength. These "coppers" are classified according to their oxygen and impurity contents since these have strong effects on electrical conductivity. Oxygen is normally present as copper oxide particles, often in the copper-copper oxide eutectic which forms interdendritically during ingot casting. Oxygen also forms a fine dispersion of blowholes which prevent pipe cavities from forming during ingot solidification. These are welded together during hot working.

The electrical conductivity, which is reported as %IACS (International Annealed Copper Standard), is affected by both oxygen and impurity atoms. Impurity atoms in solid solution degrade the conductivity, but if they can react with oxygen to form oxides they have a less detrimental effect. On the other hand, oxygen in the form of copper oxide can create problems when the material is heated above 400°C (752°F) in atmospheres containing hydrogen. The hydrogen atoms diffuse into the copper and reduce copper oxide particles to create steam under high pressure which can cause rupture along grain boundaries. This "steam embrittlement" creates problems during annealing, brazing, or welding in a reducing atmosphere.

In general, coppers have good resistance to corrosion by non-oxidizing acids unless the acids are aerated. Coppers also resist caustic solutions, saline solutions, and natural and process waters, including ground water. They are not used in oxidizing environments such as nitric acid, ammonia, ferric chloride, acid chromate solutions, mercury salts, perchlorates, or persulphates.

UNS C11000, the most common of the electrical coppers, is called electrolytic tough pitch (ETP) copper. It contains 0.02-0.04% oxygen, and less than 50 ppm total metallic impurities including sulphur. This gives it a conductivity of 101%IACS in annealed form. It is used for building sheet products, gaskets, radiators, fasteners, and chemical process equipment in addition to numerous electrical applications (wire, busbar, stranded conductors, switches, etc.).

There are many variations on ETP copper, including the oxygen-free coppers produced by remelting electrolytic copper under carefully controlled reducing atmospheres. Oxygen-free electronic copper (UNS C10100) and oxygen-free copper (UNS C10200) are used for electrical and electronic applications where their high conductivity (101%IACS) and high ductility are required.

UNS C12500 is fire refined tough pitch (FRTTP) copper, i.e., deoxidized copper which has not been electrolytically refined. It contains 500 to 3000 ppm of cuprous oxide, and is used for architectural, automotive, and electrical applications which are not demanding enough to require ETP copper.

Phosphorus is added to some alloys to tie up the oxygen as phosphorus pentoxide. If the amount of phosphorus is just sufficient to do this without leaving excess phosphorus in solid solution, these alloys retain high electrical conductivity (e.g., UNS C10800 and C12000 at greater than 90%IACS). Alternatively, excess phosphorus may be added (e.g., deoxidized high-phosphorus (DHP) copper UNS C12200) so that there is phosphorus available to provide deoxidation during hot working or annealing; this also increases the weldability. However, the electrical conductivity is lowered by the excess phosphorus, so that this alloy finds its major use as piping and tubing.

Small additions (a few tenths of a percent at most) of elements such as cadmium (UNS C11100, C14300) or silver (UNS C10400, C10500, C10700, C11300, C11400, C11500, C11600, C12900) are made to oxygen-free, ETP and FRTTP coppers in order to impart resistance to softening at slightly elevated temperatures, for example so that they can withstand the conditions encountered during soldering of automotive radiators or semiconductor packaging. Silver is especially useful in this respect as small amounts raise the recrystallization temperature markedly, while having little effect on electrical conductivity. The zirconium-coppers, such as UNS C15000 with 0.15%Zr, are heat-treatable by precipitation hardening and retain strength at temperatures as high as 450°C (842°F).

The machinability of these coppers is poor because of their high ductility, but some compositions have been developed specifically to counteract this deficiency. UNS C14500 and C14700 contain small additions of tellurium and sulphur, respectively, to make them free-machining for use in screw machine products requiring some combination of conductivity, corrosion resistance, colour, etc., for example electrical and plumbing components and fittings.

### **High-Copper Alloys (UNS C16200-C19600)**

These materials, sometimes referred to as dilute copper alloys, contain more than 96%Cu generally with more than 0.7% impurities and additions, including beryllium, cadmium, chromium, and iron. Many of the alloys in this classification are heat-treatable by precipitation hardening. The first stage of this process involves solution treating at temperatures above 750°C (1382°F) to take the alloying elements into solid solution, then quenching to create a supersaturated solid solution. This is then given an aging treatment at 260-500°C (500-932°F) to allow a fine dispersion of strengthening particles to precipitate from solution. The coarseness of the dispersion of particles determines the strength and ductility. If aging is carried out too long or at too high a temperature, the particles become too coarse, the strength falls below the maximum possible (the "peak aged" condition), and the alloy is said to be "overaged." The particles which precipitate from solution are generally intermetallic phases or non-equilibrium transition phases which are their precursors. For example, in the beryllium-copper system the precipitating intermetallic phase is (Cu,Co)Be, a mixed copper-cobalt beryllide.

The most important of the high-copper alloys are beryllium-copper alloys, which can be precipitation hardened to very high strength levels. There are two commercially important groups of beryllium-copper alloys, with different beryllium contents as well as additions of cobalt or nickel. One group, the "red" alloys, which includes alloys UNS C17500 and C17510, contains approximately 0.2-0.7%Be with additions of nickel or cobalt totaling 1.4-2.7%. These alloys maintain a moderate electrical conductivity (50%IACS) and yield strengths as high as 895 MPa (130 ksi) and find applications as fasteners and connectors, springs, switch parts, and spot welding tips. The higher alloyed "gold" alloys, such as UNS C17000 and C17200, contain 1.4-2.7%Be, which gives them their shiny lustrous colour, plus about 0.25%Co. These are even stronger than the "red" alloys, with yield strength as high as 1380 MPa (200 ksi). For enhanced machinability, lead additions can be made (UNS C17300) but electrical conductivity is as low as 20%IACS. These alloys are used for applications requiring high strength combined with good formability, for example in bellows, valves, pumps, rolling mill parts, and nonsparking

safety tools in addition to electrical and electronic components. The beryllium-copper alloys are available as rod, bar, flat products, tubing, billets, and forgings and extrusions.

Among other precipitation-hardening alloys in this series are UNS C18200 and C18400 which are chromium-copper alloys with excellent cold workability and good hot workability. These find applications in welding equipment. The copper-nickel-phosphorus alloys UNS C19000 and C19100 are also precipitation hardenable.

High-copper alloys which are not heat-treatable include the leaded free-machining copper UNS C18700 (Cu-1%Pb) and the copper-iron-phosphorus alloys UNS C19200, C19210, C19400, C19500, and C19700. Many of these latter alloys are selected for use where a combination of high strength and conductivity is required. Other attractive properties of individual alloys in this group include formability and resistance to softening and stress corrosion. They are used for electrical and electronic components; UNS C19200 and C19210 are also used for tubing in automotive, heat exchanger, and air conditioning applications.

### **Brasses (UNS C21000-C28000)**

The brasses are a very large family of alloys based on the copper-zinc system. Commercial brasses contain up to about 40% zinc, and some also contain small amounts (up to about 5%) of alloying elements such as tin, aluminum, silicon, manganese, and lead. Alloys containing up to about 30%Zn are solid solutions; these are referred to as  $\alpha$ -solid solutions, hence the brasses are known as  $\alpha$ -brasses. These solid solution alloys are not heat-treatable but are solid solution strengthened and can be strengthened further by cold work. Among them are the very widely used Cu-30%Zn alloy known as cartridge brass, which has the optimum combination of strength and ductility, maintaining the high formability of copper.

In these alloys increasing zinc content increases the strength and ductility, while the colour changes from red through gold to green-yellow. The ductility reaches a maximum at about 30%Zn. All of these alloys have excellent cold workability and alloys up to about 20%Zn have good hot workability as well, provided that the lead content is very low. They are used in some cases after plating with chromium or nickel

If the zinc content is higher than the solubility limit, e.g. 40%Zn, the microstructures consist of a mixture of the  $\alpha$ -solid solution with a body-centered cubic solid solution known as the  $\beta$  phase; hence, alloys such as this are known as  $\alpha$ - $\beta$  brasses. The most common of these alloys is Cu-

40%Zn, known as Muntz metal (UNS C28000). In fact, during cooling of these alloys, the  $\beta$  phase transforms at about 465°C (869°F) to an ordered  $\beta'$  phase, which has higher strength and much lower ductility than the  $\beta$  phase. The strengths of these alloys increase with increasing zinc content up to about 45%Zn. However, the presence of the  $\beta$  phase reduces the ductility of these brasses and makes them difficult to cold work, although it does make them more machinable. These alloys can be readily hot worked since at hot working temperatures they consist entirely of  $\beta$  phase. For example, a 40%Zn alloy is single phase  $\beta$  above 760°C (1400°F).

Another consequence of the phase behaviour of these  $\alpha$ - $\beta$  alloys is that they are heat-treatable since at high temperature the  $\beta$  phase is stable while at lower temperatures the stable state is a two-phase  $\alpha$ - $\beta$  mixture. Thus if the alloy is quenched from above 760°C (1400°F) to  $\alpha$  temperature in the range 500-700°C (932-1292°F), particles of the  $\alpha$  phase can be made to precipitate in the  $\beta$  matrix, which becomes  $\beta'$  on further cooling. Although the  $\beta'$  phase is too brittle to be useful, alloys in which it co-exists with precipitated  $\alpha$  phase have useful properties, depending on the precise heat treatment and resultant microstructure.

This series of plain copper-zinc brasses includes alloys with zinc contents ranging upward from 5%. The 5%Zn alloy UNS C21000 is known as gilding metal. UNS C22000 and C22600, containing 10% and 12.5%Zn, are called commercial bronze and jewelry bronze respectively, despite being brasses. UNS C23000, which contains 15%Zn, is known as red brass; UNS C24000, containing 20%Zn, is called low brass; while cartridge brass, UNS C26000, contains 30%Zn. Yellow brass, UNS C26800 and C27000, contains approximately 35%Zn while C28000, Muntz metal, contains 40%Zn.

The lower zinc alloys are used for jewelry and coinage applications and as a base for gold plate and enamel. The mid-range zinc alloys are also suitable for these applications but in addition find usage in architectural, hardware, fasteners, and munitions applications. The higher zinc material is used in applications where greater strength is important. For example cartridge brass is very widely used in such applications as architectural grillwork, automotive radiator cores and tanks, lamp fixtures, locks, plumbing fittings, and pump cylinders. Muntz metal with its attractive hot workability and machinability is used in architectural panels, in heavy plate for structural applications, and as bolting, valve stems, and forgings.

**Leaded Brasses (UNS C31200-C38500)**

This is a series similar to the brasses described above but with small lead contents in order to make them machinable. Lead is insoluble in the solid solution matrix of these alloys. It exists in the microstructure as small inclusions of metallic lead, which act as chip breakers during machining, thus making them free-machining. This has little effect on strength; however, since these lead particles melt at low temperatures, their presence dramatically reduces the hot workability of the alloys.

These alloys are referred to as medium leaded brasses when their lead content is about 1%, high leaded at 2%, and extra high leaded at 2.5%Pb. UNS C31400 is commercial bronze (9%Zn) with 2%Pb; a variant UNS C31600 also contains 1%Ni. These are used for hardware and electrical applications. UNS C33000, C33200, C33500, and C34000 contain 32-35%Zn with 0.5 -2%Pb and are used when both machinability and cold working properties are required, as in plumbing, hardware, and munitions applications. Leaded alloys containing slightly higher zinc content (up to about 37% but still solid solution alloys), such as UNS C34200, C35000, C35600, and C36000 are used for products such as gears, pinions, wheels, key and lock components, valve stems, and parts for clocks and meters.

Higher zinc contents cause the structure to consist of  $\alpha$  and  $\beta$  phases as in the unleaded brasses discussed above. Copper alloys UNS C36500 (uninhibited leaded Muntz metal) contains about 40%Zn with 0.6%Pb. The addition of about 0.1% of arsenic, antimony, or phosphorus serves to provide high resistance to dezincification, giving applications as tube sheets in condensers and heat exchangers. UNS C37000 (free-cutting Muntz metal) has 39%Zn and 1%Pb for use in automatic screw machine parts. Architectural bronze, UNS C38500 (40%Zn, 3%Pb), is used for such architectural components as trim, as well as hardware.

Although the presence of lead is normally seriously detrimental to hot workability, as discussed above, the leaded high zinc brasses can be hot worked because the lead goes into solution in the  $\beta$  phase which is predominant at high working temperatures. Thus UNS C37700, forging brass (38%Zn, 2%Pb), is the standard against which the forging qualities of all other copper alloys are judged.

**Tin Brasses (UNS C40400-C48600)**

This series of alloys includes material with zinc ranging from 3% to 40% and tin ranging from 0.5% to about 2% (a few as high as 5%). The presence of small amounts of tin in these alloys improves their strengths,

as well as their corrosion resistance in sea water. For this reason cartridge brass (30%Zn) containing 1% tin is called "admiralty metal," while Muntz metal (40%Zn) containing 1% tin is called "naval brass." The leaded alloys in this series, as in the UNS C3xxxx series, contain lead for improved machinability, but at the expense of hot workability.

Alloys in this series containing <15%Zn find applications as rolled strip, bar, and sheet for such purposes as electrical switch springs, terminals and connectors. Examples are UNS C41500 (7%Zn, 2%Sn), C42200 (11%Zn, 1%Sn), and C43400 (14%Zn, 1%Sn). UNS C43500 (18%Zn, 1%Sn), with its higher strength is used as strip and tubing, for example in musical instruments. Small amounts of arsenic, antimony and phosphorus can be added to the higher zinc alloys in this series, as in the UNS C3xxxx series, in order to inhibit dezincification. This creates inhibited admiralty metal, which contains 28%Zn, 1%Sn, and 0.06% of either arsenic (UNS C44300, arsenical admiralty metal), antimony (UNS C44400, antimonial admiralty metal), or phosphorus (UNS C44500, phosphorized admiralty metal). Applications include tubes and other components of heat exchangers, condensers, and distillation equipment. Naval brass (39%Zn, 1%Sn) is available in uninhibited form (UNS C46400) or inhibited by the same three elements (UNS C46500, C46600, 46700, respectively), for use in marine hardware, shafts, fittings, and fasteners. Uninhibited naval brass is also available as a medium- or high-leaded alloy (UNS C48200 and C48500, respectively) with improved machinability for hardware and screw machine products.

### **Phosphor Bronzes (UNS C50100-C52400) and Leaded Phosphor Bronzes (UNS C53400-54400)**

Phosphor bronzes are copper-tin alloys with small amounts of phosphorus added to improve ingot castability and to act as a deoxidizer. These alloys are stronger than the brasses and can be cold worked to even higher strength. They also have good resistance to wear and to sea water corrosion as well as to stress corrosion. Their cold formabilities are good, but not as good as brass, and they have a poor capacity for hot forming.

In the copper-tin system, the maximum solubility of tin in copper is about 16% as compared to almost 40%Zn in the copper-zinc system. However, non-equilibrium microstructures are common in copper-tin alloys, since many of the phase transformations are very sluggish. For example, the phase diagram predicts that the  $\epsilon$  phase should be present at room temperature; however, this is not observed in alloys containing less than 5%Sn, and commonly annealed alloys of 8%Sn are single phase solid solutions. When the solubility limit is exceeded, it is often the  $\delta$  phase which is observed at room temperature, even though the phase diagram

predicts that this phase is unstable below 350°C (662°F). The hardness of the  $\delta$  phase contributes to wear resistance of the alloys and improves their suitability for use as bearing materials.

If phosphorus is present in excess of that required for deoxidation, it occurs as the hard intermetallic compound  $\text{Cu}_3\text{P}$ , which can have a strengthening effect. Most of the phosphor bronzes contain about 0.2%P, which is sufficient for purposes of deoxidation, while tin contents range up to above 10%. Most alloys are produced as flat products, bar, rod, wire, and tubing. Common alloys include UNS C50500 (1.3%Sn), which is used in such applications as electrical hardware, and UNS C51000 (5%Sn) and C51100 (4%Sn) which are used for architectural, electrical, fasteners, and industrial components. For more severe service conditions, higher tin alloys are employed, including UNS C52100 (8%Sn) and C52400 (10%Sn). Examples of specific applications include bridge bearing and expansion plates and fittings, Bourdon tubes, fasteners, chemical hardware, and textile machinery components.

In addition to these lead-free alloys, there is a free-machining phosphor bronze, UNS C54400, which contains 4% of each of tin, lead, and zinc. This is used for bearings, bushings, gears, and screw machine products.

### **Aluminum Bronzes (UNS C60800-C64210)**

These materials have good strength properties, with good resistance to wear and corrosion; the latter property is due to the formation of a protective surface film of aluminum oxide. This gives them resistance to non-oxidizing mineral acids as long as dissolved oxygen or oxidizing agents are not present in quantity. As well, they are suitable for service in alkalis, neutral salts, non-oxidizing acid salts, and many organic acids. They have good resistance to corrosion by water, including sea water, although resistance is less in softened water. They are susceptible to stress corrosion cracking in moist ammonia and mercury compounds.

The commercial alloys in this system contain 5-13%Al with minor amounts of nickel, iron, silicon, and cobalt. In these alloys, a range of microstructures can be obtained depending on composition and heat treatment. Alloys containing 5-8%Al are solid solution alloys similar to the  $\alpha$ -brasses. Aluminum is a highly effective solid solution strengthening agent, comparable to tin and much more effective than zinc; hence, these alloys have good strength (increasing with aluminum content) as well as good toughness, cold workability, and corrosion resistance. Examples include UNS C60800 (5%Al) which is used in the form of seamless tubing for heat exchangers and condensers, and UNS C61000 (8%Al) which is produced as rod and wire for bolts, shafts and



pump parts. It is also used as a weld overlay on steel for improved wear resistance. Alloys UNS C61300 (7%Al with 3%Fe and 0.3%Sn) and C61400 (7%Al with 2%Fe) are both used as seamless tubing and pipe as well as rod, bar, plate, and sheet for various condenser and heat exchanger applications. The microstructures of the latter two alloys exhibit precipitates of an iron-rich phase in the solid solution.

At higher aluminum contents the alloys become heat-treatable, with duplex microstructures consisting of mixtures of the  $\alpha$ -solid solution with metastable  $\beta$  phase particles, for example UNS C62300 (10%Al, 3%Fe) and C62400 (11%Al, 3%Fe). In addition, precipitates of an iron-rich phase may also be present. The precise microstructural features depend on the heat treatment, including the cooling rate. Above about 9.5%Al, a eutectoid decomposition can occur during slow cooling, as the high temperature  $\beta$  phase decomposes to a lamellar mixture of  $\alpha$ -solid solution and the intermetallic  $\gamma_2$  phase. This lamellar structure is comparable to that of pearlite in the iron-carbon system and in fact is sometimes referred to by that name. The eutectoid composition in this system is 11.8%Al, so hypereutectoid or hypoeutectoid alloys (containing more or less aluminum than the eutectoid amount) develop slow cooled microstructures consisting of pearlite with proeutectoid  $\gamma_2$  phase and  $\alpha$  phase, respectively. One commercial hypereutectoid alloy is UNS C62500 (13%Al, 4%Fe) which has low ductility and impact resistance because of the presence of the brittle  $\gamma_2$  phase, but finds applications as wear strips and as metal forming dies and rolls.

The brittleness of the  $\gamma_2$  phase makes its presence undesirable in these alloys, although it does improve machinability. However, as in the iron-carbon system, quenching from the  $\beta$  phase region causes the microstructure to transform to needles of a  $\beta'$ -martensite phase which is metastable and hence does not appear on the phase diagram. Unlike iron-carbon martensite, this martensite does not have a particularly high strength; however, it can be strengthened appreciably by tempering in the range 400-650°C (752-1202°F). The microstructure after tempering consists of a fine dispersion of the  $\gamma_2$  phase in an  $\alpha$  phase matrix. This provides a good combination of strength and ductility, which can be controlled by controlling the aging time and temperature.

Additions of up to 5%Fe and 5%Ni render these alloys especially strong and tough, with excellent high temperature oxidation and corrosion resistance. This provides applications as high strength fasteners, gear wheels, pump parts, and structural members. Alloys available include UNS C63000 (10%Al, 5%Ni, 3%Fe) and C63200 (9%Al, 5%Ni, 4%Fe).

UNS C63800 (3%Al, 2%Si, 0.4%Co) is a high strength aluminum bronze in which the presence of cobalt is responsible for strengthening by a dispersion of intermetallic particles. This alloy also has excellent resistance to crevice corrosion and to high temperature oxidation and is used for springs, switch parts, contacts, glass sealing, and porcelain enamelling.

### **Silicon Bronzes (UNS C64700-C66100)**

These alloys contain 1-3%Si, with small additions of manganese and iron to improve properties. They are not heat treatable but can be cold worked to high strength levels. Their combination of corrosion resistance with high strength and toughness compares favourably to that of low-carbon steels.

Low-silicon bronze UNS C65100 (1.5%Si), available in bar, rod, wire, and shapes as well as tubular and flat products, is used for aircraft hydraulic pressure lines, heat exchanger tubes, and marine and industrial hardware and fasteners. The high-silicon bronze UNS C65500 (3%Si) is used for similar applications as well as for chemical process equipment and marine propeller shafts.

### **Copper-Nickels (UNS C70100-C72950)**

Nickel has complete solid solubility in copper so that a continuous range of solid solution copper-nickel alloys is possible, all with the fcc crystal structure. The cupronickel alloys containing 10-30%Ni have moderate strength provided by the nickel which also improves the oxidation and corrosion resistance of copper. These alloys have good hot and cold formability and are produced as flat products, pipe, rod, tube, and forgings. The common alloys are UNS C70600 (10%Ni), C71000 (20%Ni), and C71500 (30%Ni). These find applications as plates and tubes for evaporators, condensers, and heat exchangers as well as for saltwater piping. The alloy UNS C71900 (30%Ni, 3%Cr) is similar to UNS C71500 but the chromium content permits it to undergo spinodal decomposition during slow cooling. This produces a two-phase microstructure, giving higher strength for a given amount of cold work. The tin-bearing copper-nickel UNS C72500 (10%Ni, 2.5%Sn) has excellent hot and cold formability in a wide range of forming processes, as well as excellent resistance to sea water. It is used for relay and switch springs, connectors, sensing bellows, and as a brazing alloy.

**Nickel Silvers (UNS C73500-C79800)**

Although these alloys are referred to as German silvers or nickel silvers, they contain no silver; they are copper-nickel-zinc alloys containing zinc in the range 17-27% along with 8-18%Ni. The use of the name silver arises from their colour, which ranges from soft ivory to silvery white as the nickel content is increased. Most of these alloys are single phase solid solutions, and have medium strengths with good cold workability. Corrosion resistance is excellent, but some are subject to dezincification and they can be susceptible to stress corrosion cracking as well.

Commercial alloys include UNS C74500 (25%Zn, 10%Ni), C75200 (17%Zn, 18%Ni), C75400 (20%Zn, 15%Ni), C75700 (23%Zn, 12%Ni), and C77000 (27%Zn, 18%Ni). Specific applications include hardware, fasteners, optical and camera parts, etching stock, and hollowware. They are particularly appropriate for articles which require a smooth surface for plating. The alloy UNS C78200 (25%Zn, 8%Ni) also contains 2%Pb to provide free-machining properties, making it suitable for use as key blanks and watch parts.

**Cast Alloys**

The cast copper alloys are generally comparable to the wrought alloys, however the ranges of allowable impurity and alloying elements are often larger in castings, as no consideration need be given to their effects on cold or hot workability. On the other hand, consideration must be given to castability, which is related to solidification shrinkage characteristics and the temperature range over which freezing occurs. Foundry alloys are conveniently classified as high-shrinkage or low-shrinkage alloys. Among the common high-shrinkage alloys are the manganese bronzes, aluminum bronzes, and silicon bronzes; the red brasses are low-shrinkage alloys. High-shrinkage alloys can produce high grade castings, but careful design is necessary to avoid internal shrinkage porosity and cracks.

Pure copper is extremely difficult to cast, with the potential for surface cracks and internal cavities. Small additions of alloying elements improve the casting characteristics, but for property improvement, larger amounts of alloying elements are necessary. In particular, for higher strength cast alloys, it is necessary to select aluminum bronzes, manganese bronzes, silicon bronzes, or some nickel silvers.

Sand casting is appropriate for all copper alloys. Permanent mold casting and die casting are applicable to tin bronzes, silicon bronzes, aluminum bronzes, and manganese bronzes, as well as to yellow brasses.

Investment casting is also applicable to many of these alloys, while plaster casting is most suitable for low-lead alloys. Most casting alloys are readily machinable, especially those containing lead particles in a copper-based solid solution. The most difficult alloys to machine are the high strength manganese bronzes and aluminum bronzes with high iron or nickel content.

### **Coppers (UNS C80100-C81200) and High Copper Alloys (UNS C81400-82800)**

The high purity copper casting alloys, such as UNS C81100 (99.7%Cu), are soft and low in strength, but can be used in applications requiring electrical and thermal conductivity along with resistance to corrosion and oxidation. However, many high copper alloys are available which give better strength while retaining good conductivity. These are typically heat-treatable alloys containing more than 96%Cu with small amounts of chromium or beryllium and various combinations of silicon, cobalt, and nickel. Examples include the precipitation-hardenable chromium coppers UNS C81400 (0.8%Cu, 0.06%Be) and C81500 (1%Cr), used as electrical and/or thermal conductors which are also structural members. The heat-treatable low-beryllium casting coppers, containing about 0.5%Be, in which the silver content provides improved surface conductivity, includes UNS C82000 (2.5%Co, 0.5%Be) which is used for circuit breaker and switch gear parts and continuous casting molds, and UNS C82200 (1.5%Ni, 0.5%Be) whose uses include brake drums and clutch rings. In addition, these three low beryllium alloys find applications as components of welding equipment, such as electrodes, holders, tips, etc.

The high-strength precipitation-hardenable high-beryllium alloys often include cobalt for grain size control and silicon for improved castability. These alloys include UNS C82500 (2%Be, 0.5%Co, 0.25%Si) which is especially suited for investment casting and finds applications as safety (non-sparking) tools, machine components, and structural parts. Several modifications to this alloy are available, including UNS C82400 (1.7%Be, 0.3%Co), a lower cost, high toughness alloy which is used in marine applications, UNS C82800 (2%Be, 0.5%Co, 0.25%Si) which is a highly castable alloy used for molds for forming of plastics as well as for precision cast parts for the communications, textile, aerospace, and business machine industries, and beryllium-copper 21C (2%Be, 1%Co) which is desirable for thin section castings because of the grain-refining effect of the cobalt.

**Red Brasses/Leaded Red Brasses (UNS C83300-C84800) and Yellow Brasses/Leaded Yellow Brasses (UNS C85200-C85800)**

The red brass casting alloys contain copper in the range of 75 - 89%, giving them a more reddish colour than the higher-zinc alloys which are called yellow brasses. The leaded red brasses are readily castable. These include the most common of the copper casting alloys UNS C83600 (5%Sn, 5%Pb, 5%Zn), also known as "ounce metal," and its modification UNS C83800 (4%Sn, 6%Pb, 7%Zn). These alloys have moderate strength, ductility and corrosion resistance with good machinability and castability, and are used for plumbing goods, general household and machinery hardware and fixtures, hydraulic and steam valves, impellers, injectors, and statuary. As the zinc content of these cast alloys increases, the cost and the mechanical properties both decrease. The alloys UNS C84400 (3%Sn, 7%Pb, 9%Zn) and C84800 (2.5%Sn, 6.5%Pb, 15%Zn), with their higher zinc contents, are sometimes referred to as "semi-red" brasses, while the leaded yellow brasses include UNS C85200 (1%Sn, 3%Pb, 24%Zn), C85400 (1%Sn, 3%Pb, 29%Zn), and C85700/C85800 (1%Sn, 1%Pb, 35%Zn). These are used for low pressure valves and fittings, as well as general hardware, ornamental castings, and especially as plumbing fittings and fixtures.

All of these red, semi-red, and yellow brasses are suitable for chromium or nickel plating after appropriate surface treatment.

**Manganese Bronzes and Leaded Manganese Bronzes (UNS C86100-C86800)**

These alloys, along with the aluminum bronzes discussed below, are higher strength materials than the cast brasses, with some having strengths well above 700 MPa (100 ksi) and with good castability and machinability. In fact, the manganese bronzes are better described as modified high-strength yellow brasses, with zinc contents in the range of 24-40%, along with 0.5-4%Mn, and varying amounts of nickel, tin, aluminum, and iron. The tin additions are made to enhance resistance to dezincification, and some also contain lead additions for improved machinability, but these additions are often detrimental to strength and ductility. The manganese bronzes are not heat treatable, but are available with a range of strengths. They find applications as marine propellers and fittings, ball bearing races, architectural components, and high strength structural components such as bridge trunnions, gears, and bearings. The lower-zinc, higher strength commercial manganese bronzes include the alloys UNS C86100/86200 (24%Zn, 3%Fe, 5%Al, 4%Mn) and C86300 (26%Zn, 3%Fe, 3%Al, 4%Mn). The higher-zinc alloys include UNS C86500 (39%Zn, 1.3%Fe, 1%Al, 0.5%Mn), as well as the

leaded manganese bronze UNS C86400 (37%Zn, 1%Sn, 1%Pb, 1%Fe, 1%Al, 0.5%Mn), and the nickel-manganese bronze UNS C86800 (35%Zn, 0.5%Sn, 3%Ni, 2%Fe, 1%Al, 3%Mn).

### **Silicon Bronzes and Silicon Brasses (UNS C87300-C87800)**

Although these alloys generally have higher strengths than the red brasses, their applications are often based on superior corrosion resistance under particular service conditions. The silicon bronze alloy known as Everdur (UNS C87300 - 4%Si, 1%Mn) is used as a substitute for tin bronze in bearings, bells, pump and valve components, and in statuary and art castings. The silicon brasses cover a range of zinc contents. Low- and moderate-zinc varieties including UNS C87600 (4.5%Si, 5.5%Zn), C87610 (4%Si, 4%Zn), and C87500/C87800 (4%Si, 14%Zn) find applications similar to those of UNS C87300.

### **Tin Bronzes and Leaded Tin Bronzes (UNS C90200-C94500)**

Cast copper-tin alloys can sustain higher tin contents than the wrought tin bronzes, which are limited to about 10%Sn for reasons of workability. Many cast alloys contain less tin than this, along with additions of zinc, nickel, and lead, but alloys with tin contents up to 20% are available. Tin bronzes are used when higher strength, leak tightness or corrosion resistance are desired or at higher temperatures than the red or semi-red brasses can tolerate. The maximum operating temperature is about 290°C (554°F) for bronzes with tin contents of less than about 8%; above this tin content the precipitation of a brittle tin-rich intermetallic phase limits the operating temperature to below about 260°C (500°F). Nickel additions to tin bronzes increase density and leak tightness, as well as making the alloy heat treatable above 5%Ni. An example is UNS C94700 (5%Sn, 2%Zn, 5%Ni).

One of the major applications for cast tin bronzes, leaded and unleaded, is as bearing materials. Alloys with high tin and phosphorus (up to 1%) contents such as UNS C91100 (16%Sn) and C91300 (19%Sn) are used in bridge turntables, where loads are high and rotational motion is slow. The phosphorus is normally added for deoxidation and strengthening along with, in some cases, nickel for control of the grain size and the distribution of lead particles.

The cast unleaded tin bronzes include UNS C90300 (8%Sn, 4%Zn), C90500 (10%Sn, 2%Zn), sometimes known as gun metal, and the gear bronzes UNS C90700 (11%Sn) and C91700 (12%Sn, 1.5%Ni). These are used as pump and valve components, as well as bearings, bushings, and gears.

A wide variety of leaded tin bronzes is available. Lead at levels up to 3% is added to tin bronzes to increase machinability, but it also decreases ductility so lower tin content is sometimes used in compensation. Common leaded tin bronzes include steam bronze (also known as Navy M bronze) UNS C92200 (6%Sn, 1.5%Pb, 4.5%Zn), Navy G bronze UNS C92300 (8%Sn, 1%Pb, 4%Zn), and UNS C92600 (10%Sn, 1%Pb, 2%Zn). The high lead tin bronzes, such as UNS C93200 (7%Sn, 7%Pb, 7%Zn), C93400 (8%Sn, 8%Pb), and C93700 (10%Sn, 10%Pb) are used where a soft bearing or bushing metal is required, at low loads and speeds, especially where lubrication may be deficient. Where loads are higher and lubrication conditions more problematic, or where corrosion or dusty atmospheres inhibit lubrication, even higher lead alloys are used, including UNS C93800 (7%Sn, 15%Pb) and C94300 (5%Sn, 25%Pb). This situation may apply for example, in bearings for railway and mine locomotives and rail cars or equipment for crushing plants in the stone and cement industries.

### **Aluminum Bronzes (UNS C95200-C95900)**

Like the wrought aluminum bronzes discussed above, these are high strength alloys, containing aluminum along with iron, manganese, and nickel. As for wrought alloys, those with aluminum contents between 9.5% and 11.5%, along with iron, are heat treatable by quenching and tempering to strengths well above 700 MPa (100 ksi). They have high ductility and toughness compared to the tin bronzes, and can be used at higher temperatures than the manganese bronzes.

Like tin and manganese bronzes, aluminum bronzes find applications as bearing and bushing alloys. The lower (8-9%) aluminum alloys are used for light-duty or high-speed machinery, while increasingly higher aluminum contents have higher hardness properties suitable for heavy duty applications such as rolling mill bearings, screwdown nuts, guides and aligning plates, and dies.

The higher strength properties of the aluminum bronzes are accompanied by less desirable behaviour in respect to other properties. The high aluminum alloys are generally less resistant to corrosion because they contain aluminum-rich phases which can be susceptible to preferential attack in some environments. They are unsuitable for use in oxidizing acids. Their machinabilities range from moderate to difficult.

Commercially available non-heat-treatable aluminum bronzes include UNS C95200 (9%Al, 3%Fe) which is used for acid-resisting pumps, gears, and valve seats, and the manganese-aluminum bronze UNS C95700 (8%Al, 3%Fe, 2%Ni, 12%Mn) which is used for propellers, impellers, and

marine fittings. The heat-treatable alloys include UNS C95400/C95410 (11%Al, 4%Fe) and C95500 (11%Al, 4%Fe, 4%Ni), which are used for valve guides and seats, bushings, gears, and impellers. Alloy UNS C95800 (9%Al, 4%Fe, 4%Ni, 1%Mn) has higher resistance to cavitation and sea water fouling and so is especially suited for marine applications such as propeller blades and hubs.

**Copper-Nickels (UNS C96200-C96800),  
Nickel Silvers (UNS C97300-97800) and  
Miscellaneous Alloys (UNS C99300-99750)**

The common cast copper nickels are the solid solution alloys UNS C96200 (10%Ni) and C96400 (30%Ni) which are used for their sea water corrosion resistance as centrifugal and sand castings for valves, pump components, etc. A heat-treatable beryllium cupronickel, UNS C96600 (30%Ni, 0.5%Be), has about twice the strength of C96400 while maintaining sea water corrosion resistance for applications as pressure housings, pump and valve bodies, and line fittings for marine service. For improved castability, a higher-beryllium cupronickel 72C (30%Ni, 1.2%Be) is also available with applications in the plastic tooling industry. Leaded nickel silver alloys are used for investment, centrifugal, permanent mold, and sand castings for hardware fittings, valves, statuary, and ornamental castings. Alloys include UNS C97300 (12%Ni, 20%Zn, 10%Pb, 2%Sn), C97600 (20%Ni, 8%Zn, 4%Pb, 4%Sn), and C97800 (25%Ni, 2%Zn, 1.5%Pb, 5%Sn).

Alloys developed for resistance to dezincification and/or dealuminification under corrosion conditions are UNS C99400 (2%Ni, 2%Fe, 1%Al, 1%Si, 3%Zn) and the higher strength equivalent alloy UNS C99500 (4%Ni, 4%Fe, 1%Al, 1%Si, 1%Zn). Uses include valves, wheels, gears, and electrical parts for mining equipment and the outboard marine industry.



| <b>SAE/AMS SPECIFICATIONS - COPPER &amp; COPPER ALLOYS</b> |                                                                                                                                                         |
|------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                 | <b>Title</b>                                                                                                                                            |
| 4500                                                       | Copper Sheet, Strip, and Plate, Soft Annealed, UNS C11000                                                                                               |
| 4501                                                       | Copper Sheet, Strip, and Plate, Oxygen-Free, Light Cold Rolled, UNS C10200                                                                              |
| 4505                                                       | Brass Sheet, Strip, and Plate, 70Cu - 30Zn, Annealed (O61), UNS C26000                                                                                  |
| 4507                                                       | Brass Sheet, Strip, and Plate, 70Cu - 30Zn, Annealed, UNS C26000                                                                                        |
| 4508                                                       | Brass Sheet, Laminated, 70Cu - 30Zn, Surface Bonded                                                                                                     |
| 4510                                                       | Phosphor Bronze Sheet, Strip, and Plate, 94.5Cu - 5.0Sn - 0.19P, Spring Temper (H08), UNS C51000                                                        |
| 4511                                                       | Copper-Beryllium Alloy Castings, 97Cu - 2.1Be - 0.52(Co + Ni) - 0.28Si, Solution and Precipitation Heat Treated (TF00), UNS 82500                       |
| 4520                                                       | Bronze Strip, 88.5Cu - 4.0Sn - 4.0Pb - 3.0Zn - 0.26P, Cold Rolled, Half Hard (H02), UNS C54400                                                          |
| 4533                                                       | Copper-Beryllium Alloy Bars and Rods, 98Cu - 1.9Be, Solution and Precipitation Heat Treated (TF00, formerly AT), UNS C17200                             |
| 4534                                                       | Copper-Beryllium Alloy, Bars and Rods, 98Cu - 1.9Be, Solution Heat Treated, Cold Worked, and Precipitation Heat Treated (TH04, formerly HT), UNS C17200 |
| 4535                                                       | Copper-Beryllium Alloy, Mechanical Tubing, 98Cu - 1.9Be, Solution and Precipitation Heat Treated (TF00, formerly AT), UNS C17200                        |
| 4553                                                       | Brass Tubing, Seamless, 85Cu - 15Zn, UNS C23000                                                                                                         |
| 4554                                                       | Brass Tubing, Seamless, 66.5Cu - 33Zn - 0.45Pb, Annealed, UNS C33000                                                                                    |
| 4555                                                       | Brass Tubing, Seamless, 66.5Cu - 32.5Zn - 0.48Pb, Light Annealed (O50), UNS C33000                                                                      |
| 4558                                                       | Brass Tubing, Seamless, 66.5Cu - 31.5Zn - 1.6Pb, Drawn Temper (H58), UNS C33200                                                                         |
| 4590                                                       | Extrusions, Nickel-Aluminum Bronze, Martensitic, 78.5Cu - 10.5Al - 5.1Ni - 4.8Fe, Solution Heat Treated and Tempered (T050), UNS C63020                 |
| 4602                                                       | Copper Bars, Rods, and Shapes, Oxygen-Free, Hard Temper (H04), UNS C10200                                                                               |
| 4610                                                       | Brass Bars and Rods, Free-Cutting, 61.5Cu - 3.1Pb - 35Zn, Half Hard (H02), UNS C36000                                                                   |
| 4611                                                       | Brass Bars and Rods, Naval, 60.5Cu - 38.7Zn - 0.8Sn, Half Hard (H02), UNS C46400                                                                        |
| 4612                                                       | Brass Rods and Bars, Naval Brass, 60.5Cu - 38.5Zn - 0.75Sn, Hard Temper (H04), UNS C46400                                                               |
| 4614                                                       | Brass Forgings, Free Cutting, 60Cu - 2.0Pb - 37.5Zn, As Forged (M10), UNS C37700                                                                        |
| 4616                                                       | Silicon Bronze Bars, Rods, Forgings, and Tubing, 92Cu - 3.2Si - 2.8Zn - 1.5Fe, Stress Relieved, UNS C65620                                              |
| 4625                                                       | Phosphor Bronze Bars, Rods, and Tubing, 95Cu - 5Sn, Hard Temper, UNS C51000                                                                             |
| 4633                                                       | Bronze, Aluminum Silicon, Rods, Bars, and Forgings, 90Cu - 7.0Al - 1.8Si, Drawn and Stress Relieved (HR50), UNS C64200                                  |
| 4634                                                       | Aluminum Bronze Bars, 90.5Cu - 7.5Al - 1.9Si, Stress Relieved, UNS C64200                                                                               |
| 4635                                                       | Aluminum Bronze Bars, Rods, and Forgings, 87Cu - 9Al - 3Fe, Stress Relieved, UNS C62300                                                                 |

| <b>SAE/AMS SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                 |
|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>AMS</b>                                                             | <b>Title</b>                                                                                                                                    |
| 4640                                                                   | Aluminum Bronze Bars, Rods, Shapes, Tubes, and Forgings, 81.5Cu - 10.0Al - 4.8Ni - 3.0Fe, Annealed, UNS C63000                                  |
| 4650                                                                   | Copper-Beryllium Alloy Bars, Rods, Shapes, and Forgings, 98Cu - 1.9Be, Solution Heat Treated TB00 (A), UNS C17200                               |
| 4651                                                                   | Copper-Beryllium Alloy Bars and Rods, 98Cu - 1.9Be (CDA 172), Hard Temper, UNS C17200                                                           |
| 4700                                                                   | Copper Wire, Bare, High Purity, UNS C10100                                                                                                      |
| 4701                                                                   | Copper Wire, Oxygen-Free, 99.95(Cu+Ag), Annealed, UNS C10200                                                                                    |
| 4710                                                                   | Brass Wire, Tinned, 65Cu - 35Zn, Annealed (061), UNS C27000                                                                                     |
| 4712                                                                   | Brass Wire, 65Cu - 35Zn, Annealed (061), UNS C27000                                                                                             |
| 4713                                                                   | Wire, Brass, 65Cu - 35Zn, Eighth-Hard (H00), UNS C27000                                                                                         |
| 4720                                                                   | Wire, Phosphor Bronze, 94Cu - 5.0Sn - 0.19P, Cold Drawn, Spring Temper (H08), UNS C51000                                                        |
| 4725                                                                   | Copper-Beryllium Alloy Wire, 98Cu - 1.9Be, Solution Heat Treated, UNS C17200                                                                    |
| 4732                                                                   | Copper-Nickel Alloy Wire and Ribbon, 77.5Cu - 22.5Ni, UNS C71110                                                                                |
| 4740                                                                   | Copper Powder, 99.0Cu minimum, As Fabricated                                                                                                    |
| 4805                                                                   | Bearings, Sintered Metal Powder, 89Cu - 10Sn, Oil Impregnated                                                                                   |
| 4820                                                                   | Bearings, Leaded Copper, 70Cu - 28.5Pb, Steel Back, UNS C98400                                                                                  |
| 4824                                                                   | Bearings, Babbitt-Coated Leaded Bronze, Steel Back, UNS C98200                                                                                  |
| 4827                                                                   | Bearings, Leaded Bronze, 80Cu - 10Pb - 10Sn, Steel Back                                                                                         |
| 4842                                                                   | Castings, Leaded Bronze, Sand and Centrifugal, 80Cu - 10Sn - 9.5Pb, As Cast, UNS C93700                                                         |
| 4845                                                                   | Tin Bronze Castings, Sand and Centrifugal, 87.5Cu - 10Sn - 2Zn, As Cast, UNS C90500                                                             |
| 4855                                                                   | Leaded Red Brass Castings, Sand and Centrifugal, 85Cu - 5.0Sn - 5.0Pb - 5.0Zn (CDA 83600), As Cast, UNS C83600                                  |
| 4860                                                                   | Manganese Bronze Castings, Sand and Centrifugal, 58Cu - 39Zn - 1.2Fe - 1.0Al - 0.80Mn (CDA 86500), As Cast, UNS C86500                          |
| 4862                                                                   | Manganese Bronze Castings, Sand and Centrifugal, 63Cu - 24Zn - 6.2Al - 3.8Mn - 3.0Fe (CDA 86300), High Strength, As Cast, UNS C86300            |
| 4870                                                                   | Aluminum Bronze Castings, Centrifugal and Chill, 85Cu - 11Al - 3.6Fe, As Cast, UNS C95420                                                       |
| 4871                                                                   | Aluminum Bronze Castings, Centrifugal and Chill, 85Cu - 11Al - 3.6Fe, Solution Heat Treated and Tempered, UNS C95420                            |
| 4873                                                                   | Aluminum Bronze Castings, Sand, 85Cu - 11Al - 3.6Fe, Solution Heat Treated and Tempered, UNS C95420                                             |
| 4880                                                                   | Aluminum Bronze Castings, Centrifugal and Continuous Cast, 81.5Cu - 10.3Al - 5.0Ni - 2.8Fe, Solution Heat Treated and Tempered, UNS C95510      |
| 4881                                                                   | Nickel-Aluminum-Bronze Castings, Martensitic, Sand and Centrifugal, 78Cu - 11Al - 5.1Ni - 4.8Fe, Solution Heat Treated and Tempered, UNS C95520 |

| <b>SAE/AMS SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                   |
|------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| <b>AMS</b>                                                             | <b>Title</b>                                                                      |
| 4890                                                                   | Copper-Beryllium Alloy Castings, Investment, 2Be - 0.4Co - 0.3Si, UNS C82500      |
| 7322                                                                   | Sealing Rings, Cast Tin Bronze, 80Cu - 19Sn, As Cast, Rockwell B85-92, UNS C91300 |

| <b>ASTM SPECIFICATIONS - COPPER &amp; COPPER ALLOYS</b>                                                    |                                                                                                   |
|------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| <b>Copper and Copper Alloys for Electron Devices and Electronic Applications and Electrical Conductors</b> |                                                                                                   |
| <b>ASTM</b>                                                                                                | <b>Title</b>                                                                                      |
| B 1                                                                                                        | Hard-Drawn Copper Wire                                                                            |
| B 2                                                                                                        | Medium-Hard-Drawn Copper Wire                                                                     |
| B 3                                                                                                        | Soft or Annealed Copper Wire                                                                      |
| B 8                                                                                                        | Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard or Soft                              |
| B 9                                                                                                        | Bronze Trolley Wire                                                                               |
| B 33                                                                                                       | Tinned Soft or Annealed Copper Wire for Electrical Purposes                                       |
| B 47                                                                                                       | Copper Trolley Wire                                                                               |
| B 48                                                                                                       | Soft Rectangular and Square Bare Copper Wire for Electrical Conductors                            |
| B 49                                                                                                       | Hot-Rolled Copper Redraw Bar for Electrical Purposes                                              |
| B 68                                                                                                       | Oxygen-Free Copper in Wrought Forms for Electron Devices                                          |
| B 96                                                                                                       | Electronic Grade Alloys of Copper and Nickel in Wrought Forms                                     |
| B 105                                                                                                      | Hard-Drawn Copper Alloy Wires for Electrical Conductors                                           |
| B 116                                                                                                      | Figure-9 Deep-Grooved and Figure-8 Copper Trolley Wire for Industrial Haulage                     |
| B 172                                                                                                      | Rope-Lay Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors      |
| B 173                                                                                                      | Rope-Lay Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors |
| B 174                                                                                                      | Bunch-Stranded Copper Conductors for Electrical Conductors                                        |
| B 187                                                                                                      | Copper Bus Bar, Rod, and Shapes                                                                   |
| B 188                                                                                                      | Seamless Copper Bus Pipe and Tube                                                                 |
| B 193                                                                                                      | Resistivity of Electrical Conductor Materials                                                     |
| B 226                                                                                                      | Cored, Annular, Concentric-Lay-Stranded Copper Conductors                                         |

| <b>ASTM SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b>                                                    |                                                                                                         |
|------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| <b>Copper and Copper Alloys for Electron Devices and Electronic Applications and Electrical Conductors (Continued)</b> |                                                                                                         |
| <b>ASTM</b>                                                                                                            | <b>Title</b>                                                                                            |
| B 272                                                                                                                  | Flat Copper Products with Finished (Rolled or Drawn) Edges (Flat Wire and Strip)                        |
| B 286                                                                                                                  | Copper Conductors for Use in Hookup Wire for Electronic Equipment                                       |
| B 372                                                                                                                  | Seamless Copper and Copper-Alloy Rectangular Waveguide Tube                                             |
| B 451                                                                                                                  | Copper Foil, Strip, and Sheet for Printed Circuits                                                      |
| B 470                                                                                                                  | Bonded Copper Conductors for Use in Hookup Wires for Electronic Equipment                               |
| B 496                                                                                                                  | Compact Round Concentric-Lay-Stranded Copper Conductors                                                 |
| B 624                                                                                                                  | High-strength, High-Conductivity Copper-Alloy Wire for Electronic Application                           |
| B 738                                                                                                                  | Fine-Wire Bunch-Stranded and Rope-Lay Bunch Stranded Copper Conductors for Use as Electrical Conductors |
| F 68                                                                                                                   | Oxygen-Free Copper in Wrought Forms for Electron Devices                                                |
| F 96                                                                                                                   | Electronic Grade Alloys of Copper and Nickel in Wrought Forms                                           |
| <b>Copper Refinery Products</b>                                                                                        |                                                                                                         |
| B 5                                                                                                                    | Electrolytic Tough-Pitch Copper - Refinery Shapes                                                       |
| B 115                                                                                                                  | Electrolytic Cathode Copper                                                                             |
| B 170                                                                                                                  | Oxygen-Free Electrolytic Copper - Refinery Shapes                                                       |
| B 216                                                                                                                  | Tough-Pitch Fire-Refined Copper for Wrought Products and Alloys - Refinery Shapes                       |
| B 224                                                                                                                  | Coppers                                                                                                 |
| B 379                                                                                                                  | Phosphorized Coppers - Refinery Shapes                                                                  |
| B 623                                                                                                                  | Tough-Pitch Fire-Refined High-Conductivity Copper - Refinery Shapes                                     |
| <b>Copper and Copper Alloy Plate, Sheet, Strip, and Rolled Bar</b>                                                     |                                                                                                         |
| B 19                                                                                                                   | Cartridge Brass Sheet, Strip, Plate, Bar, and Disks                                                     |
| B 36/B 36M                                                                                                             | Brass Plate, Sheet, Strip, and Rolled Bar                                                               |
| B 96                                                                                                                   | Copper-Silicon Alloy Plate, Sheet, Strip, and Rolled Bar for General Purposes and Pressure Vessels      |
| B 96M                                                                                                                  | Copper-Silicon Alloy Plate, Sheet, Strip, and Rolled Bar for General Purposes (Metric)                  |
| B 100                                                                                                                  | Rolled Copper-Alloy Bearing and Expansion Plates and Sheets for Bridge and Other Structural Uses        |
| B 101                                                                                                                  | Lead-Coated Copper Sheet and Strip for Building Construction                                            |
| B 103/B 103M                                                                                                           | Phosphor Bronze Plate, Sheet, Strip, and Rolled Bar                                                     |

| <b>ASTM SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b>            |                                                                                                                                                                                |
|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Copper and Copper Alloy Plate, Sheet, Strip, and Rolled Bar (Continued)</b> |                                                                                                                                                                                |
| <b>ASTM</b>                                                                    | <b>Title</b>                                                                                                                                                                   |
| B 121/B 121M                                                                   | Lead Brass Plate, Sheet, Strip, and Rolled Bar                                                                                                                                 |
| B 122                                                                          | Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel Silver), and Copper-Nickel Alloy Plate, Sheet, Strip, and Rolled Bar                                                 |
| B 129                                                                          | Cartridge Brass Cartridge Case Cups                                                                                                                                            |
| B 130                                                                          | Commercial Bronze Strip for Bullet Jackets                                                                                                                                     |
| B 131                                                                          | Copper Alloy Bullet Jacket Cups                                                                                                                                                |
| B 152                                                                          | Copper Sheet, Strip, Plate, and Rolled Bar                                                                                                                                     |
| B 152M                                                                         | Copper Sheet, Strip, Plate, and Rolled Bar (Metric)                                                                                                                            |
| B 169                                                                          | Aluminum Bronze Plate, Sheet, Strip, and Rolled Bar                                                                                                                            |
| B 169M                                                                         | Aluminum Bronze Plate, Sheet, Strip, and Rolled Bar (Metric)                                                                                                                   |
| B 171                                                                          | Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers, and Heat Exchangers                                                                                             |
| B 171M                                                                         | Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers, and Heat Exchangers (Metric)                                                                                    |
| B 194                                                                          | Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar                                                                                                                     |
| B 248                                                                          | General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar                                                                                   |
| B 248M                                                                         | General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar (Metric)                                                                          |
| B 291                                                                          | Copper-Zinc Manganese Alloy (Manganese Brass) Sheet and Strip                                                                                                                  |
| B 370                                                                          | Copper Sheet and Strip for Building Construction                                                                                                                               |
| B 422                                                                          | Copper-Aluminum-Silicon-Cobalt Alloy, Copper-Nickel-Aluminum-Silicon Alloy, Copper-Nickel-Silicon-Magnesium Alloys, and Copper-Nickel-Aluminum-Magnesium Alloy Sheet and Strip |
| B 432                                                                          | Copper and Copper Alloy Clad Steel Plate                                                                                                                                       |
| B 451                                                                          | Copper Foil, Strip, and Sheet for Printed Circuits and Carrier Tapes                                                                                                           |
| B 465                                                                          | Copper-Iron Alloy Plate, Sheet, Strip, and Rolled Bar                                                                                                                          |
| B 506                                                                          | Copper-Clad Stainless Steel Sheet and Strip for Building Construction                                                                                                          |
| B 508                                                                          | Copper Alloy Strip for Flexible Metal Hose                                                                                                                                     |
| B 534                                                                          | Copper-Cobalt-Beryllium Alloy and Copper-Nickel-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar                                                                            |
| B 569                                                                          | UNS No. C26000 Brass Strip in Narrow Widths and Light Gage for Heat-Exchanger Tubing                                                                                           |
| B 591                                                                          | Copper-Zinc-Tin Alloys Plate, Sheet, Strip, and Rolled Bar                                                                                                                     |

| <b>ASTM SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b>            |                                                                                                      |
|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
| <b>Copper and Copper Alloy Plate, Sheet, Strip, and Rolled Bar (Continued)</b> |                                                                                                      |
| <b>ASTM</b>                                                                    | <b>Title</b>                                                                                         |
| B 592                                                                          | Copper-Zinc-Aluminum-Cobalt Alloy Plate, Sheet, Strip, and Rolled Bar                                |
| B 638                                                                          | Copper and Copper Alloy Solar Heat Absorber Panels                                                   |
| B 694                                                                          | Copper, Copper Alloy, and Copper-Clay Stainless Steel Sheet and Strip for Electrical Cable Shielding |
| B 740                                                                          | Copper-Nickel-Tin Spinodal Alloy Strip                                                               |
| B 747                                                                          | Copper Zirconium Alloy Sheet and Strip                                                               |
| B 754                                                                          | Measuring and Recording the Deviations from Flatness in Copper and Copper Alloy Strip                |
| B 768                                                                          | Copper-Cobalt-Beryllium Alloy Strip and Sheet                                                        |
| <b>Copper and Copper Alloy Rod, Bar, and Shapes, and Die Forgings</b>          |                                                                                                      |
| B 16                                                                           | Free-Cutting Brass Rod, Bar, and Shapes for Use in Screw Machines                                    |
| B 16M                                                                          | Free-Cutting Brass Rod, Bar, and Shapes for Use in Screw Machines (Metric)                           |
| B 21                                                                           | Naval Brass Rod, Bar, and Shapes                                                                     |
| B 21M                                                                          | Naval Brass Rod, Bar, and Shapes (Metric)                                                            |
| B 98                                                                           | Copper-Silicon Alloy Rod, Bar, and Shapes                                                            |
| B 98M                                                                          | Copper-Silicon Alloy Rod, Bar, and Shapes (Metric)                                                   |
| B 124                                                                          | Copper and Copper Alloy Forging Rod, Bar, and Shapes                                                 |
| B 124M                                                                         | Specification for Copper and Copper-Alloy Forging Rod, Bar, and Shapes (Metric)                      |
| B 133                                                                          | Copper Rod, Bar, and Shapes                                                                          |
| B 133M                                                                         | Copper Rod, Bar, and Shapes (Metric)                                                                 |
| B 138                                                                          | Manganese Bronze Rod, Bar, and Shapes                                                                |
| B 138M                                                                         | Manganese Bronze Rod, Bar, and Shapes (Metric)                                                       |
| B 139                                                                          | Phosphor Bronze Rod, Bar, and Shapes                                                                 |
| B 139M                                                                         | Phosphor Bronze Rod, Bar, and Shapes (Metric)                                                        |
| B 140                                                                          | Copper-Zinc-Lead (Leaded Red Brass or Hardware Bronze) Rod, Bar, and Shapes                          |
| B 140M                                                                         | Copper-Zinc-Lead (Leaded Red Brass or Hardware Bronze) Rod, Bar and Shapes (Metric)                  |
| B 150                                                                          | Aluminum Bronze Rod, Bar, and Shapes                                                                 |
| B 150M                                                                         | Aluminum Bronze Rod, Bar, and Shapes (Metric)                                                        |

| <b>ASTM SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b>               |                                                                                                   |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| <b>Copper and Copper Alloy Rod, Bar, and Shapes, and Die Forgings (Continued)</b> |                                                                                                   |
| <b>ASTM</b>                                                                       | <b>Title</b>                                                                                      |
| B 151                                                                             | Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar                            |
| B 151M                                                                            | Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar (Metric)                   |
| B 187                                                                             | Copper Bus Bar, Rod, and Shapes                                                                   |
| B 196                                                                             | Copper-Beryllium Alloy Rod and Bar                                                                |
| B 196M                                                                            | Copper-Beryllium Alloy Rod and Bar (Metric)                                                       |
| B 249                                                                             | General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, and Shapes                     |
| B 249M                                                                            | General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, and Shapes (Metric)            |
| B 283                                                                             | Copper and Copper-Alloy Die Forgings (Hot-Pressed)                                                |
| B 301                                                                             | Free-Cutting Copper Rod and Bar                                                                   |
| B 301M                                                                            | Free-Cutting Copper Rod and Bar (Metric)                                                          |
| B 371                                                                             | Copper-Zinc-Silicon Alloy Rod                                                                     |
| B 411                                                                             | Copper-Nickel-Silicon Alloy Rod and Bar                                                           |
| B 441                                                                             | Copper-Cobalt-Beryllium (UNS No. C17500) and Copper-Nickel-Beryllium (UNS No. C17510) Rod and Bar |
| B 453                                                                             | Copper-Zinc-Lead Alloy (Leaded Brass) Rod                                                         |
| B 453M                                                                            | Copper-Zinc-Lead Alloy (Leaded Brass) Rod (Metric)                                                |
| B 455                                                                             | Copper-Zinc-Lead Alloy (Leaded Brass) Extruded Shapes                                             |
| B 570                                                                             | Copper-Beryllium Alloy Forgings and Extrusions                                                    |
| F 467                                                                             | Nonferrous Nuts for General Use                                                                   |
| F 468                                                                             | Nonferrous Bolts, Hex Cap Screws, and Studs for General Use                                       |
| <b>Copper, Copper Alloy, and Copper-Clad Wire</b>                                 |                                                                                                   |
| B 99                                                                              | Copper-Silicon Alloy Wire for General Purposes                                                    |
| B 99M                                                                             | Copper-Silicon Alloy Wire for General Purposes (Metric)                                           |
| B 134                                                                             | Brass Wire                                                                                        |
| B 159                                                                             | Phosphor Bronze Wire                                                                              |
| B 159M                                                                            | Phosphor Bronze Wire (Metric)                                                                     |
| B 189                                                                             | Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes                        |

| <b>ASTM SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                     |
|---------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| <b>Copper, Copper Alloy, and Copper-Clad Wire (Continued)</b>       |                                                                                     |
| <b>ASTM</b>                                                         | <b>Title</b>                                                                        |
| B 197                                                               | Copper-Beryllium Alloy Wire                                                         |
| B 197M                                                              | Copper-Beryllium Alloy Wire (Metric)                                                |
| B 206                                                               | Copper-Nickel-Zinc Alloy (Nickel Silver) Wire and Copper-Nickel Alloy Wire          |
| B 206M                                                              | Copper-Nickel-Zinc Alloy (Nickel Silver) Wire and Copper-Nickel Alloy Wire (Metric) |
| B 229                                                               | Concentric-Lay-Stranded Copper and Copper-Clad Steel Composite Conductors           |
| B 246                                                               | Tinned Hard-Drawn and Medium-Hard-Drawn Copper Wire for Electrical Purposes         |
| B 250                                                               | General Requirements for Wrought Copper-Alloy Wire                                  |
| B 250M                                                              | General Requirements for Wrought Copper-Alloy Wire (Metric)                         |
| B 272                                                               | Flat Copper Products with Finished (Rolled or Drawn) Edges (Flat Wire and Strip)    |
| B 298                                                               | Silver-Coated Soft or Annealed Copper Wire                                          |
| B 355                                                               | Nickel-Coated Soft or Annealed Copper Wire                                          |
| B 412                                                               | Copper-Nickel-Silicon Alloy Wire                                                    |
| B 42                                                                | Seamless Copper Pipe, Standard Sizes                                                |
| <b>Copper and Copper Alloy Pipe And Tube</b>                        |                                                                                     |
| B 43                                                                | Seamless Red Brass Pipe, Standard Sizes                                             |
| B 68                                                                | Seamless Copper Tube, Bright Annealed                                               |
| B 68M                                                               | Seamless Copper Tube, Bright Annealed (Metric)                                      |
| B 75                                                                | Seamless Copper Tube                                                                |
| B 75M                                                               | Seamless Copper Tube (Metric)                                                       |
| B 88                                                                | Seamless Copper Water Tube                                                          |
| B 88M                                                               | Seamless Copper Water Tube (Metric)                                                 |
| B 111                                                               | Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock                  |
| B 111M                                                              | Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock (Metric)         |
| B 135                                                               | Seamless Brass Tube                                                                 |
| B 135M                                                              | Seamless Brass Tube (Metric)                                                        |
| B 153                                                               | Expansion (Pin Test) of Copper and Copper Alloy Pipe and Tubing                     |



| <b>ASTM SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                 |
|---------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| <b>Copper and Copper Alloy Pipe And Tube (Continued)</b>            |                                                                                                 |
| <b>ASTM</b>                                                         | <b>Title</b>                                                                                    |
| B 188                                                               | Seamless Copper Bus Pipe and Tube                                                               |
| B 251                                                               | General Requirements for Wrought Seamless Copper and Copper-Alloy Tube                          |
| B 251M                                                              | General Requirements for Wrought Seamless Copper and Copper-Alloy Tube (Metric)                 |
| B 280                                                               | Seamless Copper Tube for Air Conditioning and Refrigeration Field Service                       |
| B 302                                                               | Threadless Copper Pipe                                                                          |
| B 306                                                               | Copper Drainage Tube (DWV)                                                                      |
| B 315                                                               | Seamless Copper Alloy Pipe and Tube                                                             |
| B 359                                                               | Copper and Copper-Alloy Seamless Condenser and Heat Exchanger Tubes with Integral Fins          |
| B 359M                                                              | Copper and Copper-Alloy Seamless Condenser and Heat-Exchanger Tubes with Integral Fins (Metric) |
| B 360                                                               | Hard-Drawn Copper Capillary Tube for Restrictor Applications                                    |
| B 395                                                               | U-Bend Seamless Copper and Copper-Alloy Heat-Exchanger and Condenser Tubes                      |
| B 395M                                                              | U-Bend Seamless Copper and Copper-Alloy Heat-Exchanger and Condenser Tubes (Metric)             |
| B 428                                                               | Angle of Twist in Rectangular and Square Copper and Copper Alloy Tube                           |
| B 447                                                               | Welded Copper Tube                                                                              |
| B 466                                                               | Seamless Copper-Nickel Pipe and Tube                                                            |
| B 466M                                                              | Seamless Copper-Nickel Pipe and Tube (Metric)                                                   |
| B 467                                                               | Welded Copper-Nickel Pipe                                                                       |
| B 469                                                               | Seamless Copper Alloy Tubes for Pressure Applications                                           |
| B 543                                                               | Welded Copper and Copper-Alloy Heat-Exchanger Tube                                              |
| B 543M                                                              | Welded Copper and Copper-Alloy Heat-Exchanger Tube (Metric)                                     |
| B 552                                                               | Seamless and Welded Copper-Nickel Tubes for Water Desalting Plants                              |
| B 587                                                               | Weld Brass Tube                                                                                 |
| B 608                                                               | Welded Copper-Alloy Pipe                                                                        |
| B 640                                                               | Welded Copper and Copper Alloy Tube for Air Conditioning and Refrigeration Service              |
| B 641                                                               | Seamless and Welded Copper Distribution Tube (Type D)                                           |
| B 642                                                               | Welded Copper Alloy UNS No. C21000 Water Tube                                                   |

| <b>ASTM SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                       |
|---------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| <b>Copper and Copper Alloy Pipe And Tube (Continued)</b>            |                                                                                                                       |
| <b>ASTM</b>                                                         | <b>Title</b>                                                                                                          |
| B 643                                                               | Copper-Beryllium Alloy Seamless Tube                                                                                  |
| B 687                                                               | Brass, Copper, and Chromium-Plated Pipe Nipples                                                                       |
| B 698                                                               | Seamless and Welded Copper and Copper Alloy Plumbing Pipe and Tube (Classification)                                   |
| B 706                                                               | Seamless Copper Alloy (UNS No. C69100) Pipe and Tube                                                                  |
| B 716                                                               | Welded Copper Water Tube                                                                                              |
| B 716M                                                              | Welded Copper Water Tube (Metric)                                                                                     |
| B 732                                                               | Evaluating the Corrosivity of Solder Fluxes for Copper Tubing Systems                                                 |
| B 743                                                               | Seamless Copper Tube in Coils                                                                                         |
| B 813                                                               | Liquid and Paste Fluxes for Soldering Applications of Copper and Copper Tube                                          |
| B 819                                                               | Seamless Copper Tube for Medical Gas Systems                                                                          |
| E 243                                                               | Electromagnetic (Eddy-Current) Testing of Seamless Copper and Copper-Alloy Tubes                                      |
| <b>Copper Alloy Ingot and Castings</b>                              |                                                                                                                       |
| B 22                                                                | Bronze Castings for Bridges and Turntables                                                                            |
| B 30                                                                | Copper-Base Alloys in Ingot Form                                                                                      |
| B 61                                                                | Bronze Castings, Steam or Valve                                                                                       |
| B 62                                                                | Composition Bronze or Ounce Metal Castings                                                                            |
| B 66                                                                | Bronze Castings for Steam Locomotive Wearing Parts                                                                    |
| B 67                                                                | Car and Tender Journal Bearings, Lined                                                                                |
| B 148                                                               | Aluminum-Bronze Sand Castings                                                                                         |
| B 176                                                               | Copper Alloy Die Castings                                                                                             |
| B 208                                                               | Preparing Tension Test Specimens for Copper-Base Alloys for Sand Permanent Mold, Centrifugal, and Continuous Castings |
| B 271                                                               | Copper-Base Alloy Centrifugal Castings                                                                                |
| B 369                                                               | Copper-Nickel Alloy Castings                                                                                          |
| B 427                                                               | Gear Bronze Alloy Castings                                                                                            |
| B 505                                                               | Copper-Base Alloy Continuous Castings                                                                                 |
| B 584                                                               | Copper Alloy Sand Castings for General Applications                                                                   |

| <b>ASTM SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                               |
|---------------------------------------------------------------------|---------------------------------------------------------------|
| <b>Copper Alloy Ingot and Castings (Continued)</b>                  |                                                               |
| <b>ASTM</b>                                                         | <b>Title</b>                                                  |
| B 644                                                               | Copper Alloy Addition Agents                                  |
| B 763                                                               | Copper Alloy Sand Castings for Valve Application              |
| B 770                                                               | Copper-Beryllium Alloy Sand Castings for General Applications |
| B 806                                                               | Copper Alloy Permanent Mold Castings for General Applications |
| B 824                                                               | General Requirements for Copper Alloy Castings                |
| <b>Copper Classifications Systems</b>                               |                                                               |
| B 224                                                               | Coppers                                                       |

| <b>AWS WELDING FILLER METAL SPECIFICATIONS - COPPER &amp; COPPER ALLOYS</b> |                                                          |
|-----------------------------------------------------------------------------|----------------------------------------------------------|
| <b>AWS</b>                                                                  | <b>Title</b>                                             |
| A5.6                                                                        | Copper and Copper Alloy Covered Electrodes               |
| A5.7                                                                        | Copper and Copper Alloy Bare Welding Rods and Electrodes |
| A5.27                                                                       | Copper and Copper Alloy Gas Welding Rods                 |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS |                     |                                                                        |                                                                                                                                                                                                                         |                                                     |     |
|-------------------------------------------------------------------|---------------------|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-----|
| UNS                                                               | AMS                 | MIL SPEC                                                               | ASTM                                                                                                                                                                                                                    | ASME                                                | AWS |
| C10100                                                            | 4700                | MIL-W-85;<br>MIL-W-3318;<br>MIL-B-18907                                | B1; B3; B8; B33; B48; B49; F68; B75; B111 (OFE);<br>B133; B152; B172; B173; B174; B187; B188; B189;<br>B224 (OFE); B246; B272; B280; B286; B298; B355;<br>B359; B432; B447; B451; B470; B496; B640; B641;<br>B698 (OFE) | ---                                                 | --- |
| C10200                                                            | 4501; 4602;<br>4701 | MIL-W-85;<br>MIL-B-2029;<br>MIL-W-6712;<br>MIL-B-18907;<br>MIL-T-24107 | B1; B2; B3; B8; F9; B33; B42; B48; B49; B68; B75;<br>B88; B111; B133; B152; B172; B173; B174; B187;<br>B188; B189; B224 (OF); B640; B641; B687; B698 (OF);<br>B716; B738; B743                                          | SB42; SB75, SB111;<br>SB133; SB152; SB359;<br>SB395 | --- |
| C10300                                                            | ---                 | MIL-T-3235;<br>MIL-B-20292                                             | B42; B68; B75; B88; B111; B133; B152; B187; B188;<br>B224 (OFXLP); B280; B302; B306; B359; B372;<br>B379 (OFXLP); B395; B432; B447; B638 (OFXLP);<br>B640; B641; B687; B698 (OFXLP); B716; B743                         | ---                                                 | --- |
| C10400                                                            | ---                 | MIL-W-3318;<br>MIL-B20292                                              | B1; B2; B3; B49; B133; B152; B187; B188; B189;<br>B224 (OFS); B246; B272; B298; B355; B506                                                                                                                              | SB152                                               | --- |
| C10500                                                            | ---                 | ---                                                                    | B1; B2; B3; B49; B133; B152; B187; B188; B189;<br>B224 (OFS); B246; B272; B298; B355; B506                                                                                                                              | SB152                                               | --- |
| C10700                                                            | ---                 | MIL-W-3318;<br>MIL-B-19231;<br>MIL-B-20292                             | B1; B2; B3; B49; B133; B152; B187; B188; B189;<br>B224 (OFS); B246; B272; B298; B355; B506                                                                                                                              | SB152                                               | --- |
| C10800                                                            | ---                 | MIL-B-20292;<br>MIL-T-24107                                            | B42; B68; B75; B88; B111; B133; B152; B224 (OFLP);<br>B280; B302; B306; B359; B360; B379; B432; B447;<br>B543; B638 (OFLP); B640; B641; B687; B698 (OFLP);<br>B716; B743                                                | ---                                                 | --- |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS (Continued) |      |                                            |                                                                                                                                                                                                                                                                        |       |     |
|-------------------------------------------------------------------------------|------|--------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----|
| UNS                                                                           | AMS  | MIL SPEC                                   | ASTM                                                                                                                                                                                                                                                                   | ASME  | AWS |
| C11000                                                                        | 4500 | MIL-W-6712;<br>MIL-C-12168;<br>MIL-B-20292 | B1; B2; B3; B8; B33; B47; B48; B49; B101; B116; B124;<br>B133; B152; B172; B173; B174; B187; B188; B189;<br>B224 (ETP); B226; B228; B229; B246; B272; B283;<br>B286; B298; B355; B370; B447; B451; B470; B496;<br>B506; B566; B638; B694; B738; F467 (110); F468 (110) | SB133 | --- |
| C11010                                                                        | ---  | ---                                        | B224 (RHC)                                                                                                                                                                                                                                                             | ---   | --- |
| C11020                                                                        | ---  | ---                                        | B224 (FRHC)                                                                                                                                                                                                                                                            | ---   | --- |
| C11030                                                                        | ---  | ---                                        | B224 (CRTP)                                                                                                                                                                                                                                                            | ---   | --- |
| C11040                                                                        | ---  | ---                                        | B49                                                                                                                                                                                                                                                                    | ---   | --- |
| C11100                                                                        | ---  | ---                                        | B224 (ETP)                                                                                                                                                                                                                                                             | ---   | --- |
| C11300                                                                        | ---  | MIL-B-20292                                | B1; B2; B3; B5 (STP); B8; B33; B47; B48; B49; B116;<br>B33; B48; B152; B172; B173; B174; B187; B188; B189;<br>B224 (ETP); B226; B228; B229; B246; B272; B286;<br>B298; B355; B442 (STP); B470; B496; B506;<br>B623 (STP)                                               | ---   | --- |
| C11400                                                                        | ---  | MIL-B-20292                                | B1; B2; B3; B4; B5 (STP); B8; B47; B48; B49; B116;<br>B152; B172; B173; B174; B187; B188; B189;<br>B224 (ETP); B226; B229; B246; B272; B286; B298;<br>B355; B442 (STP); B470; B496; B506; B623 (STP)                                                                   | ---   | --- |
| C11500                                                                        | ---  | ---                                        | B1; B2; B3; B5 (STP); B8; B33; B47; B49; B116; B172;<br>B173; B174; B189; B224 (ETP); B226; B228; B229;<br>B246; B272; B286; B298; B355; B442 (STP); B470;<br>B496; B623 (STP)                                                                                         | ---   | --- |
| C11600                                                                        | ---  | MIL-B-19231;<br>MIL-B-20292                | B1; B2; B3; B5 (STP); B8; B33; B47; B48; B49; B116;<br>B152; B172; B173; B174; B187; B188; B189;<br>B224 (ETP); B226; B229; B246; B272; B286; B298;<br>B355; B442 (STP); B470; B496; B506; B623 (STP)                                                                  | ---   | --- |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS (Continued) |     |                                                                            |                                                                                                                                                                                                                                           |                                                                               |               |
|-------------------------------------------------------------------------------|-----|----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|---------------|
| UNS                                                                           | AMS | MIL SPEC                                                                   | ASTM                                                                                                                                                                                                                                      | ASME                                                                          | AWS           |
| C12000                                                                        | --- | MIL-W-85;<br>MIL-T-3235;<br>MIL-B-18907;<br>MIL-B-20292;<br>MIL-T-24107    | B5 (DLP); B42; B68; B75; B88; B111; B133; B152;<br>B187; B188; B224 (DLP); B447; B451; B506;<br>B623 (DLP); B638; B640; B641; B687; B698 (DLP);<br>B716; B743                                                                             | SB42; SB75; SB111;<br>SB133; SB359; SB395                                     | ---           |
| C12100                                                                        | --- | MIL-B-20292                                                                | B224 (DLPS)                                                                                                                                                                                                                               | ---                                                                           | ---           |
| C12200                                                                        | --- | MIL-T-3235;<br>MIL-B-18907;<br>MIL-B-20292;<br>MIL-T-22214;<br>MIL-T-24107 | B5 (DHP); B42; B68; B75; B88; B101; B111; B133;<br>B152; B224 (DHP); B272; B280; B302; B306; B359;<br>B360; B370; B379 (OFLP); B395; B432; B442 (DHP);<br>B447; B506; B543; B623 (DHP); B638; B640; B641;<br>B687; B698 (DHP); B716; B743 | B16.22; B16.29; SB42;<br>SB75; SB111; SB133;<br>SB152; SB359; SB395;<br>SB543 | ---           |
| C12300                                                                        | --- | ---                                                                        | B5 (DHPS); B152; B224 (DHPS); B442 (DHPS); B506;<br>B623 (DHPS)                                                                                                                                                                           | SB152                                                                         | ---           |
| C12900                                                                        | --- | MIL-B-20292                                                                | B224 (FRSTP)                                                                                                                                                                                                                              | ---                                                                           | ---           |
| C14180                                                                        | --- | MIL-B-7883(BCu-1)                                                          | ---                                                                                                                                                                                                                                       | SFA5.8 (BCu-1)                                                                | A5.8 (BCu-1)  |
| C14181                                                                        | --- | ---                                                                        | ---                                                                                                                                                                                                                                       | SFA5.8 (BCu-1x)                                                               | A5.8 (BCu-1x) |
| C14200                                                                        | --- | MIL-T-24107                                                                | B5 (DPA); B75; B111; B133; B152; B216 (DPA);<br>B224 (DPA); B359; B379 (DPA); B395; B442 (DPA);<br>B447; B623 (DPA)                                                                                                                       | SB75; SB111; SB133;<br>SB359; SB395                                           | ---           |
| C14420                                                                        | --- | ---                                                                        | B152                                                                                                                                                                                                                                      | ---                                                                           | ---           |
| C14500                                                                        | --- | ---                                                                        | B5 (DPTE); B124; B216 (DPTE); B224 (DPTE); B283;<br>B301; B442 (DPTE); B623 (SPTE)                                                                                                                                                        | B16.22                                                                        | ---           |
| C14510                                                                        | --- | ---                                                                        | B301                                                                                                                                                                                                                                      | ---                                                                           | ---           |
| C14520                                                                        | --- | ---                                                                        | B301                                                                                                                                                                                                                                      | ---                                                                           | ---           |
| C14700                                                                        | --- | ---                                                                        | B124; B224; B283; B301                                                                                                                                                                                                                    | B16.22                                                                        | ---           |
| C15000                                                                        | --- | ---                                                                        | B224                                                                                                                                                                                                                                      | ---                                                                           | ---           |
| C15100                                                                        | --- | ---                                                                        | B747                                                                                                                                                                                                                                      | ---                                                                           | ---           |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS (Continued) |                                                         |                                                                        |                                                |                                 |                             |
|-------------------------------------------------------------------------------|---------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------|---------------------------------|-----------------------------|
| UNS                                                                           | AMS                                                     | MIL SPEC                                                               | ASTM                                           | ASME                            | AWS                         |
| C16200                                                                        | ---                                                     | ---                                                                    | B105; B624                                     | ---                             | ---                         |
| C16500                                                                        | ---                                                     | ---                                                                    | B9; B105                                       | ---                             | ---                         |
| C17000                                                                        | ---                                                     | ---                                                                    | B194; B196; B570                               | ---                             | ---                         |
| C17200                                                                        | 4530; 4532;<br>4533; 4534;<br>4535; 4650;<br>4651; 4725 | MIL-C-21657                                                            | B194; B196; B197; B570; B643                   | ---                             | ---                         |
| C17300                                                                        | ---                                                     | ---                                                                    | B196; B197                                     | ---                             | ---                         |
| C17410                                                                        | ---                                                     | ---                                                                    | B768                                           | ---                             | ---                         |
| C17500                                                                        | ---                                                     | MIL-C-81020                                                            | B441; B534                                     | ---                             | ---                         |
| C17510                                                                        | ---                                                     | MIL-C-81021                                                            | B441; B534                                     | ---                             | ---                         |
| C18200                                                                        | ---                                                     | MIL-C-19311                                                            | F9                                             | ---                             | ---                         |
| C18700                                                                        | ---                                                     | ---                                                                    | B301                                           | ---                             | ---                         |
| C18980                                                                        | ---                                                     | MIL-C-19654<br>(MIL-RCu-2)                                             | ---                                            | SFA5.7 (ERCu);<br>SFA5.27 (RCu) | A5.7 (ERCu);<br>A5.27 (RCu) |
| C19200                                                                        | ---                                                     | ---                                                                    | B111; B359; B395; B465; B469; B638; B640; B698 | SB111; SB359; SB395;<br>B640    | ---                         |
| C19400                                                                        | ---                                                     | ---                                                                    | B465; B543; B638; B640; B694; B698             | SB543                           | ---                         |
| C19500                                                                        | ---                                                     | ---                                                                    | B465                                           | ---                             | ---                         |
| C21000                                                                        | ---                                                     | ---                                                                    | B36; B134; B587; B642; B698 (Gilding-95%)      | ---                             | ---                         |
| C22000                                                                        | ---                                                     | MIL-W-85;<br>MIL-C-3383;<br>MIL-W-6712;<br>MIL-B-18907;<br>MIL-B-20292 | B36; B130; B131; B134; B135; B372; B587; B694  | ---                             | ---                         |
| C22600                                                                        | ---                                                     | ---                                                                    | B36                                            | ---                             | ---                         |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS (Continued) |                        |                                       |                                                                                |                                                  |     |
|-------------------------------------------------------------------------------|------------------------|---------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------|-----|
| UNS                                                                           | AMS                    | MIL SPEC                              | ASTM                                                                           | ASME                                             | AWS |
| C23000                                                                        | ---                    | MIL-T-20168                           | B36; B43; B111; B134; B135; B359; B395; B543; B587; B687; B698 (Red Brass-85%) | B16.22; B16.29; SB43; SB111; SB359; SB395; SB543 | --- |
| C24000                                                                        | ---                    | ---                                   | B36; B134                                                                      | ---                                              | --- |
| C26000                                                                        | 4505; 4507; 4508; 4555 | MIL-C-10375; MIL-T-20219; MIL-S-22499 | B19; B36; B129; B134; B135; B569; B587                                         | ---                                              | --- |
| C26800                                                                        | ---                    | MIL-W-6712                            | B36; B587                                                                      | ---                                              | --- |
| C27000                                                                        | 4710; 4712; 4713       | ---                                   | B134; B135; B587; F467; F468                                                   | ---                                              | --- |
| C27200                                                                        | ---                    | ---                                   | B36; B135; B587                                                                | ---                                              | --- |
| C27400                                                                        | ---                    | ---                                   | B134                                                                           | ---                                              | --- |
| C28000                                                                        | ---                    | ---                                   | B111; B135                                                                     | SB111                                            | --- |
| C31400                                                                        | ---                    | MIL-V-18436                           | B140                                                                           | ---                                              | --- |
| C31600                                                                        | ---                    | MIL-V-18436                           | B140                                                                           | ---                                              | --- |
| C32000                                                                        | ---                    | ---                                   | B140                                                                           | ---                                              | --- |
| C33000                                                                        | 4555                   | MIL-T-46072                           | B135                                                                           | ---                                              | --- |
| C33200                                                                        | 4558                   | MIL-T-46072                           | B135                                                                           | ---                                              | --- |
| C33500                                                                        | ---                    | ---                                   | B121; B453                                                                     | ---                                              | --- |
| C34000                                                                        | ---                    | ---                                   | B121; B453                                                                     | ---                                              | --- |
| C34200                                                                        | ---                    | ---                                   | B121                                                                           | ---                                              | --- |
| C34500                                                                        | ---                    | ---                                   | B453                                                                           | ---                                              | --- |
| C35000                                                                        | ---                    | ---                                   | B121; B453                                                                     | ---                                              | --- |
| C35300                                                                        | ---                    | ---                                   | B121; B453                                                                     | ---                                              | --- |
| C35600                                                                        | ---                    | ---                                   | B121; B453                                                                     | ---                                              | --- |
| C36000                                                                        | 4610                   | MIL-V-18436                           | B16                                                                            | ---                                              | --- |
| C36500                                                                        | ---                    | ---                                   | B124; B171; B283; B432                                                         | SB171                                            | --- |



| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS (Continued) |            |                          |                                          |                                   |                                      |
|-------------------------------------------------------------------------------|------------|--------------------------|------------------------------------------|-----------------------------------|--------------------------------------|
| UNS                                                                           | AMS        | MIL SPEC                 | ASTM                                     | ASME                              | AWS                                  |
| C37000                                                                        | ---        | MIL-T-46072              | B135                                     | ---                               | ---                                  |
| C37700                                                                        | 4614       | ---                      | B124; B283                               | SB283                             | ---                                  |
| C38000                                                                        | ---        | ---                      | B455                                     | ---                               | ---                                  |
| C38500                                                                        | ---        | ---                      | B455                                     | ---                               | ---                                  |
| C40500                                                                        | ---        | ---                      | B591                                     | ---                               | ---                                  |
| C41100                                                                        | ---        | MIL-B-13501              | B105; B508; B591                         | ---                               | ---                                  |
| C41300                                                                        | ---        | ---                      | B591                                     | ---                               | ---                                  |
| C41500                                                                        | ---        | ---                      | B591                                     | ---                               | ---                                  |
| C42200                                                                        | ---        | ---                      | B591                                     | ---                               | ---                                  |
| C42500                                                                        | ---        | ---                      | B591                                     | ---                               | ---                                  |
| C43000                                                                        | ---        | ---                      | B591                                     | ---                               | ---                                  |
| C43400                                                                        | ---        | ---                      | B591                                     | ---                               | ---                                  |
| C44300                                                                        | ---        | ---                      | B111; B135; B171; B359; B395; B432; B543 | SB111; SB171; SB359; SB395; SB543 | ---                                  |
| C44400                                                                        | ---        | ---                      | B111; B171; B359; B395; B432; B543       | SB111; SB171; SB359; SB395; SB543 | ---                                  |
| C44500                                                                        | ---        | ---                      | B111; B171; B359; B395; B432; B543       | SB111; SB171; SB359; SB395; SB543 | ---                                  |
| C46200                                                                        | ---        | ---                      | B21; F68; F467; F468                     | ---                               | ---                                  |
| C46400                                                                        | 4611; 4612 | MIL-W-6712               | B21; B124; B171; B283; B432; F467; F468  | SB171                             | ---                                  |
| C46500                                                                        | ---        | ---                      | B171; B432                               | SB171                             | ---                                  |
| C47000                                                                        | ---        | MIL-B-7883<br>(RBCuZn-A) | ---                                      | SFA5.8 (RBCuZn-A)                 | A5.8 (RBCuZn-A);<br>A5.27 (RBCuZn-A) |
| C47940                                                                        | ---        | ---                      | B21                                      | ---                               | ---                                  |
| C48200                                                                        | ---        | ---                      | B21; B124; B283                          | ---                               | ---                                  |
| C48500                                                                        | ---        | ---                      | B21; B124; B283                          | ---                               | ---                                  |
| C50100                                                                        | ---        | ---                      | B105                                     | ---                               | ---                                  |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS (Continued) |                     |                                           |                                                                     |                                          |                                      |
|-------------------------------------------------------------------------------|---------------------|-------------------------------------------|---------------------------------------------------------------------|------------------------------------------|--------------------------------------|
| UNS                                                                           | AMS                 | MIL SPEC                                  | ASTM                                                                | ASME                                     | AWS                                  |
| C50200                                                                        | ---                 | ---                                       | B105                                                                | ---                                      | ---                                  |
| C50500                                                                        | ---                 | ---                                       | B9; B105; B508                                                      | ---                                      | ---                                  |
| C50700                                                                        | ---                 | ---                                       | B105                                                                | ---                                      | ---                                  |
| C51000                                                                        | 4510; 4625;<br>4720 | MIL-T-3595;<br>MIL-W-6712;<br>MIL-B-13501 | B100; B103; B139; B159; F467 (510); F468 (510)                      | ---                                      | ---                                  |
| C51100                                                                        | ---                 | ---                                       | B100; B103                                                          | ---                                      | ---                                  |
| C51800                                                                        | ---                 | ---                                       | ---                                                                 | SFA5.7 (ERCuSn-A);<br>SFA5.21 (ERCuSn-A) | A5.7 (ERCuSn-A);<br>A5.21 (ERCuSn-A) |
| C52100                                                                        | ---                 | ---                                       | B103; B139; B159                                                    | SFA5.7 (ERCuSn-C)                        | A5.7 (ERCuSn-C)                      |
| C52400                                                                        | ---                 | ---                                       | B103; B139; B159                                                    | SFA5.21 (ERCuSn-D)                       | A5.21 (ERCuSn-D)                     |
| C53400                                                                        | ---                 | ---                                       | B103; B139                                                          | ---                                      | ---                                  |
| C54400                                                                        | 4520                | ---                                       | B103; B139                                                          | ---                                      | ---                                  |
| C55180                                                                        | ---                 | ---                                       | ---                                                                 | SFA5.8 (BCuP-1)                          | A5.8 (BCuP-1)                        |
| C55181                                                                        | ---                 | ---                                       | ---                                                                 | SFA5.8 (BCuP-2)                          | A5.8 (BCuP-2)                        |
| C55280                                                                        | ---                 | ---                                       | ---                                                                 | SFA5.8 (BCuP-6)                          | A5.8 (CVuP-6)                        |
| C55281                                                                        | ---                 | MIL-B-7883 (BCuP-3)                       | ---                                                                 | SFA5.8 (BCuP-3)                          | A5.8 (BCuP-3)                        |
| C55282                                                                        | ---                 | ---                                       | ---                                                                 | SFA5.8 (BCuP-7)                          | A5.8 (BCuP-7)                        |
| C55283                                                                        | ---                 | ---                                       | ---                                                                 | SFA5.8 (BCuP-4)                          | A5.8 (BCuP-4)                        |
| C55284                                                                        | ---                 | MIL-B-7883 (BCuP-5)                       | ---                                                                 | SFA5.8 (BCuP-5)                          | A5.8 (BCuP-5)                        |
| C60800                                                                        | ---                 | ---                                       | B111; B359; B395                                                    | SB111; SB359; SB395                      | ---                                  |
| C61000                                                                        | ---                 | ---                                       | ---                                                                 | SB169;<br>SFA5.7 (ERCuAl-Al)             | A5.7 (ERCuAl-Al)                     |
| C61300                                                                        | ---                 | ---                                       | B111; B150; B169; B171; B315; B432; B608;<br>F467 (613); F468 (613) | ---                                      | ---                                  |
| C61400                                                                        | ---                 | ---                                       | B111; B150; B169; B171; B315; B432; B608; F467;<br>F468             | SB150; SB169; SB171                      | ---                                  |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS (Continued) |            |                                               |                                                               |                     |                                     |
|-------------------------------------------------------------------------------|------------|-----------------------------------------------|---------------------------------------------------------------|---------------------|-------------------------------------|
| UNS                                                                           | AMS        | MIL SPEC                                      | ASTM                                                          | ASME                | AWS                                 |
| C61800                                                                        | ---        | MIL-W-6712;<br>MIL-E-23765/3<br>(MIL-CuAl-A2) | ---                                                           | SFA5.7 (ERCuAl-A2)  | A5.7 (ERCuAl-A2)                    |
| C61900                                                                        | ---        | ---                                           | B124; B150; B283                                              | ---                 | ---                                 |
| C62300                                                                        | 4635       | MIL-B-16166                                   | B124; B150; B283                                              | SB150               | ---                                 |
| C62400                                                                        | ---        | ---                                           | B150                                                          | SFA5.7 (ERCuAl-A3)  | A5.7 (ERCuAl-A3)                    |
| C63000                                                                        | 4640       | MIL-B-16166                                   | B124; B150; B171; B283; F467; F468                            | SB150; SB171        | ---                                 |
| C63200                                                                        | ---        | ---                                           | B124; B150; B283                                              | ---                 | ---                                 |
| C63280                                                                        | ---        | MIL-E-23765/3<br>(MIL-CuNiAl)                 | ---                                                           | SFA5.7 (ERCuNiAl)   | A5.7 (ERCuNiAl)                     |
| C63380                                                                        | ---        | MIL-E-23765/3<br>(MIL-CuMnNiAl)               | ---                                                           | SFA5.7 (ERCuMnNiAl) | A5.7 (ERCuMnNiAl)                   |
| C63800                                                                        | ---        | ---                                           | B422                                                          | ---                 | ---                                 |
| C64200                                                                        | 4631       | ---                                           | B124; B150; B283; F467; F468                                  | SB150; SB283        | ---                                 |
| C64210                                                                        | ---        | ---                                           | B124; B150; B283                                              | ---                 | ---                                 |
| C64700                                                                        | ---        | ---                                           | B411; B412                                                    | ---                 | ---                                 |
| C65100                                                                        | ---        | ---                                           | B96; B98; B99; B105; B315; B432; F467; F468                   | SB98; SB315         | ---                                 |
| C65400                                                                        | ---        | ---                                           | B96                                                           | ---                 | ---                                 |
| C65500                                                                        | 4615; 4665 | MIL-T-8231                                    | B96; B98; B99; B100; B105; B124; B283; B315; B432; F467; F468 | SB96; SB98; SB315   | ---                                 |
| C65600                                                                        | ---        | MIL-E-23765/3<br>(MIL-CuSi)                   | ---                                                           | SFA5.7 (ERCuSi-A)   | A5.7 (ERCuSi-A);<br>A5.27 (RCuSi-A) |
| C66100                                                                        | ---        | ---                                           | B98; F467; F468                                               | SB98                | ---                                 |
| C66400                                                                        | ---        | ---                                           | B694                                                          | ---                 | ---                                 |
| C66410                                                                        | ---        | ---                                           | B694                                                          | ---                 | ---                                 |
| C66700                                                                        | ---        | ---                                           | B291                                                          | ---                 | ---                                 |
| C67000                                                                        | ---        | ---                                           | B138                                                          | ---                 | ---                                 |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS (Continued) |     |                                                             |                                                                                 |                                                              |                                      |
|-------------------------------------------------------------------------------|-----|-------------------------------------------------------------|---------------------------------------------------------------------------------|--------------------------------------------------------------|--------------------------------------|
| UNS                                                                           | AMS | MIL SPEC                                                    | ASTM                                                                            | ASME                                                         | AWS                                  |
| C67500                                                                        | --- | ---                                                         | B124; B138; B283; F467; F468                                                    | ---                                                          | ---                                  |
| C68000                                                                        | --- | ---                                                         | ---                                                                             | ---                                                          | A5.27 (RCuZn-B)                      |
| C68100                                                                        | --- | ---                                                         | ---                                                                             | SFA5.27 (RBCuZn-C)                                           | A5.8 (RBCuZn-C);<br>A5.27 (RBCuZn-C) |
| C68700                                                                        | --- | ---                                                         | B111; B359; B395; B543                                                          | SB111, SB359; SB395;<br>SB543                                | ---                                  |
| C68800                                                                        | --- | ---                                                         | B592                                                                            | ---                                                          | ---                                  |
| C69100                                                                        | --- | ---                                                         | B706                                                                            | ---                                                          | ---                                  |
| C69400                                                                        | --- | ---                                                         | B371                                                                            | ---                                                          | ---                                  |
| C69430                                                                        | --- | ---                                                         | B371                                                                            | ---                                                          | ---                                  |
| C69700                                                                        | --- | ---                                                         | B371                                                                            | ---                                                          | ---                                  |
| C69710                                                                        | --- | ---                                                         | B371                                                                            | ---                                                          | ---                                  |
| C70200                                                                        | --- | MIL-B-18907;<br>MIL-B-20292                                 | ---                                                                             | ---                                                          | ---                                  |
| C70400                                                                        | --- | ---                                                         | B111; B359; B395; B466; B543                                                    | SB111; SB359; SB466;<br>SB543                                | ---                                  |
| C70600                                                                        | --- | MIL-T-15005;<br>MIL-C-15726;<br>MIL-T-16420;<br>MIL-T-22214 | B111; B122; B151; B171; B359; B395; B432; B466;<br>B467; B469; B543; B552; B608 | SB111; SB171; SB359;<br>SB395; SB402; SB466;<br>SB467; SB543 | ---                                  |
| C70690                                                                        | --- | ---                                                         | F96                                                                             | ---                                                          | ---                                  |
| C71000                                                                        | --- | ---                                                         | B111; B122; B206; B359; B395; B466; B543; B694;<br>F467; F468                   | SB111; SB359; SB395;<br>SB466                                | ---                                  |
| C71500                                                                        | --- | MIL-T-15005;<br>MIL-C-15726;<br>MIL-T-16420;<br>MIL-T-22214 | B111; B122; B171; B359; B395; B432; B466; B467;<br>B543; B552; B608; F467; F468 | SB111; SB171; SB359;<br>SB395; SB402; SB466;<br>SB467; SB543 | ---                                  |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS (Continued) |     |                                                         |                                                |                                                        |                                                  |
|-------------------------------------------------------------------------------|-----|---------------------------------------------------------|------------------------------------------------|--------------------------------------------------------|--------------------------------------------------|
| UNS                                                                           | AMS | MIL SPEC                                                | ASTM                                           | ASME                                                   | AWS                                              |
| C71580                                                                        | --- | ---                                                     | F96                                            | ---                                                    | ---                                              |
| C71581                                                                        | --- | MIL-E-21562<br>(RN7,EN67,RN67);<br>MIL-I-23413 (MIL-67) | ---                                            | SFA5.7 (ERCuNi);<br>SFA5.27 (RCuNi);<br>SFA5.30 (IN67) | A5.7 (ERCuNi);<br>A5.27 (RCuNi);<br>A5.30 (IN67) |
| C71590                                                                        | --- | ---                                                     | F96                                            | ---                                                    | ---                                              |
| C71640                                                                        | --- | ---                                                     | B111; B543; B552                               | ---                                                    | ---                                              |
| C72200                                                                        | --- | ---                                                     | B111; B122; B171; B359; B395; B466; B543; B552 | ---                                                    | ---                                              |
| C72500                                                                        | --- | ---                                                     | B122                                           | ---                                                    | ---                                              |
| C72700                                                                        | --- | ---                                                     | B740                                           | ---                                                    | ---                                              |
| C72900                                                                        | --- | ---                                                     | B740                                           | ---                                                    | ---                                              |
| C73500                                                                        | --- | ---                                                     | B122                                           | ---                                                    | ---                                              |
| C74000                                                                        | --- | ---                                                     | B122                                           | ---                                                    | ---                                              |
| C74500                                                                        | --- | ---                                                     | B122; B151; B206                               | ---                                                    | ---                                              |
| C75200                                                                        | --- | ---                                                     | B122; B151; B206; B458 (1)                     | ---                                                    | ---                                              |
| C75700                                                                        | --- | ---                                                     | B151; B206                                     | ---                                                    | ---                                              |
| C76200                                                                        | --- | ---                                                     | B122                                           | ---                                                    | ---                                              |
| C76400                                                                        | --- | ---                                                     | B151; B206                                     | ---                                                    | ---                                              |
| C77000                                                                        | --- | ---                                                     | B122; B151; B206                               | ---                                                    | ---                                              |
| C77300                                                                        | --- | ---                                                     | ---                                            | SFA5.7 (RBCuZn-D);<br>SFA5.27 (RBCuZn-D)               | A5.8 (RBCuZn-D)<br>A5.27 (RBCuZn-D)              |
| C77400                                                                        | --- | ---                                                     | B124; B283                                     | ---                                                    | ---                                              |
| C79200                                                                        | --- | ---                                                     | B151; B206                                     | ---                                                    | ---                                              |
| C81400                                                                        | --- | ---                                                     | B770                                           | ---                                                    | ---                                              |
| C82000                                                                        | --- | ---                                                     | B30 (10C); B770                                | ---                                                    | ---                                              |
| C82200                                                                        | --- | ---                                                     | B30 (3C, 14C); B770                            | ---                                                    | ---                                              |
| C82400                                                                        | --- | ---                                                     | B30 (165C, 165CT); B770                        | ---                                                    | ---                                              |

| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |            |                                       |                                                   |                                                            |            |
|------------------------------------------------------------------------------------------|------------|---------------------------------------|---------------------------------------------------|------------------------------------------------------------|------------|
| <b>UNS</b>                                                                               | <b>AMS</b> | <b>MIL SPEC</b>                       | <b>ASTM</b>                                       | <b>ASME</b>                                                | <b>AWS</b> |
| C82500                                                                                   | 4890       | MIL-C-11866 (17);<br>MIL-C-22087 (10) | B30 (20C, 20CT); B770                             | ---                                                        | ---        |
| C82510                                                                                   | ---        | ---                                   | B30 (21C); B770                                   | ---                                                        | ---        |
| C82600                                                                                   | ---        | ---                                   | BS0 (245C, 245CT); B770                           | ---                                                        | ---        |
| C82800                                                                                   | ---        | ---                                   | B30 (275C, 275CT); B770                           | ---                                                        | ---        |
| C83400                                                                                   | ---        | MIL-B-46066                           | ---                                               | ---                                                        | ---        |
| C83450                                                                                   | ---        | ---                                   | B30; B584; B763                                   | ---                                                        | ---        |
| C83600                                                                                   | 4855       | MIL-C-11866 (25);<br>MIL-V-18436      | B30 (4A); B62; B271; B505; B584 (formerly B145)   | B16.15; B16.18; B16.23;<br>B16.24; B16.26; B16.32;<br>SB62 | ---        |
| C83800                                                                                   | ---        | ---                                   | B30; B271; B505; B584 (formerly 145); B763        | B16.15; B16.18; B16.23                                     | ---        |
| C84200                                                                                   | ---        | ---                                   | B30; B505                                         | ---                                                        | ---        |
| C84400                                                                                   | ---        | ---                                   | B30; B271; B505; B584 (formerly B145); B763       | B16.15; B16.18; B16.23;<br>B16.26; B16.32                  | ---        |
| C84800                                                                                   | ---        | ---                                   | B30; B271; B505; B584 (formerly B145); B763       | ---                                                        | ---        |
| C85200                                                                                   | ---        | ---                                   | B30; B271; B584 (formerly B146); B763             | ---                                                        | ---        |
| C85400                                                                                   | ---        | ---                                   | B30; B271; B584 (formerly B146); B763             | ---                                                        | ---        |
| C85700                                                                                   | ---        | ---                                   | B30; B176; B271; B584; B763                       | ---                                                        | ---        |
| C85800                                                                                   | ---        | ---                                   | B30; B176                                         | ---                                                        | ---        |
| C86200                                                                                   | ---        | ---                                   | B30; B271; B505; B584 (formerly B147); B763       | ---                                                        | ---        |
| C86300                                                                                   | 4862       | MIL-C-11866 (21)                      | B22; B30; B271; B505; B584 (formerly B147); B763  | ---                                                        | ---        |
| C86400                                                                                   | ---        | ---                                   | B30; B271; B505; B584 (formerly B132, B147); B763 | ---                                                        | ---        |
| C86500                                                                                   | 4860       | ---                                   | B30; B176; B271; B505; B584 (formerly B147); B763 | ---                                                        | ---        |
| C86700                                                                                   | ---        | ---                                   | B30; B271; B584 (formerly B132); B763             | ---                                                        | ---        |
| C87300                                                                                   | ---        | MIL-C-11866<br>(Comp 19)              | B30; B271; B584; B763                             | ---                                                        | ---        |
| C87400                                                                                   | ---        | ---                                   | B30; B271; B584 (formerly B198); B763             | ---                                                        | ---        |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS (Continued) |            |                  |                                                  |             |     |
|-------------------------------------------------------------------------------|------------|------------------|--------------------------------------------------|-------------|-----|
| UNS                                                                           | AMS        | MIL SPEC         | ASTM                                             | ASME        | AWS |
| C87500                                                                        | ---        | ---              | B30; B271; B584 (formerly B198); B763; B806      | ---         | --- |
| C87600                                                                        | ---        | ---              | B30; B584; B763                                  | ---         | --- |
| C87610                                                                        | ---        | ---              | B30; B584; B763                                  | ---         | --- |
| C87800                                                                        | ---        | ---              | B30; B176; B806                                  | ---         | --- |
| C90300                                                                        | ---        | MIL-C-11866 (26) | B30; B271; B505; B584 (formerly B143); B763      | ---         | --- |
| C90500                                                                        | 4845       | ---              | B22; B30; B271; B505; B584 (formerly B143); B763 | ---         | --- |
| C90700                                                                        | ---        | ---              | B30; B427; B505                                  | ---         | --- |
| C90800                                                                        | ---        | ---              | B30; B427                                        | ---         | --- |
| C91000                                                                        | ---        | ---              | B30; B505                                        | ---         | --- |
| C91100                                                                        | ---        | ---              | B22; B30                                         | ---         | --- |
| C91300                                                                        | 7322       | ---              | B22; B30; B505                                   | ---         | --- |
| C91600                                                                        | ---        | ---              | B30; B427                                        | ---         | --- |
| C91700                                                                        | ---        | ---              | B30; B427                                        | ---         | --- |
| C92200                                                                        | ---        | MIL-V-17547      | B30; B271; B505; B584 (formerly B143)            | SB61; SB584 | --- |
| C92300                                                                        | ---        | ---              | B30; B271; B505; B584 (formerly B143); B763      | ---         | --- |
| C92500                                                                        | ---        | ---              | B30; B505                                        | ---         | --- |
| C92600                                                                        | ---        | ---              | B584                                             | ---         | --- |
| C92700                                                                        | ---        | ---              | B30; B505                                        | ---         | --- |
| C92800                                                                        | 7320       | ---              | B30; B505                                        | ---         | --- |
| C92900                                                                        | ---        | ---              | B30; B427; B505                                  | ---         | --- |
| C93200                                                                        | ---        | ---              | B30; B271; B505; B584 (formerly B144); B763      | ---         | --- |
| C93400                                                                        | ---        | ---              | B30; B505                                        | ---         | --- |
| C93500                                                                        | ---        | ---              | B30; B271; B505; B584 (formerly B144); B763      | ---         | --- |
| C93600                                                                        | ---        | ---              | B30; B271; B505                                  | ---         | --- |
| C93700                                                                        | 4842; 4827 | ---              | B30; B271; B505; B584 (formerly B144); B763      | SB584       | --- |
| C93800                                                                        | ---        | ---              | B30; B66; B271; B505; B584; B763                 | ---         | --- |
| C93900                                                                        | ---        | ---              | B30; B505                                        | ---         | --- |

| AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER & COPPER ALLOYS (Continued) |                           |                          |                                                  |                             |     |
|-------------------------------------------------------------------------------|---------------------------|--------------------------|--------------------------------------------------|-----------------------------|-----|
| UNS                                                                           | AMS                       | MIL SPEC                 | ASTM                                             | ASME                        | AWS |
| C94000                                                                        | ---                       | ---                      | B30; B505                                        | ---                         | --- |
| C94100                                                                        | ---                       | ---                      | B30; B67; B505                                   | ---                         | --- |
| C94300                                                                        | ---                       | ---                      | B30; B66; B271; B505; B584 (formerly B144); B763 | ---                         | --- |
| C94400                                                                        | ---                       | ---                      | B30; B66                                         | ---                         | --- |
| C94500                                                                        | ---                       | ---                      | B30; B66                                         | ---                         | --- |
| C94700                                                                        | ---                       | ---                      | B30; B505; B584 (formerly B292); B763            | ---                         | --- |
| C94800                                                                        | ---                       | ---                      | B30; B505; B584 (formerly B292); B763            | ---                         | --- |
| C94900                                                                        | ---                       | ---                      | B30; B584 (formerly B292); B763                  | ---                         | --- |
| C95200                                                                        | ---                       | ---                      | B30; B148; B271; B505; B763                      | B16.24; SB148; SB505; SB271 | --- |
| C95300                                                                        | ---                       | MIL-C-11866 (22)         | B30; B148; B271; B505; B763; B806                | ---                         | --- |
| C95400                                                                        | ---                       | MIL-C-11866<br>(Comp 23) | B30; B148; B271; B505; B763; B806                | SB148; SB271                | --- |
| C95410                                                                        | ---                       | ---                      | B30; B148; B271; B505; B763; B806                | ---                         | --- |
| C95420                                                                        | 4870; 4871;<br>4872; 4873 | ---                      | ---                                              | ---                         | --- |
| C95500                                                                        | ---                       | ---                      | B30; B148; B271; B505; B763; B806                | ---                         | --- |
| C95510                                                                        | 4880                      | ---                      | ---                                              | ---                         | --- |
| C95520                                                                        | 4881                      | ---                      | ---                                              | ---                         | --- |
| C95600                                                                        | ---                       | ---                      | B30; B148; B763                                  | ---                         | --- |
| C95700                                                                        | ---                       | ---                      | B30; B148; B505                                  | ---                         | --- |
| C95800                                                                        | ---                       | MIL-B-24480              | B30; B148; B271; B505; B763; B806                | ---                         | --- |
| C95900                                                                        | ---                       | ---                      | B148; B505                                       | ---                         | --- |
| C96200                                                                        | ---                       | MIL-V-18436              | B30; B369                                        | ---                         | --- |
| C96400                                                                        | ---                       | ---                      | B30; B369; B505                                  | ---                         | --- |
| C96700                                                                        | ---                       | ---                      | B30 (72C); B770                                  | ---                         | --- |



| <b>AMERICAN CROSS REFERENCED SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |            |                 |                                             |             |            |
|------------------------------------------------------------------------------------------|------------|-----------------|---------------------------------------------|-------------|------------|
| <b>UNS</b>                                                                               | <b>AMS</b> | <b>MIL SPEC</b> | <b>ASTM</b>                                 | <b>ASME</b> | <b>AWS</b> |
| C96800                                                                                   | ---        | ---             | B30; B584                                   | ---         | ---        |
| C97300                                                                                   | ---        | ---             | B30; B271; B505; B584 (formerly B149); B763 | ---         | ---        |
| C97600                                                                                   | ---        | MIL-V-18436     | B30; B271; B505; B584 (formerly B149); B763 | SB584       | ---        |
| C97800                                                                                   | ---        | MIL-V-18436     | B30; B271; B505; B584 (formerly B149); B763 | ---         | ---        |
| C98200                                                                                   | 4824       | ---             | ---                                         | ---         | ---        |
| C98400                                                                                   | 4822       | MIL-B-13506     | ---                                         | ---         | ---        |
| C99400                                                                                   | ---        | ---             | B30; B763                                   | ---         | ---        |
| C99500                                                                                   | ---        | ---             | B30; B763                                   | ---         | ---        |
| C99700                                                                                   | ---        | ---             | B30; B176                                   | ---         | ---        |
| C99750                                                                                   | ---        | ---             | B30; B176                                   | ---         | ---        |

This cross-reference table lists the basic specification or standard number, and since these standards are constantly being revised, it should be kept in mind that they are presented herein as a guide and may not reflect the latest revision.

| <b>COMMON NAMES OF COPPER &amp; COPPER ALLOYS WITH UNS No.</b> |            |                            |            |
|----------------------------------------------------------------|------------|----------------------------|------------|
| <b>Common Name</b>                                             | <b>UNS</b> | <b>Common Name</b>         | <b>UNS</b> |
| Admiralty, Antimonial (Cu-Zn-Sn)                               | C44400     | Aluminum Bronze            | C63000     |
| Admiralty, Arsenical (Cu-Zn-Sn)                                | C44300     | Aluminum Bronze            | C63200     |
| Admiralty, Phosphorized (Cu-Zn-Sn)                             | C44500     | Aluminum Bronze            | C63800     |
| Aluminum Brass, Arsenical                                      | C68700     | Aluminum Bronze            | C64200     |
| Aluminum Bronze                                                | C60800     | Aluminum Bronze D          | C61400     |
| Aluminum Bronze                                                | C61000     | Aluminum Silicon Bronze    | C64210     |
| Aluminum Bronze                                                | C61300     | Architectural Bronze       | C38500     |
| Aluminum Bronze                                                | C61800     | Beryllium Copper           | C17000     |
| Aluminum Bronze                                                | C61900     | Beryllium Copper           | C17200     |
| Aluminum Bronze                                                | C62300     | Beryllium Copper           | C17500     |
| Aluminum Bronze                                                | C62400     | Beryllium Copper with Lead | C17300     |

| <b>COMMON NAMES OF COPPER &amp; COPPER ALLOYS WITH UNS No. (Continued)</b> |            |                                    |            |
|----------------------------------------------------------------------------|------------|------------------------------------|------------|
| <b>Common Name</b>                                                         | <b>UNS</b> | <b>Common Name</b>                 | <b>UNS</b> |
| Brass                                                                      | C27200     | Cast Copper Alloy                  | C99500     |
| Brass Alloy                                                                | C47940     | Cast Copper Alloy                  | C99700     |
| Bronze, Low Fuming                                                         | C68100     | Cast Copper Alloy                  | C99750     |
| Bronze, Low Fuming (Nickel)                                                | C68000     | Cast Copper Nickel Beryllium Alloy | C96700     |
| Cadmium Copper                                                             | C16200     | Cast Copper-Nickel                 | C96200     |
| Cadmium Copper Alloy                                                       | C16500     | Cast Copper-Nickel                 | C96400     |
| Cartridge Brass, 70%                                                       | C26000     | Cast Copper-Nickel Alloy           | C96800     |
| Cast Aluminum Bronze                                                       | C95200     | Cast High-Leaded Tin Bronze        | C94400     |
| Cast Aluminum Bronze                                                       | C95300     | Cast High-Leaded Tin Bronze        | C94500     |
| Cast Aluminum Bronze                                                       | C95400     | Cast High-Leaded Tin Bronze        | C93200     |
| Cast Aluminum Bronze                                                       | C95410     | Cast High-Leaded Tin Bronze        | C93400     |
| Cast Aluminum Bronze                                                       | C95420     | Cast High-Leaded Tin Bronze        | C93500     |
| Cast Aluminum Bronze                                                       | C95500     | Cast High-Leaded Tin Bronze        | C93600     |
| Cast Aluminum Bronze                                                       | C95510     | Cast High-Leaded Tin Bronze        | C93700     |
| Cast Aluminum Bronze                                                       | C95520     | Cast High-Leaded Tin Bronze        | C93720     |
| Cast Aluminum Bronze                                                       | C95600     | Cast High-Leaded Tin Bronze        | C93800     |
| Cast Aluminum Bronze                                                       | C95700     | Cast High-Leaded Tin Bronze        | C93900     |
| Cast Aluminum Bronze                                                       | C95800     | Cast High-Leaded Tin Bronze        | C94000     |
| Cast Aluminum Bronze                                                       | C95900     | Cast High-Leaded Tin Bronze        | C94100     |
| Cast Beryllium Copper                                                      | C82000     | Cast High-Leaded Tin Bronze        | C94300     |
| Cast Beryllium Copper, 165C                                                | C82400     | Cast High-Leaded Tin Bronze        | C94320     |
| Cast Beryllium Copper, 20C                                                 | C82500     | Cast High-Leaded Tin Bronze        | C94330     |
| Cast Beryllium Copper, 245C                                                | C82600     | Cast Leaded Copper                 | C98200     |
| Cast Beryllium Copper, 275C                                                | C82800     | Cast Leaded Copper                 | C98400     |
| Cast Beryllium Copper, 35B, 35C                                            | C82200     | Cast Leaded Copper                 | C98820     |
| Cast Chromium Copper, 70C                                                  | C81400     | Cast Leaded Copper                 | C98840     |
| Cast Copper Alloy                                                          | C99400     | Cast Leaded Manganese Bronze       | C86400     |

| <b>COMMON NAMES OF COPPER &amp; COPPER ALLOYS WITH UNS No. (Continued)</b> |            |                                          |            |
|----------------------------------------------------------------------------|------------|------------------------------------------|------------|
| <b>Common Name</b>                                                         | <b>UNS</b> | <b>Common Name</b>                       | <b>UNS</b> |
| Cast Leaded Manganese Bronze                                               | C86700     | Cast Semi-Red Brass                      | C84800     |
| Cast Leaded Red Brass                                                      | C83600     | Cast Silicon Brass                       | C87400     |
| Cast Leaded Red Brass                                                      | C83800     | Cast Silicon Brass                       | C87500     |
| Cast Leaded Tin Bronze                                                     | C87610     | Cast Silicon Brass                       | C87600     |
| Cast Leaded Tin Bronze                                                     | C92200     | Cast Silicon Bronze                      | C87800     |
| Cast Leaded Tin Bronze                                                     | C92300     | Cast Tin Bronze                          | C91600     |
| Cast Leaded Tin Bronze                                                     | C92500     | Cast Tin Bronze                          | C91700     |
| Cast Leaded Tin Bronze                                                     | C92600     | Cast Tin Bronze                          | C90300     |
| Cast Leaded Tin Bronze                                                     | C92700     | Cast Tin Bronze                          | C90500     |
| Cast Leaded Tin Bronze                                                     | C92800     | Cast Tin Bronze                          | C90700     |
| Cast Leaded Tin Bronze                                                     | C92900     | Cast Tin Bronze                          | C90800     |
| Cast Leaded Yellow Brass                                                   | C85200     | Cast Tin Bronze                          | C91000     |
| Cast Leaded Yellow Brass                                                   | C85400     | Cast Tin Bronze                          | C91100     |
| Cast Leaded Yellow Brass                                                   | C85700     | Cast Tin Bronze                          | C91300     |
| Cast Leaded Yellow Brass                                                   | C85800     | Chemically Refined Tough Pitch Copper    | C11030     |
| Cast Manganese Bronze                                                      | C86300     | Chromium Copper                          | C18200     |
| Cast Manganese Bronze                                                      | C86500     | Commercial Bronze, 90%                   | C22000     |
| Cast Manganese Bronze                                                      | C86200     | Copper Alloy                             | C66400     |
| Cast Nickel-Silver                                                         | C97300     | Copper Alloy                             | C68800     |
| Cast Nickel-Silver                                                         | C97600     | Copper Alloy                             | C69100     |
| Cast Nickel-Silver                                                         | C97800     | Copper Beryllium Alloy                   | C17510     |
| Cast Nickel-Tin Bronze                                                     | C94700     | Copper Brazing Filler Metal              | C14180     |
| Cast Nickel-Tin Bronze                                                     | C94800     | Copper Silicon                           | C65400     |
| Cast Nickel-Tin Bronze                                                     | C94900     | Copper Silicon Alloy                     | C87300     |
| Cast Red Brass                                                             | C83400     | Copper Vacuum Grade Brazing Filler Metal | C14181     |
| Cast Semi-Red Brass                                                        | C84200     | Copper Welding Filler Metal              | C18980     |
| Cast Semi-Red Brass                                                        | C84400     | Copper-Beryllium                         | C82510     |

| <b>COMMON NAMES OF COPPER &amp; COPPER ALLOYS WITH UNS No. (Continued)</b> |            |                                                     |            |
|----------------------------------------------------------------------------|------------|-----------------------------------------------------|------------|
| <b>Common Name</b>                                                         | <b>UNS</b> | <b>Common Name</b>                                  | <b>UNS</b> |
| Copper-Beryllium Alloy (Beryllium-Copper)                                  | C17410     | Electronic/Electrowon Tough Pitch Copper            | C11040     |
| Copper-Nickel                                                              | C71580     | Fine Refined High Conductivity Tough Pitch Copper   | C11020     |
| Copper-Nickel                                                              | C71640     | Fire-Refined Tough Pitch Copper with Silver (FRSTP) | C12900     |
| Copper-Nickel                                                              | C72200     | Forging Brass                                       | C37700     |
| Copper-Nickel                                                              | C72500     | Free Cutting Brass                                  | C36000     |
| Copper-Nickel                                                              | C70200     | Free Cutting Muntz Metal (Cu-Zn-Pb)                 | C37000     |
| Copper-Nickel Tin Spinodal Alloy                                           | C72700     | Gilding, 95% (Copper/Zinc)                          | C21000     |
| Copper-Nickel Tin Spinodal Alloy                                           | C72900     | High Copper Alloy                                   | C19200     |
| Copper-Nickel Welding Filler Metal                                         | C71581     | High Copper Alloy                                   | C19400     |
| Copper-Nickel, 10%                                                         | C70600     | High Copper Alloy                                   | C19500     |
| Copper-Nickel, 20%                                                         | C71000     | High Leaded Brass (Tube)                            | C33200     |
| Copper-Nickel, 30%                                                         | C71500     | High Leaded Brass, 62%                              | C35300     |
| Copper-Nickel, 5%                                                          | C70400     | High Leaded Brass, 64-½%                            | C34200     |
| Copper-Nickel, 70Cu-30Ni                                                   | C71590     | High Silicon Bronze A                               | C65500     |
| Copper-Nickel, 90Cu-10Ni                                                   | C70690     | Jewelry Bronze, 87-½%                               | C22600     |
| Copper-Phosphorus Brazing Filler Metal                                     | C55180     | Leaded Brass                                        | C34500     |
| Copper-Phosphorus Brazing Filler Metal                                     | C55181     | Leaded Brass                                        | C38000     |
| Copper-Tellurium                                                           | C14520     | Leaded Brass Alloy                                  | C35600     |
| Copper-Tellurium Alloy                                                     | C14510     | Leaded Commercial Bronze                            | C31400     |
| Copper-Tellurium-Tin Alloy                                                 | C14420     | Leaded Commercial Bronze (Nickel Bearing)           | C31600     |
| Cu-Ag-P Brazing Filler Metal                                               | C55280     | Leaded Copper                                       | C18700     |
| Cu-Ag-P Brazing Filler Metal                                               | C55281     | Leaded Muntz Metal, Uninhibited (Cu-Zn-Pb)          | C36500     |
| Cu-Ag-P Brazing Filler Metal                                               | C55282     | Leaded Nickel silver                                | C79200     |
| Cu-Ag-P Brazing Filler Metal                                               | C55283     | Leaded Red Brass                                    | C32000     |
| Cu-Ag-P Brazing Filler Metal                                               | C55284     | Leaded Red Brass                                    | C83450     |
| Electrolytic Tough Pitch Anneal Resistant                                  | C11100     | Leaded Silicon Brass                                | C69700     |
| Electrolytic Tough Pitch Copper (ETP)                                      | C11000     | Low Brass, 80%                                      | C24000     |

| <b>COMMON NAMES OF COPPER &amp; COPPER ALLOYS WITH UNS No. (Continued)</b> |            |                                                 |            |
|----------------------------------------------------------------------------|------------|-------------------------------------------------|------------|
| <b>Common Name</b>                                                         | <b>UNS</b> | <b>Common Name</b>                              | <b>UNS</b> |
| Low Leaded Brass                                                           | C33500     | Nickel Silver                                   | C77400     |
| Low Leaded Brass (Tube)                                                    | C33000     | Nickel Silver, 55-18                            | C77000     |
| Low Silicon Bronze B                                                       | C65100     | Nickel Silver, 65-10                            | C74500     |
| Manganese Aluminum Bronze Welding Filler Metal                             | C63380     | Nickel Silver, 65-12                            | C75700     |
| Manganese Brass                                                            | C66700     | Nickel Silver, 65-18                            | C75200     |
| Manganese Bronze                                                           | C67300     | Oxygen-Free Copper (OF)                         | C10200     |
| Manganese Bronze                                                           | C67400     | Oxygen-Free Copper with Silver (OFS)            | C10400     |
| Manganese Bronze A                                                         | C67500     | Oxygen-Free Copper with Silver (OFS)            | C10500     |
| Manganese Bronze B                                                         | C67000     | Oxygen-Free Copper with Silver (OFS)            | C10700     |
| Medium Leaded Brass, 62%                                                   | C35000     | Oxygen-Free Electronic Copper (OFE)             | C10100     |
| Medium Leaded Brass, 64-½%                                                 | C34000     | Oxygen-Free Extra Low Phosphorus Copper (OFXLP) | C10300     |
| Misc. Copper Zinc Alloy                                                    | C66410     | Oxygen-Free Low Phosphorus Copper (OFLP)        | C10800     |
| Muntz Metal, 60%                                                           | C28000     | Phosphor Bronze                                 | C50100     |
| Naval Brass, 63-½%                                                         | C46200     | Phosphor Bronze                                 | C50200     |
| Naval Brass, Arsenical                                                     | C46500     | Phosphor Bronze                                 | C50700     |
| Naval Brass, High Leaded                                                   | C48500     | Phosphor Bronze                                 | C51100     |
| Naval Brass, Medium Leaded                                                 | C48200     | Phosphor Bronze                                 | C51800     |
| Naval Brass, Uninhibited                                                   | C46400     | Phosphor Bronze B-1                             | C53400     |
| Naval Brass, Welding and Brazing Rod                                       | C47000     | Phosphor Bronze B-2                             | C54400     |
| Nickel Aluminum Bronze Welding Filler Metal                                | C63280     | Phosphor Bronze, 1.25% E                        | C50500     |
| Nickel Brass Welding and Brazing Filler Metal                              | C77300     | Phosphor Bronze, 10% D                          | C52400     |
| Nickel Silver                                                              | C73500     | Phosphor Bronze, 5% A                           | C51000     |
| Nickel Silver                                                              | C74000     | Phosphor Bronze, 8%                             | C52100     |
| Nickel Silver                                                              | C76200     | Phosphorus Deoxidized Copper, Arsenical (DPA)   | C14200     |
| Nickel Silver                                                              | C76400     | Phosphorus Deoxidized Copper, Tellurium Bearing | C14500     |

| <b>COMMON NAMES OF COPPER &amp; COPPER ALLOYS WITH UNS No. (Continued)</b> |            |                                      |            |
|----------------------------------------------------------------------------|------------|--------------------------------------|------------|
| <b>Common Name</b>                                                         | <b>UNS</b> | <b>Common Name</b>                   | <b>UNS</b> |
| Phosphorus Deoxidized, High Residual Phosphorus Copper (DHP)               | C12200     | Tin Brass                            | C41500     |
| Phosphorus Deoxidized, Low Residual Phosphorus Copper (DLP)                | C12000     | Tin Brass                            | C42200     |
| Silicon Brass                                                              | C69710     | Tin Brass                            | C42500     |
| Silicon Bronze                                                             | C64700     | Tin Brass                            | C43000     |
| Silicon Bronze                                                             | C65600     | Tin Brass                            | C43400     |
| Silicon Bronze                                                             | C66100     | Tough Pitch Copper with Silver (STP) | C11300     |
| Silicon Red Brass                                                          | C69400     | Tough Pitch Copper with Silver (STP) | C11400     |
| Silicon Red Brass                                                          | C69430     | Tough Pitch Copper with Silver (STP) | C11500     |
| Silver-Bearing, High Residual Phosphorus Copper (DHP)                      | C12300     | Tough Pitch Copper with Silver (STP) | C11600     |
| Silver-Bearing, Low Residual Phosphorus Copper (DLP)                       | C12100     | Yellow Brass, 63%                    | C27400     |
| Sulfur-Bearing Copper                                                      | C14700     | Yellow Brass, 65%                    | C27000     |
| Tin Brass                                                                  | C40500     | Yellow Brass, 66%                    | C26800     |
| Tin Brass                                                                  | C41100     | Zirconium Copper                     | C15000     |
| Tin Brass                                                                  | C41300     | Zirconium Copper                     | C15100     |

| <b>BRITISH BSI SPECIFICATIONS - COPPER &amp; COPPER ALLOYS</b> |                                                                                                             |
|----------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                      | <b>Title</b>                                                                                                |
| 61                                                             | Threads for Light Gauge Copper Tubes and Fittings                                                           |
| 125                                                            | Hard-Drawn Copper and Copper-Cadmium Conductors for Overhead Power Transmission Purposes                    |
| 159                                                            | High-Voltage Busbars and Busbar Connections                                                                 |
| 181                                                            | Copper-Cadmium Jointing Sleeves for Telegraph and Telephone Purposes                                        |
| 1184                                                           | Copper and Copper Alloy Traps                                                                               |
| 1306                                                           | Copper and Copper Alloy Pressure Piping Systems                                                             |
| 1400                                                           | Copper Alloy Ingots and Copper Alloy and High Conductivity Copper Castings                                  |
| 1431                                                           | Wrought Copper and Wrought Zinc Rainwater Goods                                                             |
| 1432                                                           | Copper for Electrical Purposes : High Conductivity Copper Rectangular Conductors with Drawn or Rolled Edges |

| <b>BRITISH BSI SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                       |
|----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                                  | <b>Title</b>                                                                                          |
| 1433                                                                       | Copper for Electrical Purposes. Rod and Bar                                                           |
| 1434                                                                       | Copper for Electrical Purposes: Copper Sections in Bars, Blanks and Segments for Commutators          |
| 1977                                                                       | High Conductivity Copper Tubes for Electrical Purposes                                                |
| 2755                                                                       | Copper and Copper- Cadmium Stranded Conductors for Overhead Electric Traction Systems                 |
| 2767                                                                       | Manually Operated Copper Alloy Valves for Radiators                                                   |
| 2870                                                                       | Rolled Copper and Copper Alloys. Sheet, Strip and Foil                                                |
| 2871 Part 1                                                                | Copper and Copper Alloys. Tubes Part 1: Copper Tubes for Water, Gas and Sanitation                    |
| 2871 Part 2                                                                | Copper and Copper Alloys. Tubes Part 2: Tubes for General Purposes                                    |
| 2871 Part 3                                                                | Copper and Copper Alloys. Tubes Part 3: Tubes for Heat Exchangers                                     |
| 2872                                                                       | Copper and Copper Alloy Forging Stock and Forgings                                                    |
| 2873                                                                       | Copper and Copper Alloys. Wire                                                                        |
| 2874                                                                       | Copper and Copper Alloy Rods and Sections (Other Than Forging Stock)                                  |
| 2875                                                                       | Copper and Copper Alloys. Plate                                                                       |
| 2901 Part 3                                                                | Filler Rods and Wires for Gas-Shielded Arc Welding Part 3: Specification for Copper and Copper Alloys |
| 3071                                                                       | Nickel-Copper Alloy Castings                                                                          |
| 3839                                                                       | Oxygen-Free High- Conductivity Copper for Electronic Tubes and Semi-Conductor Devices                 |
| 4608                                                                       | Copper for Electrical Purposes. Rolled Sheet, Strip and Foil                                          |
| 5561                                                                       | Spools for Copper Wire                                                                                |
| 5624                                                                       | The Lining of Vessels and Equipment for Chemical Processes: Copper and Copper Alloys                  |
| 5899                                                                       | Method for Hydrogen Embrittlement Test for Copper                                                     |
| 5909                                                                       | Scale Adhesion Test for Oxygen-Free Copper                                                            |
| 6017                                                                       | Copper Refinery Shapes                                                                                |
| 6926                                                                       | Copper for Electrical Purposes: High Conductivity Copper Wire Rod                                     |
| 6931                                                                       | Glossary of Terms for Copper and Copper Alloys                                                        |
| 7428                                                                       | Estimating the Average Grain Size of Copper and Copper Alloys                                         |
| CP143 Part 12                                                              | Sheet Roof and Wall Coverings Part 12: Copper. Metric Units                                           |
| MA 60                                                                      | Summary and Application of Cooper and Copper Alloy Tubes for Ships' Pipework Systems                  |

| <b>BRITISH BSI SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                       |
|----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| <b>BS</b>                                                                  | <b>Title</b>                                                                                                          |
| MA 75 Part 1                                                               | Bulkhead Pieces and Tank Pads Part 1: Bulkhead Pieces of Fabricated Steel or Copper Alloy and Steel Pad Pieces        |
| B 23                                                                       | Copper-Aluminium-Nickel-Iron Alloy Rods, Sections, Forging Stock And Forgings                                         |
| B 24                                                                       | Copper-Tin-Phosphorous Alloy Rods and Sections                                                                        |
| B 25                                                                       | Copper-Nickel-Silicon Alloy Rods, Sections, Forging Stock and Forgings (Heat Treated)                                 |
| B 26                                                                       | Copper-Nickel-Silicon Alloy Rods and Sections (Cold Worked and Heat Treated)                                          |
| B 27                                                                       | Copper-Zinc-Aluminium- Nickel-Silicon Alloy Tube                                                                      |
| B 28                                                                       | Copper-Beryllium Alloy Strip, Foil and Parts (Solution Treated (W) and Precipitated)                                  |
| B 29                                                                       | Copper-Beryllium Alloy Strip, Foil and Parts (Solution Treated, Cold Rolled: Quarter Hard (W(1/4H)) and Precipitated) |
| B 30                                                                       | Copper-Beryllium Alloy Strip, Foil and Parts (Solution Treated, Cold Rolled: Half Hard (W(½H)) and Precipitated)      |
| B 31                                                                       | Copper-Beryllium Alloy Strip, Foil and Parts (Solution Treated, Cold Rolled: Full Hard (W(H)) and Precipitated)       |
| B 32                                                                       | Copper-Beryllium Alloy Rods, Sections and Parts (Solution Treated (W) and Precipitated)                               |
| B 33                                                                       | Copper-Beryllium Alloy Wire and Springs (Solution Treated (W) and Precipitated)                                       |
| B 100                                                                      | Inspection, Testing and Acceptance of Wrought Copper Alloys                                                           |
| 2B 8                                                                       | Specification For Aircraft Material. Phosphor Bronze Casting for Bearings.                                            |
| HC 502                                                                     | Copper Base Aluminium- Nickel-Iron Alloy Castings (620 MPa) (Al 9.5, Ni 5, Fe 5)                                      |
| HR 205                                                                     | Nickel-Copper Alloy Sheet and Strip: Annealed (Nickel Base, Cu 31)                                                    |

| <b>GERMAN DIN SPECIFICATIONS - COPPER &amp; COPPER ALLOYS</b> |                                                                                                                                                |
|---------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                    | <b>Title</b>                                                                                                                                   |
| 1705                                                          | Copper-Tin and Copper- Tin-Zinc Casting Alloys; (Cast Tin Bronze and Gunmetal); Castings                                                       |
| 1705 Suppl. 1                                                 | Copper-Tin and Copper- Tin-Zinc Casting Alloys; (Cast Tin Bronze and Gunmetal); Castings; Reference Data on Mechanical and Physical Properties |
| 1708                                                          | Copper; Cathodes and Refinery Shapes                                                                                                           |
| 1714                                                          | Copper-Aluminium Casting Alloys; (Cast Aluminium Bronze); Castings                                                                             |
| 1714 Suppl. 1                                                 | Copper-Aluminium Casting Alloys; (Cast Aluminium Bronze); Castings; Reference Data on Mechanical and Physical Properties                       |
| 1716                                                          | Copper-Lead-Tin Casting Alloys; (Cast Tin-Lead Bronze); Castings                                                                               |



| <b>GERMAN DIN SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                  |
|---------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                | <b>Title</b>                                                                                                                     |
| 1716 Suppl. 1                                                             | Copper-Lead-Tin Casting Alloys; (Cast Tin-Lead Bronze); Castings; Reference Data on Mechanical and Physical Properties           |
| 1718                                                                      | Copper Alloys; Definitions                                                                                                       |
| 1733 Pt 1                                                                 | Filler Metals for Welding Copper and Copper Alloys; Composition, Application and Technical Delivery Conditions                   |
| 1751                                                                      | Sheet and Sheet Cut to Length of Copper and Wrought Copper Alloys; Cold Rolled; Dimensions                                       |
| 1754 Pt 1                                                                 | Copper Tubes; Seamless Drawn; Dimension Ranges and Coordination of Tolerances                                                    |
| 1754 Pt 2                                                                 | Copper Tubes; Seamless Drawn; Preferred Dimensions for General Purposes                                                          |
| 1754 Pt 3                                                                 | Copper Tubes; Seamless Drawn; Preferred Dimensions for Pipelines                                                                 |
| 1755 Pt 1                                                                 | Wrought Copper Alloy Tubes; Seamless Drawn; Dimension Ranges and Coordination of Tolerances                                      |
| 1755 Pt 2                                                                 | Copper Wrought Alloy Tubes; Seamless Drawn; Preferred Dimensions for General Purposes                                            |
| 1755 Pt 3                                                                 | Copper Wrought Alloy Tubes; Seamless Drawn; Preferred Dimensions for Pipelines                                                   |
| 1756                                                                      | Round Rod of Copper and Wrought Copper Alloys; Drawn; Dimensions                                                                 |
| 1757                                                                      | Wire of Copper and Wrought Copper Alloys, Drawn; Dimensions                                                                      |
| 1759                                                                      | Rectangular Bars of Copper and Wrought Copper Alloys; Drawn, with Sharp Edges; Dimensions, Permissible Variations, Static Values |
| 1761                                                                      | Square Rod of Copper and Copper Wrought Alloys; Drawn, with Sharp Edges; Dimensions                                              |
| 1763                                                                      | Hexagon Rod of Copper and Wrought Copper Alloys; Drawn, with Sharp Edges; Dimensions                                             |
| 1777                                                                      | Wrought Copper Alloy Strip for Springs; Technical Delivery Conditions                                                            |
| 1782                                                                      | Round Rod of Copper and Wrought Copper Alloys; Extruded; Dimensions                                                              |
| 1785                                                                      | Wrought Copper and Copper Alloy Tubes for Condensers and Heat Exchangers                                                         |
| 1786                                                                      | Seamless Drawn Copper Tubes for Piping Systems                                                                                   |
| 1787                                                                      | Copper; Half-Finished Products                                                                                                   |
| 1791                                                                      | Strip and Strip Cut to Length of Copper and Wrought Copper Alloys; Cold Rolled; Dimensions                                       |
| 1850 Pt 1                                                                 | Bushes for Plain Bearings; Made from Copper Alloys, Solid                                                                        |
| 3352 Pt 11                                                                | Flanged Copper Alloy Gate Valves                                                                                                 |
| 3352 Pt 12                                                                | Socket End Copper Alloy Gate Valves                                                                                              |
| 8513 Pt 1                                                                 | Brazing and Braze Weld Filler Metals; Copper Base Brazing Alloys; Composition, Use, Technical Conditions of Delivery             |
| 8552 Pt 3                                                                 | Edge Preparation for Welding; Groove Forms on Copper and Copper Alloys; Gas Welding and Gas-Shielded Arc Welding                 |
| 17650                                                                     | Copper Sheet and Strip for Use in Building Construction; Technical Delivery Conditions                                           |

| <b>GERMAN DIN SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                 |
|---------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                | <b>Title</b>                                                                                                    |
| 17652                                                                     | Copper Drawing Stock                                                                                            |
| 17655                                                                     | Unalloyed and Low Alloy Copper Materials for Casting; Castings                                                  |
| 17656                                                                     | Copper Casting Alloys; Ingot Metals; Composition                                                                |
| 17657                                                                     | Copper Master Alloys; Composition Copper-Nickel Casting Alloys; Castings                                        |
| 17660                                                                     | Wrought Copper Alloys; Copper-Zinc Alloys; (Brass); (Special Brass); Composition                                |
| 17662                                                                     | Wrought Copper Alloys; Copper-Tin Alloys; (Tin Bronze); Composition                                             |
| 17663                                                                     | Wrought Copper Alloys; Copper-Nickel-Zinc Alloys; (Nickel Silver); Composition                                  |
| 17664                                                                     | Wrought Copper Alloys; Copper-Nickel Alloys; Composition                                                        |
| 17665                                                                     | Wrought Copper Alloys; Copper-Aluminium Alloys; (Aluminium Bronze); Composition                                 |
| 17666                                                                     | Low Alloy Wrought Copper Alloys;                                                                                |
| 17670 Pt 1                                                                | Wrought Copper and Copper Alloy Plate, Sheet and Strip; Properties                                              |
| 17670 Pt 2                                                                | Plate, Sheet and Strip of Copper and Wrought Copper Alloys; Technical Conditions of Delivery                    |
| 17671 Pt 1                                                                | Wrought Copper and Copper Alloy Tubes; Properties                                                               |
| 17671 Pt 2                                                                | Tubes of Copper and Wrought Copper Alloys; Technical Conditions of Delivery                                     |
| 17672 Pt 1                                                                | Wrought Copper and Copper Alloy Rod and Bar; Properties                                                         |
| 17672 Pt 2                                                                | Bars of Copper and Wrought Copper Alloys; Technical Conditions of Delivery                                      |
| 17673 Pt 1                                                                | Wrought Copper and Copper Alloy Drop Forgings; Properties                                                       |
| 17673 Pt 2                                                                | Drop Forgings of Copper and Wrought Copper Alloys; Technical Conditions of Delivery                             |
| 17673 Pt 3                                                                | Drop Forgings of Copper and Wrought Copper Alloys; Design Principles                                            |
| 17673 Pt 4                                                                | Drop Forgings of Copper and Wrought Copper Alloys; Permissible Variations                                       |
| 17674 Pt 1                                                                | Wrought Copper and Copper Alloy Extruded Sections; Properties                                                   |
| 17674 Pt 2                                                                | Copper and Wrought Copper Alloy Extruded Sections; Technical Conditions of Delivery                             |
| 17674 Pt 3                                                                | Copper and Wrought Copper Alloy Extruded Sections; Design                                                       |
| 17674 Pt 4                                                                | Copper and Copper Wrought Alloy Extruded Sections; Extruded, Permissible Variations                             |
| 17674 Pt 5                                                                | Copper and Wrought Copper Alloy Extruded Sections; Drawn; Permissible Variations                                |
| 17675 Pt 1                                                                | Plates of Copper and Wrought Copper Alloys for Condensers and Heat Exchangers; Strength Properties              |
| 17675 Pt 2                                                                | Plates of Copper and Wrought Copper Alloys for Condensers and Heat Exchangers; Technical Conditions of Delivery |

| <b>GERMAN DIN SPECIFICATIONS - COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                      |
|---------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>DIN</b>                                                                | <b>Title</b>                                                                                                                                         |
| 17675 Pt 3                                                                | Plates of Copper and Wrought Copper Alloys for Condensers and Heat Exchangers; Dimensions                                                            |
| 17677 Pt 1                                                                | Wrought Copper and Copper Alloy Wire; Properties                                                                                                     |
| 17677 Pt 2                                                                | Wires of Copper and Wrought Copper Alloys; Technical Conditions of Delivery                                                                          |
| 17678 Pt 1                                                                | Wrought Copper and Copper Alloy Hand Forgings; Properties                                                                                            |
| 17678 Pt 2                                                                | Hand Forgings of Copper and Wrought Copper Alloys; Technical Conditions of Delivery                                                                  |
| 17678 Pt 3                                                                | Hand Forgings of Copper and Wrought Copper Alloys; Basis of Design                                                                                   |
| 17678 Pt 4                                                                | Hand Forgings of Copper and Wrought Copper Alloys; Permissible Variations                                                                            |
| 17679                                                                     | Wrought Copper and Copper Alloy Tubes with Rolled Fins for Use in Heat Exchangers                                                                    |
| 17682                                                                     | Round Spring Wires Made of Wrought Copper Alloys; Strength Properties; Technical Conditions of Delivery                                              |
| 40500 Pt 4                                                                | Copper for Electrical Engineering; Wires of Copper and Copper-Silver Alloy; Technical Conditions of Delivery                                         |
| 40500 Pt 5                                                                | Copper for Electrical Purposes; Tinned Wire; Technical Delivery Conditions                                                                           |
| 46211                                                                     | Stamped Cable Sockets for Copper Conductors                                                                                                          |
| 46415                                                                     | Copper and Copper Alloy Band; Cold Rolled with Rounded (Lightly Rolled) Edges; Dimensions                                                            |
| 46416 Pt 4                                                                | Winding Wires; Round Copper Wires, Insulated; Enameled, Heat Resistant with a Temperature Index of 155, Type W 155, Technical Conditions of Delivery |
| 46431                                                                     | Round Copper Wires for Electrical Purposes; Precision Drawn; Dimensions                                                                              |
| 48203 Pt 1                                                                | Copper Wires and Copper Stranded Conductors; Technical Delivery Conditions                                                                           |
| 48203 Pt 2                                                                | Wrought Copper Alloy (Bz) Wires and Conductors; Technical Delivery Conditions                                                                        |
| 48203 Pt 7                                                                | Copper Covered Steel Wires and Copper Covered Steel Stranded Conductors; Technical Delivery Conditions                                               |
| 50916 Pt 2                                                                | Testing of Copper Alloys; Stress Corrosion Cracking Test Using Ammonia; Testing of Components                                                        |
| 86086                                                                     | Copper-Nickel Alloy Welding Pipe Fittings; Technical Delivery Conditions                                                                             |
| LN 29557 Pt 2                                                             | Aerospace; Laminated Shim of Wrought Copper Alloy; Dimensions, Masses                                                                                |

| <b>JAPANESE JIS SPECIFICATIONS - COPPER AND COPPER ALLOYS</b> |                                                                                                        |
|---------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| <b>Wrought Alloys</b>                                         |                                                                                                        |
| <b>JIS</b>                                                    | <b>Title</b>                                                                                           |
| H 3100                                                        | Copper and Copper Alloy Sheets, Plates and Strips                                                      |
| H 3110                                                        | Phosphor Bronze and Nickel Silver Sheets, Plates and Strips                                            |
| H 3130                                                        | Copper Beryllium Alloy, Phosphor Bronze and Nickel Silver Sheets, Plates and Strips for Springs        |
| H 3140                                                        | Copper Bus Bars                                                                                        |
| H 3250                                                        | Copper and Copper Alloy Rods and Bars                                                                  |
| H 3260                                                        | Copper and Copper Alloy Wires                                                                          |
| H 3270                                                        | Copper Beryllium Alloy, Phosphor Bronze and Nickel Silver Rods, Bars and Wires                         |
| H 3300                                                        | Copper and Copper Alloy Seamless Pipes and Tubes                                                       |
| H 3320                                                        | Copper and Copper Alloy Welded Pipes and Tubes                                                         |
| H 3401                                                        | Pipe Fittings of Copper and Copper Alloy                                                               |
| H 3510                                                        | Oxygen Free Copper Sheet, Plate, Strip, Seamless Pipe and Tube, Rod, Bar and Wire for Electron Devices |
| <b>Castings</b>                                               |                                                                                                        |
| H 5100                                                        | Copper Castings                                                                                        |
| H 5101                                                        | Brass Castings                                                                                         |
| H 5102                                                        | High Strength Brass Castings                                                                           |
| H 5111                                                        | Bronze Castings                                                                                        |
| H 5112                                                        | Silicon Bronze Castings                                                                                |
| H 5113                                                        | Phosphor Bronze Castings                                                                               |
| H 5114                                                        | Aluminum Bronze Castings                                                                               |
| H 5115                                                        | Leaded Tin Bronze Castings                                                                             |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS</b> |                                                                                                                                                                                                                                                                                                                            |
|-----------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                | <b>Chemical Composition</b>                                                                                                                                                                                                                                                                                                |
| C10100                                                    | Cu 99.99 min Ag 0.0025 max As 0.0005 max Bi 0.0001 max Cd 0.0001 max Fe 0.0010 max Hg 0.0001 max Mn 0.0005 max Ni 0.0010 max O <sub>2</sub> 0.0005 max P 0.0003 max Pb 0.0005 max S 0.0018 max Sb 0.0004 max Se 0.0010 max Sn 0.0002 max Te 0.0002 max Zn 0.0001 max Other total As, Bi, Mn, Sb, Se, Sn, and Te 0.0040 max |
| C10200                                                    | Cu (incl Ag) 99.95 min                                                                                                                                                                                                                                                                                                     |
| C10300                                                    | Cu (incl Ag) 99.95 min P 0.001-0.005                                                                                                                                                                                                                                                                                       |
| C10400                                                    | Cu (incl Ag) 99.95 min Ag 0.027 min                                                                                                                                                                                                                                                                                        |
| C10500                                                    | Cu (incl Ag) 99.95 min Ag 0.034 min                                                                                                                                                                                                                                                                                        |
| C10700                                                    | Cu (incl Ag) 99.95 min Ag 0.085 min                                                                                                                                                                                                                                                                                        |
| C10800                                                    | Cu (incl Ag+P) 99.95 min P 0.005-0.012                                                                                                                                                                                                                                                                                     |
| C11000                                                    | Cu (incl Ag) 99.90 min                                                                                                                                                                                                                                                                                                     |
| C11010                                                    | Cu (incl Ag) 99.90 min Other Unspecified oxygen and trace elements                                                                                                                                                                                                                                                         |
| C11020                                                    | Cu (incl Ag) 99.90 min Other Unspecified oxygen and trace elements                                                                                                                                                                                                                                                         |
| C11030                                                    | Cu (incl Ag) 99.90 min Other Unspecified oxygen and trace elements                                                                                                                                                                                                                                                         |
| C11040                                                    | Cu 99.90 min Ag 0.0025 max As 0.0005 max Bi 0.00010 max Fe 0.0010 max Ni 0.0010 max O <sub>2</sub> 0.010-0.065 Pb 0.0005 max S 0.0015 max Sb 0.0004 max Se 0.0002 max Sn 0.0005 max Te 0.0002 max Other Bi+Se+Te 0.0003 max total, Total all (except Cu+O <sub>2</sub> ) 0.0065 max                                        |
| C11100                                                    | Cu (incl Ag) 99.90 min Note: Small amounts of Cd or other elements may be added to improve the resistance to softening at elevated temperatures                                                                                                                                                                            |
| C11300                                                    | Cu (incl Ag) 99.90 min Ag 0.027 min Note: Oxygen and trace elements may vary depending on the process                                                                                                                                                                                                                      |
| C11400                                                    | Cu (incl Ag) 99.90 min Ag 0.034 min Note: Oxygen and trace elements may vary depending on the process                                                                                                                                                                                                                      |
| C11500                                                    | Cu (incl Ag) 99.90 min Ag 0.054 min Note: Oxygen and trace elements may vary depending on the process                                                                                                                                                                                                                      |
| C11600                                                    | Cu (incl Ag) 99.90 min Ag 0.085 min Note: Oxygen and trace elements may vary depending on the process                                                                                                                                                                                                                      |
| C12000                                                    | Cu (incl Ag) 99.90 min P 0.004-0.012                                                                                                                                                                                                                                                                                       |
| C12100                                                    | Cu (incl Ag) 99.90 min Ag 0.014 min P 0.005-0.012                                                                                                                                                                                                                                                                          |
| C12200                                                    | Cu (incl Ag) 99.90 min P 0.015-0.040                                                                                                                                                                                                                                                                                       |
| C12300                                                    | Cu (incl Ag) 99.90 min P 0.015-0.040                                                                                                                                                                                                                                                                                       |
| C12900                                                    | Cu (incl Ag) 99.88 min Ag 0.054 min As 0.012 max Bi 0.003 max Ni 0.050 max Pb 0.004 max Sb 0.003 max Te 0.025 max Other Se included in Te                                                                                                                                                                                  |
| C14180                                                    | Cu (incl Ag) 99.90 min Al 0.01 max P 0.075 max Pb 0.02 max                                                                                                                                                                                                                                                                 |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                             |
|-----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                 |
| C14181                                                                | Cu (incl Ag) 99.90 min C 0.005 max Cd 0.002 max P 0.002 max Pb 0.002 max Zn 0.002                                                           |
| C14200                                                                | Cu (incl Ag) 99.4 min As 0.15-0.50 P 0.015-0.040                                                                                            |
| C14420                                                                | Cu (incl Ag+Sn+Te) 99.90 min Sn 0.05-0.15 Te 0.02-0.05                                                                                      |
| C14500                                                                | Cu (incl Ag+Te) 99.90 min P 0.004-0.012 Te 0.40-0.70 Note: Other deoxidizers may be used instead of P                                       |
| C14510                                                                | Cu (incl Ag+Te) 99.90 min P 0.010-0.030 Pb 0.05 max Te 0.30-0.70                                                                            |
| C14520                                                                | Cu (incl Ag+Te) 99.40 min P 0.004-0.020 Te 0.40-0.7                                                                                         |
| C14700                                                                | Cu (incl Ag+P+S) 99.90 min S 0.20-0.50 P 0.002-0.005 Note: For oxygen-free and deoxidized grades: O, P, B, Li, etc., limits as agreed upon  |
| C15000                                                                | Cu (incl Ag) 99.80 min Zr 0.10-0.20 Other Cu+sum of named elements 99.9 min                                                                 |
| C15100                                                                | Cu (incl Ag) 99.82 min Al 0.005 max Mn 0.005 max Zr 0.05-0.15                                                                               |
| C16200                                                                | Cu (incl Ag) rem Cd 0.7-1.2 Fe 0.02 max Other Cu+sum of named elements 99.5 min                                                             |
| C16500                                                                | Cu (incl Ag) rem Cd 0.6-1.0 Fe 0.02 max Sn 0.50-0.7 Other Cu+sum of named elements 99.5 min                                                 |
| C17000                                                                | Cu (incl Ag) rem Al 0.20 max Be 1.60-1.79 Si 0.20 max; Ni+Co 0.20 min Other Ni+Fe+Co 0.6 max; Cu+sum of named elements 99.5 min             |
| C17200                                                                | Cu (incl Ag) rem Al 0.20 max Be 1.80-2.00 Si 0.20 max; Ni+Co 0.20 min Other Ni+Fe+Co 0.6 max; Cu+sum of named elements 99.5 min             |
| C17300                                                                | Cu (incl Ag) rem Al 0.20 max Be 1.80-2.00 Pb 0.20-0.6 Si 0.20 max; Ni+Co 0.20 min Other Ne+Fe+Co 0.6 max; Cu+sum of named elements 99.5 min |
| C17410                                                                | Cu (incl Ag) rem Al 0.20 max Be 0.15-0.50 Co 0.35-0.6 Fe 0.20 max Si 0.20 max Other Cu+sum of named elements 99.5 min                       |
| C17500                                                                | Cu (incl Ag) rem Be 0.40-0.7 Co 2.4-2.7 Fe 0.10 max Other Cu+sum of named elements 99.5 min                                                 |
| C17510                                                                | Cu (incl Ag) rem Al 0.20 max Be 0.20-0.6 Co 0.30 max Fe 0.10 max Ni 1.4-2.2 Other Cu+sum of named elements 99.5 min                         |
| C18200                                                                | Cu (incl Ag) rem Cr 0.6-1.2 Fe 0.10 max Pb 0.05 max Si 0.10 max Other Cu+sum of named elements 99.5 min                                     |
| C18700                                                                | Cu (incl Ag) rem Pb 0.8-1.5 Other Cu+sum of named elements 99.5 min                                                                         |
| C18980                                                                | Cu (incl Ag) 98.0 min Mn 0.50 max P 0.15 max Pb 0.02 max Si 0.50 max Sn 1.0 max Other Cu+sum of named elements 99.5 min                     |
| C19200                                                                | Cu 98.7 min Fe 0.8-1.2 P 0.01-0.04 Zn 0.20 max Other Cu+sum of named elements 99.8 min                                                      |
| C19400                                                                | Cu 97.0 min Fe 2.1-2.6 P 0.015-0.15 Pb 0.03 max Zn 0.05-0.20 Other Cu+sum of named elements 99.8 min                                        |
| C19500                                                                | Cu 96.0 min Al 0.02 max Co 0.30-1.3 Fe 1.0-2.0 P 0.01-0.35 Pb 0.02 max Sn 0.10-1.0 Zn 0.20 max Other Cu+sum of named elements 99.8 min      |
| C21000                                                                | Cu 94.0-96.0 Fe 0.05 max Pb 0.03 max Zn rem Other Cu+sum of named elements 99.8 min                                                         |
| C22000                                                                | Cu 89.0-91.0 Fe 0.05 max Pb 0.05 max Zn rem Other Cu+sum of named elements 99.8 min                                                         |
| C22600                                                                | Cu 86.0-89.0 Fe 0.05 max Pb 0.05 max Zn rem Other Cu+sum of named elements 99.8 min                                                         |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                               |
|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                   |
| C23000                                                                | Cu 84.0-86.0 Fe 0.05 max Pb 0.05 max Zn rem Other Cu+sum of named elements 99.8 min                                                           |
| C24000                                                                | Cu 78.5-81.5 Fe 0.05 max Pb 0.05 max Zn rem Other Cu+sum of named elements 99.8 min                                                           |
| C26000                                                                | Cu 68.5-71.5 Fe 0.05 max Pb 0.07 max Zn rem Other Cu+sum of named elements 99.7 min                                                           |
| C26800                                                                | Cu 64.0-68.5 Fe 0.05 max Pb 0.15 max Zn rem Other Cu+sum of named elements 99.7 min                                                           |
| C27000                                                                | Cu 63.0-68.5 Fe 0.07 max Pb 0.10 max Zn rem Other Cu+sum of named elements 99.7 min                                                           |
| C27200                                                                | Cu 62.0-65.0 Fe 0.07 max Pb 0.07 max Zn rem Other Cu+sum of named elements 99.7 min                                                           |
| C27400                                                                | Cu 61.0-64.0 Fe 0.05 max Pb 0.10 max Zn rem Other Cu+sum of named elements 99.7 min                                                           |
| C28000                                                                | Cu 59.0-63.0 Fe 0.07 max Pb 0.30 max Zn rem Other Cu+sum of named elements 99.7 min                                                           |
| C31400                                                                | Cu 87.5-90.5 Fe 0.10 max Ni 0.7 max Pb 1.3-2.5 Zn rem Other Cu+sum of named elements 99.6 min                                                 |
| C31600                                                                | Cu 87.5-90.5 Fe 0.10 max Ni 0.7-1.2 P 0.04-0.10 Pb 1.3-2.5 Zn rem Other Cu+sum of named elements 99.6 min                                     |
| C32000                                                                | Cu 83.5-86.5 Fe 0.10 max Ni 0.25 max Pb 1.5-2.2 Zn rem Other Cu+sum of named elements 99.6 min                                                |
| C33000                                                                | Cu 65.0-68.0 Fe 0.07 max Pb 0.25-0.7 Zn rem Other Cu+sum of named elements 99.6 min                                                           |
| C33200                                                                | Cu 65.0-68.0 Fe 0.07 max Pb 1.5-2.5 Zn rem Other Cu+sum of named elements 99.6 min                                                            |
| C33500                                                                | Cu 62.0-65.0 Fe 0.15 max Pb 0.25-0.7 Zn rem Other Cu+sum of named elements 99.6 min Note: Fe 0.010 max for flat products                      |
| C34000                                                                | Cu 62.0-65.0 Fe 0.15 max Pb 0.8-1.5 Zn rem Other Cu+sum of named elements 99.6 min Note: Fe 0.010 max for flat products                       |
| C34200                                                                | Cu 62.0-65.0 Fe 0.15 max Pb 1.5-2.5 Zn rem Other Cu+sum of named elements 99.6 min Note: Fe 0.010 max for flat products                       |
| C34500                                                                | Cu 62.0-65.0 Fe 0.15 max Pb 1.5-2.5 Zn rem Other Cu+sum of named elements 99.6 min                                                            |
| C35000                                                                | Cu 60.0-63.0 Fe 0.15 max Pb 0.8-2.0 Zn rem Other Cu+sum of named elements 99.6 min Note: For rod, Cu 61.0 min; for flat products, Fe 0.10 max |
| C35300                                                                | Cu 60.0-63.0 Fe 0.15 max Pb 1.5-2.5 Zn rem Other Cu+sum of named elements 99.5 min Note: For rod, Cu 61.0 min; for flat products, Fe 0.10 max |
| C35600                                                                | Cu 60.0-63.0 Fe 0.15 max Pb 2.0-3.0 Zn rem Other Cu+sum of named elements 99.5 min Note: For flat products, Fe 0.10 max                       |
| C36000                                                                | Cu 60.0-63.0 Fe 0.35 max Pb 2.5-3.7 Zn rem Other Cu+sum of named elements 99.5 min                                                            |
| C36500                                                                | Cu 58.0-61.0 Fe 0.15 max Pb 0.25-0.7 Sn 0.25 max Zn rem Other Cu+sum of named elements 99.6 min                                               |
| C37000                                                                | Cu 59.0-62.0 Fe 0.15 max Pb 0.8-1.5 Zn rem Other Cu+sum of named elements 99.6 min                                                            |
| C37700                                                                | Cu 58.0-61.0 Fe 0.30 max Pb 1.5-2.5 Zn rem Other Cu+sum of named elements 99.5 min                                                            |
| C38000                                                                | Cu 55.0-60.0 Al 0.50 max Fe 0.35 max Pb 1.5-2.5 Sn 0.30 max Zn rem Other Cu+sum of named elements 99.5 min                                    |
| C38500                                                                | Cu 55.0-59.0 Fe 0.35 max Pb 2.5-3.5 Zn rem Other Cu+sum of named elements 99.5 min                                                            |
| C40500                                                                | Cu 94.0-96.0 Fe 0.05 Pb 0.05 max Sn 0.7-1.3 Zn rem Other Cu+sum of named elements 99.7 min                                                    |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                    |
|-----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                        |
| C41100                                                                | Cu 89.0-92.0 Fe 0.05 max Pb 0.10 max Sn 0.30-0.7 Zn rem Other Cu+sum of named elements 99.7 min                                                    |
| C41300                                                                | Cu 89.0-93.0 Fe 0.05 max Pb 0.10 max Sn 0.7-1.3 Zn rem Other Cu+sum of named elements 99.7 min                                                     |
| C41500                                                                | Cu 89.0-93.0 Fe 0.05 max Pb 0.10 max Sn 1.5-2.2 Zn rem Other Cu+sum of named elements 99.7 min                                                     |
| C42200                                                                | Cu 86.0-89.0 Fe 0.05 max P 0.35 max Pb 0.05 max Sn 0.8-1.4 Zn rem Other Cu+sum of named elements 99.7 min                                          |
| C42500                                                                | Cu 87.0-90.0 Fe 0.05 max P 0.35 max Pb 0.05 max Sn 1.5-3.0 Zn rem Other Cu+sum of named elements 99.7 min                                          |
| C43000                                                                | Cu 84.0-87.0 Fe 0.05 max Pb 0.10 max Sn 1.7-2.7 Zn rem Other Cu+sum of named elements 99.7 min                                                     |
| C43400                                                                | Cu 84.0-87.0 Fe 0.05 max Pb 0.05 max Sn 0.40-1.0 Zn rem Other Cu+sum of named elements 99.7 min                                                    |
| C44300                                                                | Cu 70.0-73.0 As 0.02-0.06 Fe 0.06 max Pb 0.07 max Sn 0.8-1.2 Zn rem Other For tubular products, Sn 0.9 min Other Cu+sum of named elements 99.6 min |
| C44400                                                                | Cu 70.0-73.0 Fe 0.06 max Pb 0.07 max Sb 0.02-0.10 Sn 0.8-1.2 Zn rem Other For tubular products, Sn 0.9 min Other Cu+sum of named elements 99.6 min |
| C44500                                                                | Cu 70.0-73.0 Fe 0.06 max P 0.02-0.10 Pb 0.07 max Sn 0.8-1.2 Zn rem Other For tubular products, Sn 0.9 min Other Cu+sum of named elements 99.6 min  |
| C46200                                                                | Cu 62.0-65.0 Fe 0.10 max Pb 0.20 max Sn 0.50-1.0 Zn rem Other Cu+sum of named elements 99.6 min                                                    |
| C46400                                                                | Cu 59.0-62.0 Fe 0.10 max Pb 0.20 max Sn 0.50-1.0 Zn rem Other Cu+sum of named elements 99.6 min                                                    |
| C46500                                                                | Cu 59.0-62.0 As 0.02-0.06 Fe 0.10 max Pb 0.20 max Sn 0.50-1.0 Zn rem Other Cu+sum of named elements 99.6 min                                       |
| C47000                                                                | Cu 57.0-61.0 Al 0.01 max Pb 0.05 max Sn 0.25-1.0 Zn rem Other Cu+sum of named elements 99.6 min                                                    |
| C47940                                                                | Cu 63.0-66.0 Fe 0.10-1.0 Ni (incl Co) 0.10-0.50 Pb 1.0-2.0 Zn rem                                                                                  |
| C48200                                                                | Cu 59.0-62.0 Fe 0.10 max Pb 0.40-1.0 Sn 0.50-1.0 Zn rem Other Cu+sum of named elements 99.6 min                                                    |
| C48500                                                                | Cu 59.0-62.0 Fe 0.10 max Pb 1.3-2.2 Sn 0.50-1.0 Zn rem Other Cu+sum of named elements 99.6 min                                                     |
| C50100                                                                | Cu rem Fe 0.05 max P 0.01-0.05 Pb 0.05 max Sn 0.50-0.8 Other Cu+sum of named elements 99.5 min                                                     |
| C50200                                                                | Cu rem Fe 0.10 max P 0.04 max Pb 0.05 max Sn 1.0-1.5 Other Cu+sum of named elements 99.5 min                                                       |
| C50500                                                                | Cu rem Fe 0.10 max P 0.03-0.35 Pb 0.05 max Sn 1.0-1.7 Zn 0.30 max Other Cu+sum of named elements 99.5 min                                          |
| C50700                                                                | Cu rem Fe 0.10 max P 0.30 max Pb 0.05 max Sn 1.5-2.0 Other Cu+sum of named elements 99.5 min                                                       |
| C51000                                                                | Cu rem Fe 0.10 max P 0.03-0.35 Pb 0.05 max Sn 4.2-5.8 Zn 0.30 max Other Cu+sum of named elements 99.5 min                                          |
| C51100                                                                | Cu rem Fe 0.10 max P 0.03-0.35 Pb 0.05 max Sn 3.5-4.9 Zn 0.30 max Other Cu+sum of named elements 99.5 min                                          |
| C51800                                                                | Cu rem Al 0.01 max P 0.10-0.35 Pb 0.02 max Sn 4.0-6.0 Other Cu+sum of named elements 99.5 min                                                      |
| C52100                                                                | Cu rem Fe 0.10 max P 0.03-0.35 Pb 0.05 max Sn 7.0-9.0 Zn 0.20 max Other Cu+sum of named elements 99.5 min                                          |
| C52400                                                                | Cu rem Fe 0.10 max P 0.03-0.35 Pb 0.05 max Sn 9.0-11.0 Zn 0.20 max Other Cu+sum of named elements 99.5 min                                         |
| C53400                                                                | Cu rem Fe 0.10 max P 0.03-0.35 Pb 0.8-1.2 Sn 3.5-5.8 Zn 0.30 max Other Cu+sum of named elements 99.5 min                                           |



| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                                                                                                                                                                                           |
| C54400                                                                | Cu rem Fe 0.10 max P 0.01-0.50 Pb 3.5-4.5 Sn 3.5-4.5 Zn 1.5-4.5 Other Cu+sum of named elements 99.5 min                                                                                                                                                                                                               |
| C55180                                                                | Cu rem P 4.8-5.2 Other Cu+P 99.85 min                                                                                                                                                                                                                                                                                 |
| C55181                                                                | Cu rem P 7.0-7.5 Other Cu+P 99.85 min                                                                                                                                                                                                                                                                                 |
| C55280                                                                | Cu rem Ag 1.8-2.2 P 6.8-7.2 Other Cu + all named elements 99.85 min                                                                                                                                                                                                                                                   |
| C55281                                                                | Cu rem Ag 4.8-5.2 P 5.8-6.2 Other Cu + all named elements 99.85 min                                                                                                                                                                                                                                                   |
| C55282                                                                | Cu rem Ag 4.8-5.2 P 6.5-7.0 Other Cu + all named elements 99.85 min                                                                                                                                                                                                                                                   |
| C55283                                                                | Cu rem Ag 5.8-6.2 P 7.0-7.5 Other Cu + all named elements 99.85 min                                                                                                                                                                                                                                                   |
| C55284                                                                | Cu rem Ag 14.5-15.5 P 4.8-5.2 Other Cu + all named elements 99.85 min                                                                                                                                                                                                                                                 |
| C60800                                                                | Cu (incl Ag) rem Al 5.0-6.5 As 0.2-0.35 Fe 0.10 max Pb 0.10 max Other Cu+sum of named elements 99.5 min                                                                                                                                                                                                               |
| C61000                                                                | Cu (incl Ag) rem Al 6.0-8.5 Fe 0.50 max Pb 0.02 max Si 0.10 max Zn 0.20 max Other Cu+sum of named elements 99.5 min                                                                                                                                                                                                   |
| C61300                                                                | Cu (incl Ag) rem Al 6.0-7.5 Fe 2.0-3.0 Mn 0.20 max Ni (incl Co) 0.15 max P 0.015 max Pb 0.01 max Si 0.10 max Sn 0.20-0.50 Zn 0.10 max Other Cu+sum of named elements 99.8 min Note: When the product is for subsequent welding applications and is so specified, the Cr, Cd, Zr, and Zn limits shall be 0.05 max each |
| C61400                                                                | Cu (incl Ag) rem Al 6.0-8.0 Fe 1.5-3.5 Mn 1.0 max P 0.015 max Pb 0.01 max Zn 0.20 max Other Cu+sum of named elements 99.5 min                                                                                                                                                                                         |
| C61800                                                                | Cu (incl Ag ) rem Al 8.5-11.0 Fe 0.50-1.5 Pb 0.02 max Si 0.10 max Zn 0.02 max Other Cu+sum of named elements 99.5 min                                                                                                                                                                                                 |
| C61900                                                                | Cu (incl Ag) rem Al 8.5-10.0 Fe 3.0-4.5 Pb 0.02 max Sn 0.06 max Zn 0.08 max Other Cu+sum of named elements 99.5 min                                                                                                                                                                                                   |
| C62300                                                                | Cu (incl Ag) rem Al 8.5-10.0 Fe 2.0-4.0 Mn 0.50 max Ni (incl Co) 1.0 max Si 0.25 max Sn 0.6 max Other Cu+sum of named elements 99.5 min                                                                                                                                                                               |
| C62400                                                                | Cu (incl Ag) rem Al 10.0-11.5 Fe 2.0-4.5 Mn 0.30 max Si 0.25 max Sn 0.20 max Other Cu+sum of named elements 99.5 min                                                                                                                                                                                                  |
| C63000                                                                | Cu (incl Ag) rem Al 9.0-11.0 Fe 2.0-4.0 Mn 1.5 max Ni (incl Co) 4.0-5.5 Si 0.25 max Sn 0.20 max Zn 0.30 max Other u+sum of named elements 99.5 min                                                                                                                                                                    |
| C63200                                                                | Cu (incl Ag) rem Al 8.7-9.5 Fe 3.5-4.3 Mn 1.2-2.0 Ni (incl Co) 4.0-4.8 Pb 0.02 max Si 0.10 max Other Cu+sum of named elements 99.5 min<br>Note: Fe content shall not exceed Ni content                                                                                                                                |
| C63280                                                                | Cu (incl Ag) rem Al 8.5-9.5 Fe 3.0-5.0 Mn 0.6-3.5 Ni 4.0-5.5 Pb 0.02 max Si 0.10 max Other Cu+sum of named elements 99.5 min<br>Note: Fe content shall not exceed Ni content                                                                                                                                          |
| C63380                                                                | Cu (incl Ag) rem Al 7.0-8.5 Fe 2.0-4.0 Mn 11.0-14.0 Ni 1.5-3.0 Pb 0.02 max Si 0.10 max Zn 0.15 max Other Cu+sum of named elements 99.5 min<br>Note: Fe content shall not exceed Ni content                                                                                                                            |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                                                          |
|-----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                                                              |
| C63800                                                                | Cu (incl Ag) rem Al 2.5-3.1 Co 0.25-0.55 Fe 0.20 max Mn 0.10 max Ni 0.20 max Pb 0.05 max Si 1.5-2.1 Zn 0.8 max Other Cu+sum of named elements 99.5 min Note: Ni does not include Co      |
| C64200                                                                | Cu (incl Ag) rem Al 6.3-7.6 As 0.15 max Fe 0.30 max Mn 0.10 max Ni (incl Co) 0.25 max Pb 0.05 max Si 1.5-2.2 Sn 0.20 max Zn 0.50 max Other Cu+sum of named elements 99.5 min             |
| C64210                                                                | Cu (incl Ag) rem Al 6.3-7.0 As 0.15 max Fe 0.30 max Mn 0.10 max Ni (incl Co) 0.25 max Pb 0.05 max Si 1.5-2.0 Sn 0.20 max Zn 0.50 max Other Cu+sum of named elements 99.5 min             |
| C64700                                                                | Cu (incl Ag) rem Fe 0.10 max Ni (incl Co) 1.6-2.2 Pb 0.10 max Si 0.40-0.8 Zn 0.50 max Other Cu+sum of named elements 99.5 min                                                            |
| C65100                                                                | Cu (incl Ag) rem Fe 0.8 max Mn 0.7 max Pb 0.05 max Si 0.8-2.0 Zn 1.5 max Other Cu+sum of named elements 99.5 min                                                                         |
| C65400                                                                | Cu (incl Ag) Cr 0.01-0.12 rem Pb 0.05 max Si 2.7-3.4 Sn 1.2-1.9 Zn 0.50 max Other Cu+sum of named elements 99.5 min                                                                      |
| C65500                                                                | Cu (incl Ag) rem Fe 0.8 max Mn 0.50-1.3 Ni (incl Co) 0.6 max Pb 0.05 max Si 2.8-3.8 Zn 1.5 max Other Cu+sum of named elements 99.5 min                                                   |
| C65600                                                                | Cu (incl Ag) rem Al 0.01 max Fe 0.50 max Mn 1.5 max Pb 0.02 max Si 2.8-4.0 Sn 1.5 max Zn 1.5 max Other Cu+sum of named elements 99.5 min                                                 |
| C66100                                                                | Cu (incl Ag) rem Fe 0.25 max Mn 1.5 max Pb 0.20-0.8 Si 2.8-3.5 Zn 1.5 max Other Cu+sum of named elements 99.5 min                                                                        |
| C66400                                                                | Cu (incl Ag) rem Co 0.30-0.7 Fe 1.3-1.7 Mn 0.05 max Ni 0.05 max P 0.02 max Pb 0.015 max Si 0.05 max Sn 0.05 max Zn 11.0-12.0 Other Fe+Co 1.8-2.3 Other Cu+sum of named elements 99.5 min |
| C66410                                                                | Cu (incl Ag) rem Al 0.05 max As 0.05 max Fe 1.8-2.3 Mn 0.05 max Ni 0.05 max P 0.02 max Pb 0.015 max Si 0.05 max Sn 0.05 max Zn 11.0-12.0 Other Cu+sum of named elements 99.5 min         |
| C66700                                                                | Cu (incl Ag) 68.5-71.5 Fe 0.10 max Mn 0.8-1.5 Pb 0.07 max Zn rem Other Cu+sum of named elements 99.5 min                                                                                 |
| C67000                                                                | Cu (incl Ag) 63.0-68.0 Al 3.0-6.0 Fe 2.0-4.0 Mn 2.5-5.0 Pb 0.20 max Sn 0.50 max Zn rem Other Cu+sum of named elements 99.5 min                                                           |
| C67300                                                                | Cu (incl Ag) 58.0-63.0 Al 0.25 max Fe 0.50 max Mn 2.0-3.5 Ni (incl Co) 0.25 max Pb 0.40-3.0 Si 0.50-1.5 Sn 0.30 max Zn rem Other Cu+sum of named elements 99.5 min                       |
| C67400                                                                | Cu (incl Ag) 57.0-60.0 Al 0.50-2.0 Fe 0.35 max Mn 2.0-3.5 Ni (incl Co) 0.25 max Pb 0.50 max Si 0.50-1.5 Sn 0.30 max Zn rem Other Cu+sum of named elements 99.5 min                       |
| C67500                                                                | Cu (incl Ag) 57.0-60.0 Al 0.25 max Fe 0.8-2.0 Mn 0.05-0.50 Pb 0.20 max Sn 0.50-1.5 Zn rem Other Cu+sum of named elements 99.5 min                                                        |
| C68000                                                                | Cu (incl Ag) 56.0-60.0 Al 0.01 max Fe 0.25-1.25 Mn 0.01-0.50 Ni (incl Co) 0.20-0.8 Pb 0.05 max Si 0.04-0.15 Sn 0.75-1.10 Zn rem Other Cu+sum of named elements 99.5 min                  |
| C68100                                                                | Cu (incl Ag) 56.0-60.0 Al 0.01 max Fe 0.25-1.25 Mn 0.01-0.50 Pb 0.05 max Si 0.04-0.15 Sn 0.75-1.10 Zn rem Other Cu+sum of named elements 99.5 min                                        |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                                                                                  |
|-----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                                                                                                                                                                                      |
| C68700                                                                | Cu (incl Ag) 76.0-79.0 Al 1.8-2.5 As 0.02-0.06 Fe 0.06 max Pb 0.07 max Zn rem Other Cu+sum of named elements 99.5 min                                                                                                                                                                                            |
| C68800                                                                | Cu (incl Ag) rem Al 3.0-3.8 Co 0.25-0.55 Fe 0.20 max Pb 0.05 max Zn 21.3-24.1 Other Cu+sum of named elements 99.5 min                                                                                                                                                                                            |
| C69100                                                                | Cu (incl Ag) 81.0-84.0 Al 0.7-1.2 Fe 0.25 max Mn 0.10 max Ni (incl Co) 0.8-1.4 Pb 0.05 max Si 0.8-1.3 Sn 0.10 max Zn rem Other Cu+sum of named elements 99.5 min                                                                                                                                                 |
| C69400                                                                | Cu (incl Ag) 80.0-83.0 Fe 0.20 max Pb 0.30 max Si 3.5-4.5 Zn rem Other Cu+sum of named elements 99.5 min                                                                                                                                                                                                         |
| C69430                                                                | Cu (incl Ag) 80.0-83.0 As 0.03-0.06 Fe 0.20 max Pb 0.30 max Si 3.5-4.5 Zn rem Other Cu+sum of named elements 99.5 min                                                                                                                                                                                            |
| C69700                                                                | Cu (incl Ag) 75.0-80.0 Fe 0.20 max Mn 0.40 max Pb 0.50-1.5 Si 2.5-3.5 Zn rem Other Cu+sum of named elements 99.5 min                                                                                                                                                                                             |
| C69710                                                                | Cu (incl Ag) 75.0-80.0 As 0.03-0.06 Fe 0.20 max Mn 0.40 max Pb 0.50-1.5 Si 2.5-3.5 Zn Rem Other Cu+sum of named elements 99.5 min                                                                                                                                                                                |
| C70200                                                                | Cu (incl Ag) rem Fe 0.10 max Mn 0.40 max Ni (incl Co) 2.0-3.0 Pb 0.05 max Other Cu+sum of named elements 99.5 min                                                                                                                                                                                                |
| C70400                                                                | Cu (incl Ag) rem Fe 1.3-1.7 Mn 0.30-0.8 Ni (incl Co) 4.8-6.2 Pb 0.05 max Zn 1.0 max Other Cu+sum of named elements 99.5 min                                                                                                                                                                                      |
| C70600                                                                | Cu (incl Ag) rem Fe 1.0-1.8 Mn 1.0 max Ni (incl Co) 9.0-11.0 Pb 0.05 max Zn 1.0 max Other Cu+sum of named elements 99.5 min Note: When the product is for subsequent welding applications, C shall be 0.05 max, Zn 0.50 max, P 0.02 max, Pb 0.02 max, and S 0.02 max                                             |
| C70690                                                                | Cu (incl Ag) rem Al 0.002 max As 0.001 max Bi 0.001 max C 0.03 max Co 0.02 max Fe 0.005 max Hg 0.0005 max Mn 0.001 max Ni (incl Co) 9.0-11.0 P 0.001 max Pb 0.001 max S 0.003 max Sb 0.001 max Si 0.02 max Sn 0.001 max Ti 0.001 max Zn 0.001 max Other Cu+sum of named elements 99.5 min                        |
| C71000                                                                | Cu (incl Ag) rem Fe 1.0 max Mn 1.0 max Ni (incl Co) 19.0-23.0 Pb 0.05 max Zn 1.0 max Other Cu+sum of named elements 99.5 min                                                                                                                                                                                     |
| C71500                                                                | Cu (incl Ag) rem Fe 0.40-1.0 Mn 1.0 max Ni (incl Co) 29.0-33.0 Pb 0.05 max Zn 1.0 max Other Cu+sum of named elements 99.5 min Note: When the product is for subsequent welding applications, C shall be 0.05 max, Pb 0.02 max, P 0.02 max, S 0.02 max, and Zn 0.50 max                                           |
| C71580                                                                | Cu (incl Ag) rem Al 0.05 max C 0.07 max Fe 0.50 max Mn 0.30 max Ni (incl Co) 29.0-33.0 P 0.03 max Pb 0.05 max S 0.024 max Si 0.15 max Zn 0.05 max Other Cu+sum of named elements 99.5 min                                                                                                                        |
| C71581                                                                | Cu (incl Ag) rem Fe 0.40-0.7 Mn 1.0 max Ni (incl Co) 29.0-32.0 P 0.02 max Pb 0.02 max S 0.01 max Si 0.25 max Ti 0.20-0.50 Other Cu+sum of named elements 99.5 min                                                                                                                                                |
| C71590                                                                | Cu (incl Ag) rem Al 0.002 max As 0.001 max Bi 0.001 max C 0.02 max Co 0.05 max Fe 0.15 max Hg 0.0005 max Mg 0.10 max Mn 0.50 max Ni 29.0-31.0 P 0.001 max Pb 0.001 max S 0.003 max Sb 0.001 max Si 0.015 max Sn 0.001 max Ti 0.001 max Zn 0.001 max                                                              |
| C71640                                                                | Cu (incl Ag) rem C 0.06 max Fe 1.7-2.3 Mn 1.5-2.5 Ni (incl Co) 29.0-32.0 Pb 0.01 max S 0.03 max Other Cu+sum of named elements 99.5 min                                                                                                                                                                          |
| C72200                                                                | Cu (incl Ag) rem C 0.03 max Cr 0.30-0.7 Fe 0.5-1.0 Mn 1.0 max Ni (incl Co) 15.0-18.0 Pb 0.05 max Si 0.03 max Ti 0.03 max Zn 1.0 max Other Cu+sum of named elements 99.8 min Note: When product is for subsequent welding applications, C shall be 0.05 max, Pb 0.02 max, P 0.02 max, S 0.02 max, and Zn 0.50 max |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                                                            |
|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                                                                |
| C72500                                                                | Cu (incl Ag) rem Fe 0.6 max Mn 0.20 max Ni (incl Co) 8.50-10.5 Pb 0.05 max Sn 1.8-2.8 Zn 0.50 max Other Cu+sum of named elements 99.8 min                                                  |
| C72700                                                                | Cu (incl Ag) rem Fe 0.50 max Mg 0.15 max Mn 0.05-0.30 Nb 0.10 max Ni (incl Co) 8.5-9.5 Pb 0.02 max Sn 5.5-6.5 Zn 0.50 max<br>Other Cu+sum of named elements 99.7 min                       |
| C72900                                                                | Cu (incl Ag) rem Fe 0.50 max Mg 0.15 max Mn 0.30 max Nb 0.10 max Ni (incl Co) 14.5-15.5 Pb 0.02 Sn 7.5-8.5 Zn 0.50 max<br>Other Cu+sum of named elements 99.7 min                          |
| C73500                                                                | Cu (incl Ag) 70.5-73.5 Fe 0.25 max Mn 0.50 max Ni (incl Co) 16.5-19.5 Pb 0.10 max Zn rem Other Cu+sum of named elements 99.5 min                                                           |
| C74000                                                                | Cu (incl Ag) 69.0-73.5 Fe 0.25 max Mn 0.50 max Ni (incl Co) 9.0-11.0 Pb 0.10 max Zn rem Other Cu+sum of named elements 99.5 min                                                            |
| C74500                                                                | Cu (incl Ag) 63.5-66.5 Fe 0.25 max Mn 0.50 max Ni (incl Co) 9.0-11.0 Pb 0.10 max Zn rem Other Cu+sum of named elements 99.5 min                                                            |
| C75200                                                                | Cu (incl Ag) 63.5-66.5 Fe 0.25 max Mn 0.50 max Ni (incl Co) 16.5-19.5 Pb 0.05 max Zn rem Other Cu+sum of named elements 99.5 min                                                           |
| C75700                                                                | Cu (incl Ag) 63.5-66.5 Fe 0.25 max Mn 0.50 max Ni (incl Co) 11.0-13.0 Pb 0.05 max Zn rem Other Cu+sum of named elements 99.5 min                                                           |
| C76200                                                                | Cu (incl Ag) 57.0-61.0 Fe 0.25 max Mn 0.50 max Ni (incl Co) 11.0-13.5 Pb 0.10 max Zn rem Other Cu+sum of named elements 99.5 min                                                           |
| C76400                                                                | Cu (incl Ag) 58.5-61.5 Fe 0.25 max Mn 0.50 max Ni (incl Co) 16.5-19.5 Pb 0.05 max Zn rem Other Cu+sum of named elements 99.5 min                                                           |
| C77000                                                                | Cu (incl Ag) 53.5-56.5 Fe 0.25 max Mn 0.50 max Ni (incl Co) 16.5-19.5 Pb 0.05 max Zn rem Other Cu+sum of named elements 99.5 min                                                           |
| C77300                                                                | Cu (incl Ag) 46.0-50.0 Al 0.01 max Ni (incl Co) 9.0-11.0 P 0.25 max Pb 0.05 max Si 0.04-0.25 Zn rem Other Cu+sum of named elements 99.5 min                                                |
| C77400                                                                | Cu (incl Ag) 43.0-47.0 Ni (incl Co) 9.0-11.0 Pb 0.20 max Zn rem Other Cu+sum of named elements 99.5 min                                                                                    |
| C79200                                                                | Cu (incl Ag) 59.5-66.5 Fe 0.25 max Mn 0.50 max Ni (incl Co) 11.0-13.0 Pb 0.8-1.4 Zn rem Other Cu+sum of named elements 99.5 min                                                            |
| C81400                                                                | Cu 98.5 min Be 0.02-0.10 Cr 0.6-1.0 Other Cu+sum of named elements 99.5 min                                                                                                                |
| C82000                                                                | Cu 95.0 min Al 0.10 max Be 0.45-0.8 Co (incl Ni) 2.4-2.7 Cr 0.10 max Fe 0.10 max Ni 0.20 max Pb 0.02 max Si 0.15 max Sn 0.10 max<br>Zn 0.10 max Other Cu+sum of named elements 99.5 min    |
| C82200                                                                | Cu 96.5 min Be 0.35-0.8 Ni 1.0-2.0 Other Cu+sum of named elements 99.5 min                                                                                                                 |
| C82400                                                                | Cu 96.4 min Al 0.15 max Be 1.65-1.75 Co 0.20-0.40 Cr 0.10 max Fe 0.20 max Ni 0.10 max Pb 0.02 max Sn 0.10 max Zn 0.10 max<br>Other Cu+sum of named elements 99.5 min                       |
| C82500                                                                | Cu 95.5 min Al 0.15 max Be 1.90-2.15 Co (incl Ni) 0.35-0.7 Cr 0.10 max Fe 0.25 max Ni 0.20 max Pb 0.02 max Si 0.20-0.35 Sn 0.10 max<br>Zn 0.10 max Other Cu+sum of named elements 99.5 min |
| C82510                                                                | Cu 95.5 min Al 0.15 max Be 1.90-2.15 Co 1.0-2.0 Cr 0.10 max Fe 0.25 max Ni 0.20 max Pb 0.02 max Si 0.20-0.35 Sn 0.10 max Zn 0.10 max<br>Other Cu+sum of named elements 99.5 min            |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                 |
|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                                                                                                                     |
| C82600                                                                | Cu 95.2 min Al 0.15 max Be 2.25-2.45 Co 0.35-0.7 Cr 0.10 max Fe 0.25 max Ni 0.20 max Pb 0.02 max Si 0.20-0.35 Sn 0.10 max Zn 0.10 max Other Cu+sum of named elements 99.5 min                                                                   |
| C82800                                                                | Cu 94.8 min Al 0.15 max Be 2.50-2.75 Co (incl Ni) 0.35-0.7 Cr 0.10 max Fe 0.25 max Ni 0.20 max Pb 0.02 max Si 0.20-0.35 Sn 0.10 max Zn 0.10 max Other Cu+sum of named elements 99.5 min                                                         |
| C83400                                                                | Cu (incl Ni) 88.0-92.0 Pb 0.50 max Sn 0.20 max Zn 8.0-12.0 Other Cu+sum of named elements 99.3 min                                                                                                                                              |
| C83450                                                                | Cu 87.0-89.0 Al 0.005 max Fe 0.30 max Ni (incl Co) 0.8-2.0 P 0.03 max Pb 1.5-3.0 S 0.08 max Sb 0.25 max Si 0.005 max Sn 2.0-3.5 Zn 5.5-7.5 Other Cu+sum of named elements 99.3 min Note: For continuous castings, P 1.5 max                     |
| C83600                                                                | Cu (incl Ni) 84.0-86.0 Al 0.005 max Fe 0.30 max Ni (incl Co) 1.0 max P 0.05 max Pb 4.0-6.0 S 0.08 max Sb 0.25 max Si 0.005 max Sn 4.0-6.0 Zn 4.0-6.0 Other Cu+sum of named elements 99.3 min Note: For continuous casting, P 1.5 max            |
| C83800                                                                | Cu (incl Ni) 82.0-83.8 Al 0.005 max Fe 0.30 max Ni (incl Co) 1.0 max P 0.03 max Pb 5.0-7.0 S 0.08 max Sb 0.25 max Si 0.005 max Sn 3.3-4.2 Zn 5.0-8.0 Other Cu+sum of named elements 99.3 min Note: For continuous casting, P 1.5 max            |
| C84200                                                                | Cu (incl Ni) 78.0-82.0 Al 0.005 max Fe 0.40 max Ni (incl Co) 0.8 max P 0.05 max Pb 2.0-3.0 S 0.08 max Sb 0.25 max Si 0.005 max Sn 4.0-6.0 Zn 10.0-16.0 Other Cu+sum of named elements 99.2 min Note: For continuous casting, P 1.5 max          |
| C84400                                                                | Cu (incl Ni) 78.0-82.0 Al 0.005 max Fe 0.40 max Ni (incl Co) 1.0 max P 0.2 max Pb 6.0-8.0 S 0.08 max Sb 0.25 max Si 0.005 max Sn 2.3-3.5 Zn 7.0-10.0 Other Cu+sum of named elements 99.2 min; Ingot 123 Note: For continuous casting, P 1.5 max |
| C84800                                                                | Cu (incl Ni) 75.0-77.0 Al 0.005 max Fe 0.40 max Ni (incl Co) 1.0 max P 0.02 max Pb 5.5-7.0 S 0.08 max Sb 0.25 max Si 0.005 max Sn 2.0-3.0 Zn 13.0-17.0 Other Cu+sum of named elements 99.2 min Note: For continuous casting, P 1.5 max          |
| C85200                                                                | Cu (incl Ni) 70.0-74.0 Al 0.005 max Fe 0.6 max Ni (incl Co) 1.0 max P 0.02 max Pb 1.5-3.8 S 0.05 max Sb 0.20 max Si 0.05 max Sn 0.7-2.0 Zn 20.0-27.0 Other Cu+sum of named elements 99.1 min                                                    |
| C85400                                                                | Cu (incl Ni) 65.0-70.0 Al 0.35 max Fe 0.7 max Ni (incl Co) 1.0 max Pb 1.5-3.8 Si 0.05 max Sn 0.50-1.5 Zn 24.0-32.0 Other Cu+sum of named elements 98.9 min                                                                                      |
| C85700                                                                | Cu (incl Ni) 58.0-64.0 Al 0.8 max Fe 0.7 max Ni (incl Co) 1.0 max Pb 0.8-1.5 Si 0.05 max Sn 0.50-1.5 Zn 32.0-40.0 Other Cu+sum of named elements 98.7 min                                                                                       |
| C85800                                                                | Cu (incl Ni) 57.0 min Al 0.50 max As 0.05 max Fe 0.50 max Mn 0.25 max Ni (incl Co) 0.50 max P 0.01 max Pb 1.5 max S 0.05 max Sb 0.05 max Si 0.25 max Sn 1.5 max Zn 31.0-41.0 Other Cu+sum of named elements 98.7 min                            |
| C86200                                                                | Cu (incl Ni) 60.0-66.0 Al 3.0-4.9 Fe 2.0-4.0 Mn 2.5-5.0 Ni (incl Co) 1.0 max Pb 0.20 max Sn 0.20 max Zn 22.0-28.0 Other Cu+sum of named elements 99.0 min                                                                                       |
| C86300                                                                | Cu (incl Ni) 60.0-66.0 Al 5.0-7.5 Fe 2.0-4.0 Mn 2.5-5.0 Ni (incl Co) 1.0 max Pb 0.20 max Sn 0.20 max Zn 22.0-28.0 Other Cu+sum of named elements 99.0 min                                                                                       |
| C86400                                                                | Cu (incl Ni) 56.0-62.0 Al 0.50-1.5 Fe 0.40-2.0 Mn 0.10-1.0 Ni (incl Co) 1.0 max Pb 0.50-1.5 Sn 0.50-1.5 Zn 34.0-42.0 Other Cu+sum of named elements 99.0 min                                                                                    |
| C86500                                                                | Cu (incl Ni) 55.0-60.0 Al 0.50-1.5 Fe 0.40-2.0 Mn 1.0-1.5 Ni (incl Co) 1.0 max Pb 0.40 max Sn 1.0 max Zn 36.0-42.0 Other Cu+sum of named elements 99.0 min                                                                                      |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                                                                                                           |
|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                                                                                                               |
| C86700                                                                | Cu (incl Ni) 53.0-60.0 Al 1.0-3.0 Fe 1.0-3.0 Mn 1.0-3.5 Ni (incl Co) 1.0 max Pb 0.5-1.5 max Sn 1.5 Zn 30.0-38.0 Other Cu+sum of named elements 99.0 min                                                                                   |
| C87300                                                                | Cu 94.0 min Fe 0.20 max Mn 0.8-1.5 Pb 0.20 max Si 3.5-4.5 Zn 0.25 max Other Cu+sum of named elements 99.5 min                                                                                                                             |
| C87400                                                                | Cu 79.0 min Al 0.8 max Pb 1.0 max Si 2.5-4.0 Zn 12.0-16.0 Other Cu+sum of named elements 99.2 min                                                                                                                                         |
| C87500                                                                | Cu 79.0 min Al 0.50 max Pb 0.50 max Si 3.0-5.0 Zn 12.0-16.0 Other Cu+sum of named elements 99.5 min                                                                                                                                       |
| C87600                                                                | Cu 88.0 min Fe 0.20 max Mn 0.25 max Pb 0.50 max Si 3.5-4.5 Zn 4.0-7.0 Other Cu+sum of named elements 99.5 min                                                                                                                             |
| C87610                                                                | Cu 90.0 min Fe 0.20 max Mn 0.25 max Pb 0.20 max Si 3.0-5.0 Zn 3.0-5.0 Other Cu+sum of named elements 99.5 min                                                                                                                             |
| C87800                                                                | Cu 80.0 min Al 0.15 max As 0.05 max Fe 0.15 max Mg 0.01 max Mn 0.15 max Ni (incl Co) 0.20 max P 0.01 max Pb 0.15 max S 0.05 max Sb 0.05 max Si 3.8-4.2 Sn 0.25 max Zn 12.0-16.0 Other Cu+sum of named elements 99.5 min                   |
| C90300                                                                | Cu (incl Ni) 86.0-89.0 Al 0.005 max Fe 0.20 max Ni (incl Co) 1.0 max P 0.05 max Pb 0.30 max S 0.05 max Sb 0.20 max Si 0.005 Sn 7.5-9.0 Zn 3.0-5.0 Other Cu+sum of named elements 99.4 min Note: For continuous casting, P 1.5 max         |
| C90500                                                                | Cu (incl Ni) 86.0-89.0 Al 0.005 max Fe 0.20 max Ni (incl Co) 1.0 max P 0.05 max Pb 0.30 max S 0.05 max Sb 0.20 max Si 0.005 max Sn 9.0-11.0 Zn 1.0-3.0 Other Cu+sum of named elements 99.7 min Note: For continuous casting, P 1.5 max    |
| C90700                                                                | Cu (incl Ni) 88.0-90.0 Al 0.005 max Fe 0.15 max Ni (incl Co) 0.50 max P 0.30 max Pb 0.50 max S 0.05 max Sb 0.20 max Si 0.005 max Sn 10.0-12.0 Zn 0.50 max Other Cu+sum of named elements 99.4 min Note: For continuous casting, P 1.5 max |
| C90800                                                                | Cu (incl Ni) 85.0-89.0 Al 0.005 max Fe 0.15 max Ni (incl Co) 0.50 max P 0.30 max Pb 0.25 max S 0.05 max Sb 0.20 max Si 0.005 max Sn 11.0-13.0 Zn 0.25 max Other Cu+sum of named elements 99.4 Note: For continuous casting, P 1.5 max     |
| C91000                                                                | Cu (incl Ni) 84.0-86.0 Al 0.005 max Fe 0.10 max Ni (incl Co) 0.8 max P 0.05 max Pb 0.20 max S 0.5 max Sb 0.20 max Si 0.005 max Sn 14.0-16.0 Zn 1.5 max Other Cu+sum of named elements 99.4 min Note: For continuous casting, P 1.5 max    |
| C91100                                                                | Cu (incl Ni) 82.0-85.0 Al 0.005 max Fe 0.25 max Ni (incl Co) 0.50 max P 1.0 max Pb 0.25 max S 0.05 max P 0.20 max Si 0.005 max Sn 15.0-17.0 Zn 0.25 max Other Cu+sum of named elements 99.4 min Note: For continuous casting, P 1.5 max   |
| C91300                                                                | Cu (incl Ni) 79.0-82.0 Al 0.005 max Fe 0.25 max Ni (incl Co) 0.50 max P 1.0 max Pb 0.25 max S 0.05 max Sb 0.20 max Si 0.005 max Sn 18.0-20.0 Zn 0.25 max Other Cu+sum of named elements 99.4 min Note: For continuous casting, P 1.5 max  |
| C91600                                                                | Cu (incl Ni) 86.0-89.0 Al 0.005 max Fe 0.20 max Ni (incl Co) 1.2-2.0 P 0.30 max Pb 0.25 max S 0.05 max Sb 0.20 max Si 0.005 max Sn 9.7-10.8 Zn 0.25 max Other Cu+sum of named elements 99.4 min Note: For continuous casting, P 1.5 max   |
| C91700                                                                | Cu (incl Ni) 84.0-87.0 Al 0.005 max Fe 0.20 max Ni (incl Co) 1.2-2.0 P 0.30 max Pb 0.25 max S 0.05 max Sb 0.20 max Si 0.005 max Sn 11.3-12.5 Zn 0.25 max Other Cu+sum of named elements 99.4 min Note: For continuous casting, P 1.5 max  |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                                                                                                      |
|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                                                                                                                                                                                                          |
| C92200                                                                | Cu (incl Ni) 86.0-90.0 Al 0.005 max Fe 0.25 max Ni (incl Co) 1.0 max P 0.05 max Pb 1.0-2.0 S 0.05 max Sb 0.25 max Si 0.005 max Sn 5.5-6.5 Zn 3.0-5.0 Other Cu+sum of named elements 99.3 min Note: For continuous casting, P 1.5 max                                                                                                 |
| C92300                                                                | Cu (incl Ni) 85.0-89.0 Al 0.005 max Fe 0.25 max Ni (incl Co) 1.0 max P 0.05 max Pb 0.30-1.0 S 0.05 max Sb 0.25 max Si 0.005 max Sn 7.5-9.0 Zn 2.5-5.0 Other Cu+sum of named elements 99.3 min Note: For continuous casting, P 1.5 max                                                                                                |
| C92500                                                                | Cu 85.0-88.0 Al 0.005 max Fe 0.30 max Ni (incl Co) 0.8-1.5 P 0.30 max S 0.05 max Pb 1.0-1.5 Sb 0.25 max Si 0.005 max Sn 10.0-12.0 Zn 0.50 max Other Cu+sum of named elements 99.3 min Note: For continuous casting, P 1.5 max                                                                                                        |
| C92600                                                                | Cu (incl Ni) 86.0-88.5 Al 0.005 max Fe 0.20 max Ni (incl Co) 0.7 max P 0.03 max Pb 0.8-1.5 S 0.05 max Sb 0.25 max Si 0.005 max Sn 9.3-10.5 Zn 1.3-2.5 Other Cu+sum of named elements 99.3 min Note: For continuous casting, P 1.5 max                                                                                                |
| C92700                                                                | Cu (incl Ni) rem Al 0.005 max Fe 0.20 max Ni (incl Co) 1.0 max P 0.25 max Pb 1.0-2.5 S 0.05 max Sb 0.25 max Si 0.005 max Sn 9.0-11.0 Zn 0.7 max Other Cu+sum of named elements 99.3 min Note: For continuous casting, P 1.5 max                                                                                                      |
| C92800                                                                | Cu (incl Ni) 78.0-82.0 Al 0.005 max Fe 0.20 max Ni (incl Co) 0.8 max P 0.05 max Pb 4.0-6.0 S 0.05 max Sb 0.25 max Si 0.005 max Sn 15.0-17.0 Zn 0.8 max Other Cu+sum of named elements 99.3 min Note: For continuous casting, P 1.5 max                                                                                               |
| C92900                                                                | Cu 82.0-86.0 Al 0.005 max Fe 0.20 max Ni (incl Co) 2.8-4.0 P 0.50 max Pb 2.0-3.2 S 0.05 max Sb 0.25 max Si 0.005 max Sn 9.0-11.0 Zn 0.25 max Other Cu+sum of named elements 99.3 min Note: For continuous casting, P 1.5 max                                                                                                         |
| C93200                                                                | Cu (incl Ni) 81.0-85.0 Al 0.005 max Fe 0.20 max Ni (incl Co) 1.0 max P 0.15 max Pb 6.0-8.0 S 0.08 max Sb 0.35 max Si 0.005 max Sn 6.3-7.5 Zn 1.0-4.0 Other Cu+sum of named elements 99.2 min Note: For continuous casting, P 1.5 max                                                                                                 |
| C93400                                                                | Cu (incl Ni) 82.0-85.0 Al 0.005 max Fe 0.20 max Ni (incl Co) 1.0 max P 0.50 max Pb 7.0-9.0 S 0.08 max Sb 0.50 max Si 0.005 max Sn 7.0-9.0 Zn 0.8 max Other Cu+sum of named elements 99.2 min Note: For continuous casting, P 1.5 max                                                                                                 |
| C93500                                                                | Cu (incl Ni) 83.0-86.0 Al 0.005 max Fe 0.20 max Ni (incl Co) 1.0 max P 0.05 max Pb 8.0-10.0 S 0.08 max Sb 0.30 max Si 0.005 max Sn 4.3-6.0 Zn 2.0 max Other Cu+sum of named elements 99.4 min Note: For continuous casting, P 1.5 max                                                                                                |
| C93600                                                                | Cu (incl Ni) 79.0-83.0 min Al 0.005 max Fe 0.20 max Ni (incl Co) 1.0 max P 0.15 max Pb 11.0-13.0 S 0.08 max Sb 0.55 max Si 0.005 max Sn 6.0-8.0 Zn 1.0 max Other Cu+sum of named elements 99.3 min Note: For continuous casting, P 1.5 max                                                                                           |
| C93700                                                                | Cu (incl Ni) 78.0-82.0 Al 0.005 max Fe 0.7 max Ni (incl Co) 0.50 max P 0.10 max Pb 8.0-11.0 S 0.08 max Sb 0.50 max Si 0.005 max Sn 9.0-11.0 Zn 0.8 max Si 0.005 max Sn 9.0-11.0 Zn 0.8 max Other Cu may include Ni; Fe 0.35 max for steel-backed bearings; Cu+sum of named elements 99.0 min Note: For continuous casting, P 1.5 max |
| C93720                                                                | Cu (incl Ni) 83.0 min Fe 0.7 max Ni (incl Co) 0.50 max P 0.10 max Pb 7.0-9.0 Sb 0.50 max Sn 3.5-4.5 Zn 4.0 max Other Cu+sum of named elements 99.0 min Note: For continuous casting, P 1.5 max                                                                                                                                       |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                           |
|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                                                                                                                               |
| C93800                                                                | Cu (incl Ni) 75.0-79.0 Al 0.005 max Fe 0.15 max Ni (incl Co) 1.0 max P 0.05 max Pb 13.0-16.0 S 0.08 max Sb 0.8 max Si 0.005 max Sn 6.3-7.5 Zn 0.8 max Other Cu+sum of named elements 98.9 min Note: For continuous casting, P 1.5 max                     |
| C93900                                                                | Cu (incl Ni) 76.5-79.5 Al 0.005 max Fe 0.40 max Ni (incl Co) 0.8 max P 1.5 max Pb 14.0-18.0 S 0.08 max Sb 0.50 max Pb 14.0-18.0 S 0.08 max Sb 0.50 max Si 0.005 max Sn 5.0-7.0 Zn 1.5 max Other Cu+sum of named elements 98.9 min                         |
| C94000                                                                | Cu (incl Ni) 69.0-72.0 Al 0.005 max Fe 0.25 max Ni (incl Co) 0.50-1.0 P 0.05 max Pb 14.0-16.0 S 0.08 max Sb 0.50 max Si 0.005 max Sn 12.0-14.0 Zn 0.50 max Other Cu+sum of named elements 98.7 min Note: For continuous casting, P 1.5 max and S 0.25 max |
| C94100                                                                | Cu (incl Ni) 72.0-79.0 Al 0.005 max Fe 0.25 max Ni (incl Co) 1.0 max P 0.05 max Pb 18.0-22.0 S 0.08 max Sb 0.8 max Si 0.005 max Sn 4.5-6.5 Zn 1.0 max Other Cu+sum of named elements 98.7 min Note: For continuous casting, P 1.5 max and S 0.25 max      |
| C94300                                                                | Cu (incl Ni) 67.0-72.0 Al 0.005 max Fe 0.15 max Ni (incl Co) 1.0 max P 0.08 max Pb 22.0-25.0 S 0.08 max Sb 0.8 max Si 0.005 max Sn 4.5-6.0 Zn 0.8 max Other Cu+sum of named elements 99.0 Note: For continuous casting, P 1.5 max and S 0.25 max          |
| C94320                                                                | Cu (incl Ni) rem Fe 0.35 max Pb 24.0-32.0 Sn 4.0-7.0 Other Cu+sum of named elements 99.0 min                                                                                                                                                              |
| C94330                                                                | Cu (incl Ni) 68.5-75.5 Fe 0.7 max Ni (incl Co) 0.50 max P 0.10 max Pb 21.0-25.0 Sb 0.50 max Sn 3.0-4.0 Zn 3.0 max Other Cu+sum of named elements 99.0 min Note: For continuous casting, P 1.5 max                                                         |
| C94400                                                                | Cu (incl Ni) rem Al 0.005 max Fe 0.15 max Ni (incl Co) 1.0 max P 0.50 max Pb 9.0-12.0 S 0.08 max Sb 0.08 max Si 0.005 max Sn 7.0-9.0 Zn 0.8 max Other Cu+sum of named elements 99.0 min Note: For continuous casting, P 1.5 max                           |
| C94500                                                                | Cu (incl Ni) rem Al 0.005 max Fe 0.15 max Ni (incl Co) 1.0 max P 0.05 max Pb 16.0-22.0 S 0.08 max Sb 0.08 max Si 0.005 max Sn 6.0-8.0 Zn 1.2 max Other Cu+sum of named elements 99.0 min Note: For continuous casting, P 1.5 max                          |
| C94700                                                                | Cu 85.0-89.0 Al 0.005 max Fe 0.25 max Mn 0.20 max Ni 4.5-6.0 P 0.05 max Pb 0.10 max S 0.05 max Sb 0.15 max Si 0.005 max Sn 4.5-6.0 Zn 1.0-2.5 Other Cu+sum of named elements 99.3 min                                                                     |
| C94800                                                                | Cu 84.0-89.0 Al 0.005 max Fe 0.25 max Mn 0.20 max Ni 4.5-6.0 P 0.05 max Pb 0.30-1.0 S 0.05 max Sb 0.15 max Si 0.005 max Sn 4.5-6.0 Zn 1.0-2.5 Other Cu+sum of named elements 99.3 min                                                                     |
| C94900                                                                | Cu 79.0-81.0 Al 0.005 max Fe 0.30 max Mn 0.10 max Ni 4.0-6.0 P 0.05 max Pb 4.0-6.0 S 0.08 max Sb 0.25 max Si 0.005 max Sn 4.0-6.0 Zn 4.0-6.0 Other Cu+sum of named elements 99.2 min                                                                      |
| C95200                                                                | Cu 86.0 min Al 8.5-9.5 Fe 2.5-4.0 Other Cu+sum of named elements 99.0 min                                                                                                                                                                                 |
| C95300                                                                | Cu 86.0 min Al 9.0-11.0 Fe 0.8-1.5 Other Cu+sum of named elements 99.0 min                                                                                                                                                                                |
| C95400                                                                | Cu 83.0 min Al 10.0-11.5 Fe 3.0-5.0 Mn 0.50 max Ni (incl Co) 1.5 max Other Cu+sum of named elements 99.5 min                                                                                                                                              |
| C95410                                                                | Cu 83.0 min Al 10.0-11.5 Fe 3.0-5.0 Mn 0.50 max Ni (incl Co) 1.5-2.5 Other Cu+sum of named elements 99.5 min                                                                                                                                              |



| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                                                                                                                               |
|-----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                                                                                                                                   |
| C95420                                                                | Cu 83.5 min Al 10.5-12.0 Fe 3.0-4.3 Mn 0.50 max Ni (incl Co) 0.50 max Other Cu+sum of named elements 99.5 min                                                                                                                                                 |
| C95500                                                                | Cu 78.0 min Al 10.0-11.5 Fe 3.0-5.0 Mn 3.5 max Ni (incl Co) 3.0-5.5 Other Cu+sum of named elements 99.5 min                                                                                                                                                   |
| C95510                                                                | Cu 78.0 min Al 9.7-10.9 Fe 2.0-3.5 Mn 1.5 max Ni (incl Co) 4.5-5.5 Sn 0.20 max Zn 0.30 max Other Cu+sum of named elements 99.8 min<br>Note: Cu included Ag and Ni included Co; Cu + all named elements 99.8 min                                               |
| C95520                                                                | Cu 74.5 min Al 10.5-11.5 Co 0.20 max Cr 0.05 max Fe 4.0-5.5 Mn 1.5 max Ni (incl Co) 4.2-6.0 Pb 0.03 max Si 0.15 max Sn 0.25 max Zn 0.30 max Other Cu+sum of named elements 99.5 min                                                                           |
| C95600                                                                | Cu 88.0 min Al 6.0-8.0 Ni (incl Co) 0.25 max Si 1.8-3.3 Other Cu+sum of named elements 99.0 min                                                                                                                                                               |
| C95700                                                                | Cu 71.0 min Al 7.0-8.5 Fe 2.0-4.0 Mn 11.0-14.0 Ni (incl Co) 1.5-3.0 Pb 0.03 max Si 0.10 max Other Cu+sum of named elements 99.5 min                                                                                                                           |
| C95800                                                                | Cu 79.0 min Al 8.5-9.5 Fe 3.5-4.5 Mn 0.8-1.5 Ni (incl Co) 4.0-5.0 Pb 0.03 max Si 0.10 max Other Fe less than Ni, total named elements 99.5 min<br>Note: Fe content shall not exceed Ni content                                                                |
| C95900                                                                | Cu rem Fe Al 12.0-13.5 3.0-5.0 Mn 1.5 max Ni (incl Co) 0.50 max Other Cu+sum of named elements 99.5 min                                                                                                                                                       |
| C96200                                                                | Cu rem C 0.10 max Fe 1.0-1.8 Mn 1.5 max Nb 0.50-1.0 Ni (incl Co) 9.0-11.0 P 0.02 max Pb 0.01 max S 0.02 max Si 0.50 max Other Cu+sum of named elements 99.5 min                                                                                               |
| C96400                                                                | Cu rem C 0.15 max Fe 0.25-1.5 Mn 1.5 max Nb 0.50-1.5 Ni (incl Co) 28.0-32.0 P 0.02 max Pb 0.03 max S 0.02 max Si 0.50 max Other Cu+sum of named elements 99.5 min Note: For welding grades, Pb 0.01 max                                                       |
| C96700                                                                | Cu rem Be 1.1-1.2 Fe 0.7-1.0 Mn 0.7 max Ni (incl Co) 29.0-33.0 Pb 0.01 max Si 0.15 max Ti 0.010-0.20 Zr 0.10-0.20 Other Cu+sum of named elements 99.5 min                                                                                                     |
| C96800                                                                | Cu rem Al 0.10 max B 0.001 max Bi 0.001 max Fe 0.50 max Mg 0.005-0.15 Mn 0.05-0.30 Nb 0.10-0.30 Ni (incl Co) 9.5-10.5 P 0.005 max Pb 0.005 max S 0.0025 max Sb 0.02 max Si 0.05 max Sn 7.5-8.5 Ti 0.01 max Zn 1.0 max Other Cu+sum of named elements 99.5 min |
| C97300                                                                | Cu 53.0-58.0 Al 0.005 max Fe 1.5 max Mn 0.50 max Ni (incl Co) 11.0-14.0 P 0.05 max Pb 8.0-11.0 S 0.08 max Sb 0.35 max Si 0.15 max Sn 1.5-3.0 Zn 17.0-25.0 Other Cu+sum of named elements 99.0 min                                                             |
| C97600                                                                | Cu 63.0-67.0 Al 0.005 max Fe 1.5 max Mn 1.0 max Ni (incl Co) 19.0-21.5 P 0.05 max Pb 3.0-5.0 S 0.08 max Sb 0.25 max Si 0.15 max Sn 3.5-4.5 Zn 3.0-9.0 Other Cu+sum of named elements 99.7 min                                                                 |
| C97800                                                                | Cu 64.0-67.0 Al 0.005 max Fe 1.5 max Mn 1.0 max Ni (incl Co) 24.0-27.0 P 0.05 max Pb 1.0-2.5 S 0.08 max Sb 0.20 max Si 0.15 max Sn 4.0-5.5 Zn 1.0-4.0 Other Cu+sum of named elements 99.6 min                                                                 |
| C98200                                                                | Cu 73.0-79.0 Fe 0.7 max Ni 0.50 max P 0.10 max Pb 21.0-27.0 Sb 0.50 max Sn 0.6-2.0 Zn 0.50 max Other Cu+sum of named elements 99.5 min                                                                                                                        |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOYS (Continued)</b> |                                                                                                                                                  |
|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNS</b>                                                            | <b>Chemical Composition</b>                                                                                                                      |
| C98400                                                                | Cu rem Ag 1.5 max Fe 0.7 max Ni 0.50 max P 0.10 max Pb 26.0-33.0 Sb 0.50 max Sn 0.50 max Zn 0.50 max Other Cu+sum of named elements 99.5 min     |
| C98820                                                                | Cu rem Fe 0.35 max Pb 40.0-44.0 Sn 1.0-5.0                                                                                                       |
| C98840                                                                | Cu rem Fe 0.35 max Pb 44.0-58.0 Sn 1.0-5.0 Other Cu+sum of named elements 99.5 min                                                               |
| C99400                                                                | Cu rem Al 0.50-2.0 Fe 1.0-3.0 Mn 0.50 max Ni 1.0-3.5 Pb 0.25 max Si 0.50-2.0 Zn 0.50-5.0 Other Cu+sum of named elements 99.7 min                 |
| C99500                                                                | Cu rem Al 0.50-2.0 Fe 3.0-5.0 Mn 0.50 max Ni 3.5-5.5 Pb 0.25 max Si 0.50-2.0 Zn 0.50-2.0 Other Cu+sum of named elements 99.7 min                 |
| C99700                                                                | Cu 54.0 min Al 0.50-3.0 Fe 1.0 max Mn 11.0-15.0 Nb 4.0-6.0 Ni 4.0-6.0 Pb 2.0 max Sn 1.0 max Zn 19.0-25.0 Other Cu+sum of named elements 99.7 min |
| C99750                                                                | Cu 55.0-61.0 Al 0.25-3.0 Fe 1.0 max Mn 17.0-23.0 Ni 5.0 max Pb 0.50-2.5 Sn 0.50-2.5 Zn 17.0-23.0 Other Cu+sum of named elements 99.7 min         |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOY - WELD FILLER METALS</b> |                       |                                                                                                            |
|-------------------------------------------------------------------------------|-----------------------|------------------------------------------------------------------------------------------------------------|
| <b>AWS A5.6</b>                                                               |                       |                                                                                                            |
| <b>Common Name</b>                                                            | <b>Classification</b> | <b>Chemical Composition</b>                                                                                |
| Copper                                                                        | ECu                   | Cu+Ag rem Mn 0.1 Fe 0.2 Si 0.1 Al 0.1 Total other elements 0.50                                            |
| Copper-Silicon<br>(Silicon Bronze)                                            | ECuSi                 | Cu+Ag rem Sn 1.5 Mn 1.5 Fe 0.50 Si 2.4-4.0 Al 0.01 Pb 0.02 Total other elements 0.50                       |
| Copper-Tin<br>(Phosphor Bronze)                                               | ECuSn-A               | Cu+Ag rem Sn 4.0-6.0 Fe 0.25 P 0.05-0.35 Al 0.01 Pb 0.02 Total other elements 0.50                         |
| Copper-Tin<br>(Phosphor Bronze)                                               | ECuSn-C               | Cu+Ag rem Sn 7.0-9.0 Fe 0.25 P 0.05-0.35 Al 0.01 Pb 0.02 Total other elements 0.50                         |
| Copper-Nickel                                                                 | ECuNi <sup>b</sup>    | Cu+Ag rem Mn 1.00-2.50 Fe 0.40-0.75 Si 0.50 Ni 29.0-33.0 P 0.020 Pb 0.02 Ti 0.50 Total other elements 0.50 |
| Copper-Aluminum<br>(Aluminum Bronze)                                          | ECuAl-A2              | Cu+Ag rem Fe 0.5-5.0 Si 1.0 Al 7.0-9.0 Pb 0.02 Total other elements 0.60                                   |
| Copper-Aluminum<br>(Aluminum Bronze)                                          | ECuAl-B               | Cu+Ag rem Fe 2.5-5.0 Si 1.0 Al 8.0-10.0 Pb 0.02 Total other elements 0.60                                  |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOY - WELD FILLER METALS (Continued)</b> |                       |                                                                                                                     |
|-------------------------------------------------------------------------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------------|
| <b>AWS A5.6 (Continued)</b>                                                               |                       |                                                                                                                     |
| <b>Common Name</b>                                                                        | <b>Classification</b> | <b>Chemical Composition</b>                                                                                         |
| Copper-Aluminum<br>(Aluminum Bronze)                                                      | ECuNiAl               | Cu+Ag rem Mn 0.5-3.5 Fe 3.0-6.0 Si 1.0 Ni 4.0-6.0 Al 6.5-8.5 Pb 0.02 Total other elements 0.60                      |
| Copper-Aluminum<br>(Aluminum Bronze)                                                      | ECuMnNiAl             | Cu+Ag rem Mn 11.0-13.0 Fe 2.0-6.0 Si 1.5 Ni 1.0-2.5 Al 5.5-7.5 Pb 0.02 Total other elements 0.60                    |
| <b>AWS A5.7</b>                                                                           |                       |                                                                                                                     |
| Copper                                                                                    | ERCu                  | Cu+Ag 98.0 min Sn 1.0 Mn 0.5 Si 0.50 P 0.15 Al 0.01 Pb 0.02 Total other elements 0.50                               |
| Copper-Silicon<br>(Silicon Bronze)                                                        | ERCuSi-A              | Cu+Ag 94.0 min Zn 1.5 Sn 1.5 Mn 1.5 Fe 0.5 Si 2.8-4.0 Al 0.01 Pb 0.02 Total other elements 0.50                     |
| Copper-Tin (Phosphor<br>Bronze)                                                           | ERCuSn-A              | Cu+Ag 93.5 min Sn 4.0-6.0 P 0.10-0.35 Al 0.01 Pb 0.02 Total other elements 0.50                                     |
| Copper-Nickel                                                                             | ERCuNi <sup>a</sup>   | Cu+Ag rem Mn 1.00 Fe 0.40-0.75 Si 0.25 Ni+Co 29.0-32.0 P 0.02 Pb 0.02 Ti 0.20-0.50 Total other elements 0.50        |
| Copper-Aluminum<br>(Aluminum Bronze)                                                      | ERCuAl-A1             | Cu+Ag rem Zn 0.10 Mn 0.50 Si 0.10 Al 6.0-9.0 Pb 0.02 Total other elements 0.50                                      |
| Copper-Aluminum<br>(Aluminum Bronze)                                                      | ERCuAl-A2             | Cu+Ag rem Zn 0.02 Fe 1.5 Si 0.10 Al 9.0-11.0 Pb 0.02 Total other elements 0.50                                      |
| Copper-Aluminum<br>(Aluminum Bronze)                                                      | ERCuAl-A3             | Cu+Ag rem Zn 0.10 Fe 3.0-5.0 Si 0.10 Al 10.0-11.0 Pb 0.02 Total other elements 0.50                                 |
| Copper-Aluminum<br>(Aluminum Bronze)                                                      | ERCuNiA1              | Cu+Ag rem Zn 0.10 Mn 0.60-3.50 Fe 3.0-5.0 Si 0.10 Ni+Co 4.00-5.50 Al 8.50-9.50 Pb 0.02<br>Total other elements 0.50 |
| Copper-Aluminum<br>(Aluminum Bronze)                                                      | ERCuMnNiA1            | Cu+Ag rem Zn 0.15 Mn 11.0-14.0 Fe 2.0-4.0 Si 0.10 Ni+Co 1.5-3.0 Al 7.0-8.5 Pb 0.02 Total other elements 0.50        |
| <b>AWS A5.27</b>                                                                          |                       |                                                                                                                     |
| Copper                                                                                    | ERCu                  | Cu+Ag 98.0 Sn 1.0 Mn 0.5 Si 0.50 P 0.15 Al 0.01 Pb 0.02 Total other elements 0.50                                   |
| Copper-Silicon<br>(Silicon Bronze)                                                        | ERCuSi-A              | Cu+Ag 94.0 Zn 1.5 Sn 1.5 Mn 1.5 Fe 0.5 Si 2.8-4.0 Al 0.01 Pb 0.02 Total other elements 0.50                         |

| <b>CHEMICAL COMPOSITION OF COPPER &amp; COPPER ALLOY - WELD FILLER METALS (Continued)</b> |                       |                                                                                                                                      |
|-------------------------------------------------------------------------------------------|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| <b>AWS A5.27 (Continued)</b>                                                              |                       |                                                                                                                                      |
| <b>Common Name</b>                                                                        | <b>Classification</b> | <b>Chemical Composition</b>                                                                                                          |
| Copper-Nickel                                                                             | ERCuNi <sup>a</sup>   | Cu+Ag rem Mn 1.00 Fe 0.40-0.70 Si 0.15 Ni+Co 29.0-32.0 P 0.02 Pb 0.02 Ti 0.20-0.50 Total other elements 0.50                         |
| Naval Brass                                                                               | RBCuZn-A              | Cu+Ag 57.0-61.0 Zn rem Sn 0.25-1.00 Al 0.01 Pb 0.05 Total other elements 0.50                                                        |
| Low-Fuming Brass (Ni)                                                                     | RCuZn-B               | Cu+Ag 56.0-60.0 Zn rem Sn 0.80-1.10 Mn 0.01-0.50 Fe 0.25-1.20 Si 0.04-0.15 Ni+Co 0.20-0.80 Al 0.01 Pb 0.05 Total other elements 0.50 |
| Low-Fuming Brass                                                                          | RCuZn-C               | Cu+Ag 56.0-60.0 Zn rem Sn 0.80-1.10 Mn 0.01-0.50 Fe 0.25-1.20 Si 0.04-0.15 Al 0.01 Pb 0.05 Total other elements 0.50                 |
| Nickel Brass                                                                              | RBCuZn-D              | Cu+Ag 46.0-50.0 Zn rem Si 0.04-0.25 Ni+Co 9.0-11.0 P 0.25 Al 0.01 Pb 0.05 Total other elements 0.50                                  |

a. Sulphur is restricted to 0.01% maximum.

b. Sulphur is restricted to 0.015% maximum.

Single values shown are maximum percentages except where otherwise noted.

| <b>MECHANICAL PROPERTIES OF COPPER ALLOYS -<br/>PLATE &amp; SHEET FOR PRESSURE VESSELS, CONDENSERS &amp; HEAT EXCHANGERS</b> |                       |                     |                                 |                                 |             |
|------------------------------------------------------------------------------------------------------------------------------|-----------------------|---------------------|---------------------------------|---------------------------------|-------------|
| <b>ASTM B 171<br/>Copper Alloy UNS No.</b>                                                                                   | <b>Thickness, in.</b> | <b>T.S.<br/>ksi</b> | <b>Y.S.<sup>a</sup><br/>ksi</b> | <b>Y.S.<sup>b</sup><br/>ksi</b> | <b>% El</b> |
| C36500, C36600, C36700, C36800                                                                                               | 2 and under           | 50                  | 20                              | 20                              | 35          |
|                                                                                                                              | over 2 to 3.5, incl   | 45                  | 15                              | 15                              | 35          |
|                                                                                                                              | over 3.5 to 5, incl   | 40                  | 12                              | 12                              | 35          |
| C44300, C44400, and C44500                                                                                                   | 4 and under           | 45                  | 15                              | 15                              | 35          |
| C46400, C46500, C46600, C46700                                                                                               | 3 and under           | 50                  | 20                              | 20                              | 35          |
|                                                                                                                              | over 3 to 5, incl     | 50                  | 18                              | 18                              | 35          |
| C61300                                                                                                                       | 2 and under           | 75                  | 37                              | 36                              | 30          |
|                                                                                                                              | over 2 to 3, incl     | 70                  | 30                              | 28                              | 35          |
|                                                                                                                              | over 3, to 5, incl    | 65                  | 28                              | 26                              | 35          |

| MECHANICAL PROPERTIES OF COPPER ALLOYS -<br>PLATE & SHEET FOR PRESSURE VESSELS, CONDENSERS & HEAT EXCHANGERS (Continued) |                     |             |                          |                          |      |
|--------------------------------------------------------------------------------------------------------------------------|---------------------|-------------|--------------------------|--------------------------|------|
| ASTM B 171<br>Copper Alloy UNS No.                                                                                       | Thickness, in.      | T.S.<br>ksi | Y.S. <sup>a</sup><br>ksi | Y.S. <sup>b</sup><br>ksi | % El |
| C61400                                                                                                                   | 2 and under         | 70          | 30                       | 28                       | 35   |
|                                                                                                                          | over 2 to 5, incl   | 65          | 28                       | 26                       | 35   |
| C63000, C63200                                                                                                           | 2 and under         | 90          | 36                       | 34                       | 10   |
|                                                                                                                          | over 2 to 3.5, incl | 85          | 33                       | 31                       | 10   |
|                                                                                                                          | over 3.5 to 5, incl | 80          | 30                       | 28                       | 10   |
| C70600                                                                                                                   | 2.5 and under       | 40          | 15                       | 15                       | 30   |
|                                                                                                                          | over 2.5 to 5, incl | 40          | 15                       | 15                       | 30   |
| C71500                                                                                                                   | 2.5 and under       | 50          | 20                       | 20                       | 30   |
|                                                                                                                          | over 2.5 to 5, incl | 45          | 18                       | 18                       | 30   |
| C72200                                                                                                                   | 2.5 and under       | 42          | 16                       | 16                       | 35   |

a. Yield Strength determined as the stress producing in elongation of 0.5% under load, that is, 0.01 in. in a gage length of 2 in.

b. Yield strength at 0.2% offset, minimum.

T.S. - Tensile Strength; Y.S. - Yield Strength.

All values are minimum, unless otherwise noted.

| <b>MECHANICAL PROPERTIES OF COPPER ALLOYS -<br/>U-BEND SEAMLESS COPPER &amp; COPPER ALLOY HEAT EXCHANGER &amp; CONDENSER TUBES</b> |                           |                        |                          |                          |                     |
|------------------------------------------------------------------------------------------------------------------------------------|---------------------------|------------------------|--------------------------|--------------------------|---------------------|
| <b>ASTM B 395</b>                                                                                                                  | <b>Temper Designation</b> |                        | <b>T.S.<br/>ksi, min</b> | <b>Y.S.<br/>ksi, min</b> | <b>% El<br/>min</b> |
| <b>Copper or Copper Alloy UNS No.</b>                                                                                              | <b>Standard</b>           | <b>Former</b>          |                          |                          |                     |
| C10200, C10300, C10800, C12000, C12200, C14200                                                                                     | H55                       | light drawn            | 36                       | 30                       | ---                 |
| C19200                                                                                                                             | H55                       | light drawn            | 40                       | 35                       | ---                 |
| C19200                                                                                                                             | O61                       | annealed               | 38                       | 12                       | ---                 |
| C23000                                                                                                                             | O61                       | annealed               | 40                       | 12                       | ---                 |
| C44300, C44400, C44500                                                                                                             | O61                       | annealed               | 45                       | 15                       | ---                 |
| C60800                                                                                                                             | O61                       | annealed               | 50                       | 19                       | ---                 |
| C68700                                                                                                                             | O61                       | annealed               | 50                       | 18                       | ---                 |
| C70400                                                                                                                             | O61                       | annealed               | 38                       | 12                       | ---                 |
| C70400                                                                                                                             | H55                       | light drawn            | 40                       | 30                       | ---                 |
| C70600                                                                                                                             | O61                       | annealed               | 40                       | 15                       | ---                 |
| C70600                                                                                                                             | H55                       | light drawn            | 45                       | 35                       | ---                 |
| C71000                                                                                                                             | O61                       | annealed               | 45                       | 16                       | ---                 |
| C71500:                                                                                                                            | O61                       | annealed               | 52                       | 18                       | ---                 |
| For wall thicknesses up to 0.048 in., incl                                                                                         | HR50                      | drawn, stress-relieved | 72                       | 50                       | 12                  |
| For wall thicknesses over 0.048 in.                                                                                                | HR50                      | drawn, stress-relieved | 72                       | 50                       | 15                  |
| C72200                                                                                                                             | O61                       | annealed               | 45                       | 16                       | ---                 |
| C72200                                                                                                                             | H55                       | light drawn            | 50                       | 45                       | ---                 |

T.S. - Tensile Strength; Y.S. - Yield Strength.

All values are minimum, unless otherwise noted.

| <b>MECHANICAL PROPERTIES OF GEAR BRONZE ALLOY CASTINGS<sup>a</sup></b> |                                    |                         |            |                       |            |             |                                |
|------------------------------------------------------------------------|------------------------------------|-------------------------|------------|-----------------------|------------|-------------|--------------------------------|
| <b>ASTM B 427</b>                                                      | <b>Cast Type</b>                   | <b>Tensile Strength</b> |            | <b>Yield Strength</b> |            | <b>% El</b> | <b>Hardness HB<sup>b</sup></b> |
| <b>Copper Alloy UNS No.</b>                                            |                                    | <b>ksi</b>              | <b>MPa</b> | <b>ksi</b>            | <b>MPa</b> |             |                                |
| C90700, C90800, C91700                                                 | Static or Centrifugally Chill Cast | 50                      | 345        | 28                    | 193        | 12          | 95                             |
| C91600                                                                 | Static or Centrifugally Chill Cast | 45                      | 310        | 25                    | 172        | 10          | 85                             |
| C90700, C90800, C91600, C91700                                         | Sand Cast                          | 35                      | 241        | 17                    | 117        | 10          | 65                             |
| C92900                                                                 | Sand or Chill Cast                 | 45                      | 310        | 25                    | 172        | 8           | 75                             |

a. The properties of a separate cast test specimen shall meet the minimum values listed. b. Brinell hardness test, 500 kg load on bar or casting, min. All values are minimum. Metric values listed are for information purposes only and are not mandatory by ASTM B 427.

| <b>MECHANICAL PROPERTIES OF COPPER ALLOY SAND CASTINGS FOR GENERAL APPLICATIONS<sup>a</sup></b> |                         |                 |                                   |                 |                     |
|-------------------------------------------------------------------------------------------------|-------------------------|-----------------|-----------------------------------|-----------------|---------------------|
| <b>ASTM B 584</b>                                                                               | <b>Tensile Strength</b> |                 | <b>Yield Strength<sup>b</sup></b> |                 | <b>% Elongation</b> |
| <b>Copper Alloy UNS No.</b>                                                                     | <b>ksi, min</b>         | <b>MPa, min</b> | <b>ksi, min</b>                   | <b>MPa, min</b> |                     |
| C83450                                                                                          | 30                      | 207             | 14                                | 97              | 25                  |
| C83600                                                                                          | 30                      | 207             | 14                                | 97              | 20                  |
| C83800                                                                                          | 30                      | 207             | 13                                | 90              | 20                  |
| C84400                                                                                          | 29                      | 200             | 13                                | 90              | 18                  |
| C84800                                                                                          | 28                      | 193             | 12                                | 83              | 16                  |
| C85200                                                                                          | 35                      | 241             | 12                                | 83              | 25                  |
| C85400                                                                                          | 30                      | 207             | 11                                | 76              | 20                  |
| C85700                                                                                          | 40                      | 276             | 14                                | 97              | 15                  |
| C86200                                                                                          | 90                      | 621             | 45                                | 310             | 18                  |
| C86300                                                                                          | 110                     | 758             | 60                                | 414             | 12                  |
| C86400                                                                                          | 60                      | 414             | 20                                | 138             | 15                  |
| C86500                                                                                          | 65                      | 448             | 25                                | 172             | 20                  |
| C86700                                                                                          | 80                      | 552             | 32                                | 221             | 15                  |
| C87300                                                                                          | 45                      | 310             | 18                                | 124             | 20                  |

| <b>MECHANICAL PROPERTIES OF COPPER ALLOY SAND CASTINGS FOR GENERAL APPLICATIONS<sup>a</sup> (Continued)</b> |                         |                 |                                   |                 |                             |
|-------------------------------------------------------------------------------------------------------------|-------------------------|-----------------|-----------------------------------|-----------------|-----------------------------|
| <b>ASTM B 584</b>                                                                                           | <b>Tensile Strength</b> |                 | <b>Yield Strength<sup>b</sup></b> |                 | <b>% Elongation<br/>min</b> |
| <b>Copper Alloy UNS No.</b>                                                                                 | <b>ksi, min</b>         | <b>MPa, min</b> | <b>ksi, min</b>                   | <b>MPa, min</b> |                             |
| C87400                                                                                                      | 50                      | 345             | 21                                | 145             | 18                          |
| C87500                                                                                                      | 60                      | 414             | 24                                | 165             | 16                          |
| C87600                                                                                                      | 60                      | 414             | 30                                | 207             | 16                          |
| C87610                                                                                                      | 45                      | 310             | 18                                | 124             | 20                          |
| C90300                                                                                                      | 40                      | 276             | 18                                | 124             | 20                          |
| C90500                                                                                                      | 40                      | 276             | 18                                | 124             | 20                          |
| C92200                                                                                                      | 34                      | 234             | 16                                | 110             | 22                          |
| C92300                                                                                                      | 36                      | 248             | 16                                | 110             | 18                          |
| C92600                                                                                                      | 40                      | 276             | 18                                | 124             | 20                          |
| C93200                                                                                                      | 30                      | 207             | 14                                | 97              | 15                          |
| C93500                                                                                                      | 28                      | 193             | 12                                | 83              | 15                          |
| C93700                                                                                                      | 30                      | 207             | 12                                | 83              | 15                          |
| C93800                                                                                                      | 26                      | 179             | 14                                | 97              | 12                          |
| C94300                                                                                                      | 24                      | 165             | ---                               | ---             | 10                          |
| C94700                                                                                                      | 45                      | 310             | 20                                | 138             | 25                          |
| C94700(HT)                                                                                                  | 75                      | 517             | 50                                | 345             | 5                           |
| C94800                                                                                                      | 40                      | 276             | 20                                | 138             | 20                          |
| C94900                                                                                                      | 38                      | 262             | 15                                | 103             | 15                          |
| C96800                                                                                                      | 125                     | 862             | 100                               | 689             | 3                           |
| C96800 (HT)                                                                                                 | 135                     | 931             | 120                               | 821             | ---                         |
| C97300                                                                                                      | 30                      | 207             | 15                                | 103             | 8                           |
| C97600                                                                                                      | 40                      | 276             | 17                                | 117             | 10                          |
| C97800                                                                                                      | 50                      | 345             | 22                                | 152             | 10                          |

a. Metric values listed are for information purposes only and are not mandatory by ASTM B 584. b. Yield strength is determined as the stress producing an elongation under load of 0.5%, that is, 0.01 in. (0.254 mm) in gage length of 2 in. or 50 mm. All values are minimum.



| ASME P-No. - BASE METAL COPPER & COPPER ALLOYS |             |                           |                     |         |                     |               |
|------------------------------------------------|-------------|---------------------------|---------------------|---------|---------------------|---------------|
| ASME Spec.                                     | Condition   | Size(s) or Thickness, in. | TS ksi <sup>a</sup> | UNS No. | Nominal Composition | Product Form  |
| <b>P No. 31</b>                                |             |                           |                     |         |                     |               |
| SB-42                                          | 061         | All                       | 30                  | C10200  | (99.95Cu+Ag)        | Seamless Pipe |
|                                                | 61          | All                       | 30                  | C12000  | (99.9Cu+Ag)         | Seamless Pipe |
|                                                | 61          | All                       | 30                  | C12200  | (99.9Cu+Ag)         | Seamless Pipe |
|                                                | H80         | 1/8-2, incl.              | 45                  | C10200  | (99.95Cu+Ag)        | Seamless Pipe |
|                                                | H55         | 2 1/2-12                  | 36                  | ---     | ---                 | Seamless Pipe |
|                                                | H80         | 1/8-2, incl.              | 45                  | C12000  | (99.9Cu+Ag)         | Seamless Pipe |
|                                                | H55         | 2 1/2-12                  | 36                  | ---     | ---                 | Seamless Pipe |
|                                                | H80         | 1/8-2, incl.              | 45                  | C12200  | (99.9Cu+Ag)         | Seamless Pipe |
| SB-75                                          | H55         | 2 1/2 -12                 | 36                  | ---     | ---                 | Seamless Pipe |
|                                                | Annealed    | All                       | 30                  | C10200  | (99.95Cu+Ag)        | Seamless Tube |
|                                                | Annealed    | All                       | 30                  | C10300  | (99.95Cu+P)         | Seamless Tube |
|                                                | Annealed    | All                       | 30                  | C12000  | (99.9Cu+Ag)         | Seamless Tube |
|                                                | Annealed    | All                       | 30                  | C12200  | (99.9Cu+Ag)         | Seamless Tube |
|                                                | Annealed    | All                       | 30                  | C14200  | (99.4Cu+Ag)         | Seamless Tube |
|                                                | Light Drawn | All                       | 36                  | C10200  | (99.95Cu+Ag)        | Seamless Tube |
|                                                | Light Drawn | All                       | 36                  | C10300  | (99.95Cu+P)         | Seamless Tube |
|                                                | Light Drawn | All                       | 36                  | C12200  | (99.9Cu+Ag)         | Seamless Tube |
|                                                | Light Drawn | All                       | 36                  | C14200  | (99.4Cu+Ag)         | Seamless Tube |
|                                                | Hard Drawn  | All                       | 45                  | C10200  | (99.95Cu+Ag)        | Seamless Tube |
|                                                | Hard Drawn  | All                       | 45                  | C10300  | (99.95Cu+P)         | Seamless Tube |
|                                                | Hard Drawn  | All                       | 45                  | C12000  | (99.9Cu+Ag)         | Seamless Tube |
|                                                | Hard Drawn  | All                       | 45                  | C12200  | (99.9Cu+Ag)         | Seamless Tube |
|                                                | Hard Drawn  | All                       | 45                  | C14200  | (99.4Cu+Ag)         | Seamless Tube |
| SB-111                                         | Annealed    | ---                       | 38                  | C19200  | (99.7Cu+Fe)         | Seamless Tube |

| ASME P-No. - BASE METAL COPPER & COPPER ALLOYS (Continued) |                         |                           |                     |         |                     |                          |
|------------------------------------------------------------|-------------------------|---------------------------|---------------------|---------|---------------------|--------------------------|
| ASME Spec.                                                 | Condition               | Size(s) or Thickness, in. | TS ksi <sup>a</sup> | UNS No. | Nominal Composition | Product Form             |
| <b>P No. 31 (Continued)</b>                                |                         |                           |                     |         |                     |                          |
| SB-111<br>(con't)                                          | Light Drawn             | ---                       | 36                  | C10200  | (99.95Cu+Ag)        | Seamless Tube            |
|                                                            | Light Drawn             | ---                       | 36                  | C12000  | (99.9Cu+Ag)         | Seamless Tube            |
|                                                            | Light Drawn             | ---                       | 36                  | C12200  | (99.9Cu+Ag)         | Seamless Tube            |
|                                                            | Light Drawn             | ---                       | 36                  | C14200  | (99.4Cu+Ag)         | Seamless Tube            |
|                                                            | Hard Drawn              | ---                       | 45                  | C10200  | (99.95Cu+Ag)        | Seamless Tube            |
|                                                            | Hard Drawn              | ---                       | 45                  | C12000  | (99.9Cu+Ag)         | Seamless Tube            |
|                                                            | Hard Drawn              | ---                       | 45                  | C12200  | (99.9Cu+Ag)         | Seamless Tube            |
|                                                            | Hard Drawn              | ---                       | 45                  | C14200  | (99.4Cu+Ag)         | Seamless Tube            |
| SB-133                                                     | 060                     | All                       | 30                  | C10200  | (99.95Cu+Ag)        | Rod and Bar              |
|                                                            | ---                     | ---                       | ---                 | C11000  | (99.90Cu+Ag)        | Rod and Bar              |
|                                                            | ---                     | ---                       | ---                 | C12000  | (99.9Cu+Ag)         | Rod and Bar              |
|                                                            | ---                     | ---                       | ---                 | C12200  | (99.9Cu+Ag)         | Rod and Bar              |
|                                                            | ---                     | ---                       | ---                 | C12500  | (99.88Cu+Ag)        | Rod and Bar              |
|                                                            | ---                     | ---                       | ---                 | C14200  | (99.4Cu+Ag)         | Rod and Bar              |
| SB-152                                                     | Hot Rolled Tempers      | ---                       | 30                  | C10200  | (99.95Cu+Ag)        | Sheet, Strip, Plate, Bar |
|                                                            | Hot Rolled and Annealed | ---                       | 30                  | C10400  | (99.95Cu+Ag)        | Sheet, Strip, Plate, Bar |
|                                                            | Hot Rolled and Annealed | ---                       | 30                  | C10500  | (99.95Cu+Ag)        | Sheet, Strip, Plate, Bar |
|                                                            | Hot Rolled and Annealed | ---                       | 30                  | C10700  | (99.95Cu+Ag)        | Sheet, Strip, Plate, Bar |
|                                                            | Hot Rolled and Annealed | ---                       | 30                  | C12200  | (99.9Cu+Ag)         | Sheet, Strip, Plate, Bar |
|                                                            | Hot Rolled and Annealed | ---                       | 30                  | C12300  | (99.90Cu+Ag)        | Sheet, Strip, Plate, Bar |
|                                                            | Hot Rolled and Annealed | ---                       | ---                 | C12500  | (99.88Cu+Ag)        | Sheet, Strip, Plate, Bar |
|                                                            | Hot Rolled and Annealed | ---                       | ---                 | C14200  | (99.4Cu+Ag)         | Sheet, Strip, Plate, Bar |
| SB-359                                                     | Annealed                | ---                       | 30                  | C10200  | (99.95Cu+Ag)        | Seamless Tube            |
|                                                            | Annealed                | ---                       | 30                  | C12000  | (99.9Cu+Ag)         | Seamless Tube            |

| ASME P-No. - BASE METAL COPPER & COPPER ALLOYS (Continued) |                                  |                           |                     |         |                     |               |
|------------------------------------------------------------|----------------------------------|---------------------------|---------------------|---------|---------------------|---------------|
| ASME Spec.                                                 | Condition                        | Size(s) or Thickness, in. | TS ksi <sup>a</sup> | UNS No. | Nominal Composition | Product Form  |
| <b>P No. 31 (Continued)</b>                                |                                  |                           |                     |         |                     |               |
| SB-359<br>(con't)                                          | Annealed                         | ---                       | 30                  | C12200  | (99.9Cu+Ag)         | Seamless Tube |
|                                                            | Annealed                         | ---                       | 30                  | C14200  | (99.4Cu+Ag)         | Seamless Tube |
|                                                            | Annealed                         | ---                       | 38                  | C19200  | (99.7Cu+Fe)         | Seamless Tube |
|                                                            | Light Drawn                      | ---                       | 36                  | C10200  | (99.95Cu+Ag)        | Seamless Tube |
|                                                            | Light Drawn                      | ---                       | 36                  | C12000  | (99.9Cu+Ag)         | Seamless Tube |
|                                                            | Light Drawn                      | ---                       | 36                  | C12200  | (99.9Cu+Ag)         | Seamless Tube |
|                                                            | Light Drawn                      | ---                       | 36                  | C14200  | (99.4Cu+Ag)         | Seamless Tube |
| SB-395                                                     | Annealed                         | ---                       | 38                  | C19200  | (99.7Cu+Fe)         | Seamless Tube |
|                                                            | Light Drawn                      | ---                       | 36                  | C10200  | (99.95Cu+Ag)        | Seamless Tube |
|                                                            | Light Drawn                      | ---                       | 36                  | C12000  | (99.9Cu+Ag)         | Seamless Tube |
|                                                            | Light Drawn                      | ---                       | 36                  | C12200  | (99.9Cu+Ag)         | Seamless Tube |
|                                                            | Light Drawn                      | ---                       | 36                  | C14200  | (99.4Cu+Ag)         | Seamless Tube |
| SB-543                                                     | As-Welded from Annealed Strip    | ---                       | 32                  | C12200  | (99.9Cu+Ag)         | Welded Tube   |
|                                                            | Light Drawn                      | ---                       | 36                  | C12200  | (99.9Cu+Ag)         | Welded Tube   |
|                                                            | Hard Drawn                       | ---                       | 45                  | C12200  | (99.9Cu+Ag)         | Welded Tube   |
|                                                            | As-Welded from Annealed Strip    | ---                       | 45                  | C19400  | (97.5Cu+Fe+Zn)      | Welded Tube   |
|                                                            | As-Welded and Annealed           | ---                       | 45                  | C19400  | (97.5Cu+Fe+Zn)      | Welded Tube   |
|                                                            | As-Welded from Cold Rolled Strip | ---                       | 50                  | C19400  | (97.5Cu+Fe+Zn)      | Welded Tube   |
| <b>P No.32</b>                                             |                                  |                           |                     |         |                     |               |
| SB-43                                                      | Annealed                         | All                       | 40                  | C23000  | (15Zn)              | Seamless Pipe |
| SB-111                                                     | Annealed                         | ---                       | 40                  | C23000  | (15Zn)              | Seamless Pipe |
|                                                            | Annealed                         | ---                       | 50                  | C28000  | (40Zn)              | Seamless Tube |
|                                                            | Annealed                         | ---                       | 45                  | C44300  | (28Zn-1Sn-0.06As)   | Seamless Tube |
|                                                            | Annealed                         | ---                       | 45                  | C44400  | (28Zn-1Sn-0.06Sb)   | Seamless Tube |

| ASME P-No. - BASE METAL COPPER & COPPER ALLOYS (Continued) |           |                           |                     |         |                     |               |
|------------------------------------------------------------|-----------|---------------------------|---------------------|---------|---------------------|---------------|
| ASME Spec.                                                 | Condition | Size(s) or Thickness, in. | TS ksi <sup>a</sup> | UNS No. | Nominal Composition | Product Form  |
| <b>P No. 32 (Continued)</b>                                |           |                           |                     |         |                     |               |
| SB-111<br>(con't)                                          | Annealed  | ---                       | 45                  | C44500  | (28Zn-1Sn-0.06P)    | Seamless Tube |
|                                                            | Annealed  | ---                       | 50                  | C68700  | (20Zn-2Al)          | Seamless Tube |
| SB-135                                                     | Annealed  | ---                       | 40                  | C23000  | (15Zn)              | Seamless Tube |
| SB-171                                                     | Annealed  | ≤ 2                       | 50                  | C36500  | (40.5Zn)            | Plate         |
|                                                            | Annealed  | ≥ 2-3.5                   | 45                  | C36500  | (40.5Zn)            | Plate         |
|                                                            | Annealed  | ≥ 3.5-5                   | 40                  | C36500  | (40.5Zn)            | Plate         |
|                                                            | Annealed  | ≤ 2                       | 50                  | C36600  | (40.5Zn-0.06As)     | Plate         |
|                                                            | Annealed  | ≥ 2-3.5                   | 45                  | C36600  | (40.5Zn-0.06As)     | Plate         |
|                                                            | Annealed  | ≥ 3.5-5                   | 40                  | C36600  | (40.5Zn-0.06As)     | Plate         |
|                                                            | Annealed  | ≤ 2                       | 50                  | C36700  | (40.5Zn-0.06Sb)     | Plate         |
|                                                            | Annealed  | ≥ 2-3.5                   | 45                  | C36700  | (40.5Zn-0.06Sb)     | Plate         |
|                                                            | Annealed  | ≥ 3.5-5                   | 40                  | C36700  | (40.5Zn-0.06Sb)     | Plate         |
|                                                            | Annealed  | ≤ 2                       | 50                  | C36800  | (40.5Zn-0.06P)      | Plate         |
|                                                            | Annealed  | ≥ 2-3.5                   | 45                  | C36800  | (40.5Zn-0.06P)      | Plate         |
|                                                            | Annealed  | ≥ 3.5-5                   | 40                  | C36800  | (40.5Zn-0.06P)      | Plate         |
|                                                            | Annealed  | ≤ 4                       | 45                  | C44300  | (28Zn-1Sn-0.06As)   | Plate         |
|                                                            | Annealed  | ≤ 4                       | 45                  | C44400  | (28Zn-1Sn-0.06Sb)   | Plate         |
|                                                            | Annealed  | ≤ 4                       | 45                  | C44500  | (28Zn-1Sn-0.06P)    | Plate         |
|                                                            | Annealed  | < 5                       | 50                  | C46400  | (39.5Zn)            | Plate         |
|                                                            | Annealed  | ≤ 5                       | 50                  | C46500  | (39.5Zn-0.06As)     | Plate         |
|                                                            | Annealed  | ≤ 5                       | 50                  | C46600  | (39.5Zn-0.06Sb)     | Plate         |
|                                                            | Annealed  | ≤ 5                       | 50                  | C46700  | (39.5Zn-0.06P)      | Plate         |
| SB-359                                                     | Annealed  | ---                       | 40                  | C23000  | (15Zn)              | Seamless Tube |
|                                                            | Annealed  | ---                       | 45                  | C44300  | (28Zn-1Sn-0.06As)   | Seamless Tube |

| ASME P-No. - BASE METAL COPPER & COPPER ALLOYS (Continued) |                               |                           |                     |         |                     |                 |
|------------------------------------------------------------|-------------------------------|---------------------------|---------------------|---------|---------------------|-----------------|
| ASME Spec.                                                 | Condition                     | Size(s) or Thickness, in. | TS ksi <sup>a</sup> | UNS No. | Nominal Composition | Product Form    |
| <b>P No. 32 (Continued)</b>                                |                               |                           |                     |         |                     |                 |
| SB-359<br>(con't)                                          | Annealed                      | ---                       | 45                  | C44400  | (28Zn-1Sn-0.06Sb)   | Seamless Tube   |
|                                                            | Annealed                      | ---                       | 45                  | C44500  | (28Zn-1Sn-0.06P)    | Seamless Tube   |
|                                                            | Annealed                      | ---                       | 50                  | C68700  | (20Zn-2Al)          | Seamless Tube   |
| SB-395                                                     | Annealed                      | ---                       | 40                  | C23000  | (15Zn)              | Seamless Tube   |
|                                                            | Annealed                      | ---                       | 45                  | C44300  | (28Zn-1Sn-0.06As)   | Seamless Tube   |
|                                                            | Annealed                      | ---                       | 45                  | C44400  | (28Zn-1Sn-0.06Sb)   | Seamless Tube   |
|                                                            | Annealed                      | ---                       | 45                  | C44500  | (28Zn-1Sn-0.06P)    | Seamless Tube   |
|                                                            | Annealed                      | ---                       | 50                  | C68700  | (20Zn-2Al)          | Seamless Tube   |
|                                                            | Annealed                      | ---                       | 50                  | C68700  | (20Zn-2Al)          | Seamless Tube   |
| SB-543                                                     | Welded and Annealed           | ---                       | 40                  | C23000  | (15Zn)              | Welded Tube     |
|                                                            | Annealed                      | ≤ 4                       | 45                  | C44300  | (28Zn-1Sn-0.06As)   | Plate           |
|                                                            | As-Welded from Annealed Strip | ---                       | 42                  | C23000  | (15Zn)              | Welded Tube     |
|                                                            | Welded and Annealed           | ---                       | 45                  | C44300  | (28Zn-1Sn-0.06As)   | Welded Tube     |
|                                                            | Welded and Annealed           | ---                       | 45                  | C44400  | (28Zn-1Sn-0.06Sb)   | Welded Tube     |
|                                                            | Welded and Annealed           | ---                       | 45                  | C44500  | (28Zn-1Sn-0.06P)    | Welded Tube     |
|                                                            | Welded and Annealed           | ---                       | 50                  | C68700  | (20Zn-2Al)          | Welded Tube     |
| <b>P No. 33</b>                                            |                               |                           |                     |         |                     |                 |
| SB-96                                                      | Annealed                      | ---                       | 50                  | C65500  | (3.3Si)             | Plate and Sheet |
| SB-98                                                      | Soft                          | ---                       | 40                  | C65100  | (1.6Si)             | Rod, Bar, Shape |
|                                                            | Half Hard                     | < 2 diam.                 | 55                  | C65100  | (1.6Si)             | Rod, Bar, Shape |
|                                                            | Bolt Temper                   | < ½                       | 85                  | C65100  | (1.6Si)             | Rod, Bar, Shape |
|                                                            | Bolt Temper                   | ½-1                       | 75                  | C65100  | (1.6Si)             | Rod, Bar, Shape |
|                                                            | Bolt Temper                   | > 1-1 ½                   | 75                  | C65100  | (1.6Si)             | Rod, Bar, Shape |
|                                                            | Soft                          | ---                       | 52                  | C65500  | (3.3Si)             | Rod, Bar, Shape |
|                                                            | Quarter Hard                  | ---                       | 55                  | C65500  | (3.3Si)             | Rod, Bar, Shape |

| ASME P-No. - BASE METAL COPPER & COPPER ALLOYS (Continued) |                                |                           |                     |         |                     |                        |
|------------------------------------------------------------|--------------------------------|---------------------------|---------------------|---------|---------------------|------------------------|
| ASME Spec.                                                 | Condition                      | Size(s) or Thickness, in. | TS ksi <sup>a</sup> | UNS No. | Nominal Composition | Product Form           |
| <b>P No. 33 (Continued)</b>                                |                                |                           |                     |         |                     |                        |
| SB-98 (con't)                                              | Half Hard                      | < 2 diam.                 | 70                  | C65500  | (3.3Si)             | Rod, Bar, Shape        |
|                                                            | Soft                           | ---                       | 52                  | C66100  | (3.2Si)             | Rod, Bar, Shape        |
|                                                            | Quarter Hard                   | ---                       | 55                  | C66100  | (3.2Si)             | Rod, Bar, Shape        |
|                                                            | Half Hard                      | < 2 diam.                 | 70                  | C66100  | (3.2Si)             | Rod, Bar, Shape        |
| SB-315                                                     | Annealed                       | ---                       | 50                  | C65500  | (3.3Si)             | Seamless Pipe and Tube |
| <b>P No. 34</b>                                            |                                |                           |                     |         |                     |                        |
| SB-111                                                     | Annealed                       | ---                       | 38                  | C70400  | (5.5Ni)             | Seamless Tube          |
|                                                            | Light Drawn                    | ---                       | 40                  | C70400  | (5.5Ni)             | Seamless Tube          |
|                                                            | Annealed                       | ---                       | 40                  | C70600  | (10Ni)              | Seamless Tube          |
|                                                            | Light Drawn                    | ---                       | 45                  | C70600  | (10Ni)              | Seamless Tube          |
|                                                            | Annealed                       | ---                       | 45                  | C71000  | (20Ni)              | Seamless Tube          |
|                                                            | Annealed                       | ---                       | 52                  | C71500  | (30Ni)              | Seamless Tube          |
|                                                            | Drawn and Stress Relvd.        | ---                       | 72                  | C71500  | (30Ni)              | Seamless Tube          |
|                                                            | 061 Annealed                   | ---                       | 63                  | C71640  | (30 ½Ni-2Fe-2Mn)    | Seamless Tube          |
|                                                            | HR50 Drawn and Stress Relived. | ---                       | 81                  | C71640  | (30 ½Ni-2Fe-2Mn)    | Seamless Tube          |
|                                                            | 061 Annealed                   | ---                       | 45                  | C72200  | (16 ½Ni-¾Fe-½Cr)    | Seamless Tube          |
|                                                            | H55 Light Drawn                | ---                       | 50                  | C72200  | (16 ½Ni-¾Fe-½Cr)    | Seamless Tube          |
| SB151                                                      | Soft                           | All                       | 38                  | C70600  | (10Ni)              | Rod and Bar            |
| SB-171                                                     | Annealed                       | ≤ 2 ½                     | 40                  | C70600  | (10Ni)              | Plate                  |
|                                                            | Annealed                       | ≤ 2 ½                     | 50                  | C71500  | (30Ni)              | Plate                  |
|                                                            | Annealed                       | Over 2 ½-5, incl.         | 45                  | C71500  | (30Ni)              | Plate                  |
| SB-359                                                     | Annealed                       | ---                       | 38                  | C70400  | (5.5Ni)             | Seamless Tube          |
|                                                            | Annealed                       | ---                       | 40                  | C70600  | (10Ni)              | Seamless Tube          |
|                                                            | Annealed                       | ---                       | 45                  | C71000  | (20Ni)              | Seamless Tube          |

| ASME P-No. - BASE METAL COPPER & COPPER ALLOYS (Continued) |                                  |                           |                     |         |                     |                        |
|------------------------------------------------------------|----------------------------------|---------------------------|---------------------|---------|---------------------|------------------------|
| ASME Spec.                                                 | Condition                        | Size(s) or Thickness, in. | TS ksi <sup>a</sup> | UNS No. | Nominal Composition | Product Form           |
| <b>P No. 34 (Continued)</b>                                |                                  |                           |                     |         |                     |                        |
| SB-359                                                     | Annealed                         | ---                       | 52                  | C71500  | (30Ni)              | Seamless Tube          |
| SB-369                                                     | As Cast                          | ---                       | 45                  | C96200  | (10Ni-1.4Fe-0.75Nb) | Casting                |
| SB-395                                                     | Annealed                         | ---                       | 40                  | C70600  | (10Ni)              | Seamless Tube          |
|                                                            | Annealed                         | ---                       | 45                  | C71000  | (20Ni)              | Seamless Tube          |
|                                                            | Annealed                         | ---                       | 52                  | C71500  | (30Ni)              | Seamless Tube          |
|                                                            | Drawn and Stress Relvd.          | ---                       | 72                  | C71500  | (30Ni)              | Seamless Tube          |
| SB-466                                                     | Annealed                         | ---                       | 38                  | C70600  | (10Ni)              | Seamless Pipe and Tube |
|                                                            | Annealed                         | ---                       | 45                  | C71000  | (20Ni)              | Seamless Pipe and Tube |
|                                                            | Annealed                         | ---                       | 50                  | C71500  | (30Ni)              | Seamless Pipe and Tube |
| SB-467                                                     | As-Welded and Annealed           | < 4 ½ O.D.                | 40                  | C70600  | (10Ni)              | Welded Pipe            |
|                                                            | As-Welded and Annealed           | > 4 ½ O.D.                | 38                  | C70600  | (10Ni)              | Welded Pipe            |
|                                                            | As-Welded from Annealed Strip    | < 4 ½ O.D.                | 45                  | C70600  | (10Ni)              | Welded Pipe            |
|                                                            | As-Welded from Cold Rolled Strip | < 4 ½ O.D.                | 54                  | C70600  | (10Ni)              | Welded Pipe            |
|                                                            | As-Welded and Annealed           | < 4 ½ O.D.                | 50                  | C71500  | (30Ni)              | Welded Pipe            |
|                                                            | As-Welded and Annealed           | > 4 ½ O.D.                | 45                  | C71500  | (30Ni)              | Welded Pipe            |
| SB-543                                                     | As-Welded and Annealed           | ---                       | 38                  | C70400  | (5.5Ni)             | Welded Tube            |
|                                                            | As-Welded and Annealed           | ---                       | 40                  | C70600  | (10Ni)              | Welded Tube            |
|                                                            | As-Welded from Annealed Strip    | ---                       | 45                  | C70600  | (10Ni)              | Welded Tube            |
|                                                            | As-Welded and Annealed           | ---                       | 52                  | C71500  | (30Ni)              | Welded Tube            |
|                                                            | Annealed                         | ---                       | 63                  | C71640  | (30 ½Ni-2Fe-2Mn)    | Welded Tube            |
|                                                            | Lt. Cold Work                    | ---                       | 75                  | C71640  | (30 ½Ni-2Fe-2Mn)    | Welded Tube            |
| <b>P No. 35</b>                                            |                                  |                           |                     |         |                     |                        |
| SB-148                                                     | As Cast                          | ---                       | 65                  | C95200  | (9Al)               | Casting                |
| SB-111                                                     | Annealed                         | ---                       | 50                  | C60800  | (5.8Al)             | Seamless Tube          |

| ASME P-No. - BASE METAL COPPER & COPPER ALLOYS (Continued) |               |                                 |                     |         |                     |                          |
|------------------------------------------------------------|---------------|---------------------------------|---------------------|---------|---------------------|--------------------------|
| ASME Spec.                                                 | Condition     | Size(s) or Thickness, in.       | TS ksi <sup>a</sup> | UNS No. | Nominal Composition | Product Form             |
| <b>P No. 35 (Continued)</b>                                |               |                                 |                     |         |                     |                          |
| SB-111                                                     | As Cast       | ---                             | 75                  | C95400  | (11Al)              | Casting                  |
| SB-150                                                     | Annealed      | $\leq \frac{1}{2}$              | 80                  | C61400  | (7Al-2.5Fe)         | Round                    |
|                                                            | Annealed      | $\geq \frac{1}{2}$ -1           | 75                  | C61400  | (7Al-2.5Fe)         | Round                    |
|                                                            | Annealed      | Over 1-3, incl.                 | 70                  | C61400  | (7Al-2.5Fe)         | Round                    |
|                                                            | Annealed      | All                             | 75                  | C62300  | (9Al-3Fe)           | Rod, Bar, Shape          |
|                                                            | Std. Strength | $\frac{1}{2}$ -1, incl.         | 100                 | C63000  | (10Al-5Ni-3Fe)      | Rod, Bar                 |
|                                                            | Std. Strength | Over 1-2, incl.                 | 90                  | C63000  | (10Al-5Ni-3Fe)      | Rod, Bar                 |
|                                                            | Std. Strength | Over 2-4, incl.                 | 85                  | C63000  | (10Al-5Ni-3Fe)      | Rod, Bar                 |
|                                                            | ---           | All                             | 85                  | C63000  | (10Al-5Ni-3Fe)      | Shape                    |
|                                                            | Annealed      | $\frac{1}{2}$ and under         | 90                  | C64200  | (7Al-2Si)           | Round                    |
|                                                            | Annealed      | Over $\frac{1}{2}$ -1, incl.    | 85                  | C64200  | (7Al-2Si)           | Round                    |
|                                                            | Annealed      | Over 1-2, incl.                 | 80                  | C64200  | (7Al-2Si)           | Round                    |
|                                                            | Annealed      | Over 2-3, incl.                 | 75                  | C64200  | (7Al-2Si)           | Round                    |
| SB-169                                                     | Annealed      | $\frac{1}{2}$ and under         | 72                  | C61400  | (7Al-2.5Fe)         | Plate, Sheet, Strip, Bar |
|                                                            | Annealed      | Over $\frac{1}{2}$ -2, include. | 70                  | C61400  | (7Al-2.5Fe)         | Plate, Sheet, Strip, Bar |
|                                                            | Annealed      | Over 2-5, incl.                 | 65                  | C61400  | (7Al-2.5Fe)         | Plate, Sheet, Strip, Bar |
| SB-171                                                     | Annealed      | $\leq 2$                        | 70                  | C61400  | (7Al-2.5Fe)         | Plate                    |
|                                                            | Annealed      | Over 2-5, incl.                 | 65                  | C61400  | (7Al-2.5Fe)         | Plate                    |
|                                                            | Annealed      | $\leq 2$                        | 90                  | C63000  | (10Al-5Ni-3Fe)      | Plate                    |
|                                                            | Annealed      | Over 2-3.5, incl.               | 85                  | C63000  | (10Al-5Ni-3Fe)      | Plate                    |
|                                                            | Annealed      | Over 3.5-5, incl.               | 80                  | C63000  | (10Al-5Ni-3Fe)      | Plate                    |
| SB-271                                                     | As Cast       | ---                             | 65                  | C95200  | (9Al)               | Centrifugal Casting      |
|                                                            | As Cast       | ---                             | 75                  | C95400  | (11Al)              | Centrifugal Casting      |
| SB-359                                                     | Annealed      | ---                             | 50                  | C60800  | (5.8Al)             | Finned Tube              |



| ASME P-No. - BASE METAL COPPER & COPPER ALLOYS (Continued) |           |                           |                     |         |                     |                    |
|------------------------------------------------------------|-----------|---------------------------|---------------------|---------|---------------------|--------------------|
| ASME Spec.                                                 | Condition | Size(s) or Thickness, in. | TS ksi <sup>a</sup> | UNS No. | Nominal Composition | Product Form       |
| <b>P No. 35 (Continued)</b>                                |           |                           |                     |         |                     |                    |
| SB-395                                                     | Annealed  | ---                       | 50                  | C60800  | (5.8Al)             | Seamless Tube      |
| SB-505                                                     | As Cast   | ---                       | 68                  | C95200  | (9Al)               | Continuous Casting |

a. Minimum specified tensile strength.

| ASME F No. - FILLER METAL COPPER & COPPER ALLOYS |            |                                            |
|--------------------------------------------------|------------|--------------------------------------------|
| F No.                                            | ASME Spec. | AWS Classification                         |
| 31                                               | SFA-5.6    | ECu                                        |
| 31                                               | SFA-5.7    | ER Cu                                      |
| 31                                               | SFA-5.27   | ER Cu                                      |
| 32                                               | SFA-5.6    | ECuSi                                      |
| 32                                               | SFA-5.7    | ER CuSi-A                                  |
| 32                                               | SFA-5.27   | ER CuSi-A                                  |
| 33                                               | SFA-5.6    | ECuSn-A, ECuSn-C                           |
| 33                                               | SFA-5.7    | ER CuSn-A                                  |
| 34                                               | SFA-5.6    | ECuNi                                      |
| 34                                               | SFA-5.7    | ER CuNi                                    |
| 34                                               | SFA-5.30   | IN 67                                      |
| 35                                               | SFA-5.27   | RB CuZn-A, RB CuZn-B, RB CuZn-C, RB CuZn-D |
| 36                                               | SFA-5.6    | ECuAl-A2, ECuAl-B                          |
|                                                  | SFA-5.7    | ER CuAl-A1, ER CuAl-A2, ER CuAl-A3         |
|                                                  | SFA-5.6    | ECuNiAl, ECuMnNiAl                         |
| 37                                               | SFA-5.7    | ER CuNiAl, ER CuMnNiAl                     |

| INTERNATIONAL CROSS REFERENCES - COPPER & COPPER ALLOYS <sup>a</sup> |               |                |                                                                       |                      |
|----------------------------------------------------------------------|---------------|----------------|-----------------------------------------------------------------------|----------------------|
| USA<br>UNS                                                           | BRITAIN<br>BS | GERMANY<br>DIN | JAPAN<br>JIS                                                          | INTERNATIONAL<br>ISO |
| C10200                                                               | C 103         | OF-Cu          | C 1020 P, C 1020 R, C 1020 B, C 1020 T                                | Cu-OF                |
| C11000                                                               | C 101, C 102  | E-Cu57         | C 1100 P, C 1100 R, C 1100 PP, C1100 B, C 1100 T                      | Cu-ETP               |
| C12000                                                               | C 106         | SW-Cu          | C 1201 P, C 1201 R, C 1201 B, C 1201 T                                | Cu-DLP               |
| C12200                                                               | C 106         | SF-Cu          | C 1220 P, C 1220 R, C 1221 P, C 1221 R, C 1221 PP, C 1220 B, C 1220 T | Cu-DHP               |
| C17000                                                               | ---           | CuBe1.7        | C 1700 P, C 1700 R                                                    | CuBe1.7              |
| C17200                                                               | CB 101        | CuBe2          | C 1720 P, C 1720 R, C 1720 B, C 1720 W                                | CuBe2                |
| C21000                                                               | ---           | CuZn5          | C 2100 P, C 2100 R, C 2100 W                                          | CuZn5                |
| C22000                                                               | CZ 101        | CuZn10         | C 2200 P, C 2200 R, C 2200 W, C 2200 T                                | CuZn10               |
| C23000                                                               | CZ 102        | CuZn15         | C 2300 P, C 2300 R, C 2300 W, C 2300 T                                | CuZn15               |
| C24000                                                               | CZ 103        | CuZn20         | C 2400 P, C 2400 R, C 2400 W                                          | CuZn20               |
| C26000                                                               | CZ 106        | CuZn30         | C 2600 P, C 2600 R, C 2600 B, C 2600 W, C 2600 T                      | CuZn30               |
| C26800                                                               | CZ 107        | CuZn36         | C 2680 P, C 2680 R                                                    | CuZn35               |
| C27000                                                               | ---           | CuZn36         | C 2700 T                                                              | CuZn35               |
| C27200                                                               | CZ 108        | CuZn37         | C 2720 P, C 2720 R                                                    | CuZn37               |
| ---                                                                  | CZ 109        | CuZn40         | C 2800 B                                                              | CuZn40               |
| C28000                                                               | CZ 119        | CuZn40         | C 2801 P, C 2801 R, C 2800 T                                          | CuZn40               |
| ---                                                                  | CZ 114        | CuZn40Al1      | C 6782 B, C 6783 B                                                    | CuZn39AlFeMn         |
| C35600                                                               | CZ 119        | CuZn36Pb1.5    | C 3560 P, C 3560 R, C 3561 P, C 3561 R                                | CuZn36Pb3            |
| ---                                                                  | CZ 120        | CuZn38Pb1.5    | C 3713 P, C 3713 R                                                    | CuZn38Pb2            |
| ---                                                                  | CZ 123        | CuZn39Pb0.5    | C 3710 P, C 3710 R, C 3712 B                                          | CuZn39Pb1            |
| C36000                                                               | CZ 124        | CuZn36Pb3      | C 3601 B, C 3602 B                                                    | CuZn36Pb3            |
| C37700                                                               | CZ 122        | CuZn39Pb2      | C 3771 B                                                              | CuZn39Pb2            |
| C42500                                                               | ---           | ---            | C 4250P, C 4250 R                                                     | ---                  |
| C44300                                                               | CZ 111        | CuZn28Sn1      | C 4430 P, C 4430 R, C 4430 T                                          | CuZn28Sn1            |

| INTERNATIONAL CROSS REFERENCES - COPPER & COPPER ALLOYS <sup>a</sup> (Continued) |               |                |                                        |                      |
|----------------------------------------------------------------------------------|---------------|----------------|----------------------------------------|----------------------|
| USA<br>UNS                                                                       | BRITAIN<br>BS | GERMANY<br>DIN | JAPAN<br>JIS                           | INTERNATIONAL<br>ISO |
| C46200                                                                           | CZ 122        | CuZn38Sn1      | C 4622 B                               | CuZn38Sn1            |
| C46400                                                                           | ---           | CuZn38Sn1      | C 4640 P, C4641 B                      | CuZn38Sn1            |
| C51000                                                                           | PB 102        | CuSn4          | C 5111 P, C 5111 R, C 5102 P, C 5102 R | CuSn4, CuSn5         |
| ---                                                                              | PB 103        | CuSn6          | C 5191 P, 5191 R                       | CuSn6                |
| C52100                                                                           | PB 104        | CuSn8          | C 5212 P, 5212 R                       | CuSn8                |
| C54400                                                                           | ---           | ---            | C 5441 B                               | CuSn4Pb4Zn3          |
| C61400                                                                           | CA 106        | ---            | C 6140 P                               | CuAl8Fe3             |
| ---                                                                              | CA 103        | CuAl8Fe3       | C 6161 P                               | CuAl10Fe3            |
| ---                                                                              | CA 105        | CuAl10Ni5Fe4   | C 6280 P                               | CuAl10Ni5Fe4         |
| C61900                                                                           | CA 104        | CuAl10Fe3Mn2   | C 6191 B                               | CuAl10Fe3            |
| C62400                                                                           | ---           | CuAl10Fe3Mn2   | C 6241 B                               | CuAl10Fe3            |
| C63000                                                                           | CA 104        | CuAl10Ni5Fe4   | C 6301 P                               | CuAl10Ni5Fe4         |
| C68700                                                                           | CZ 110        | CuZn20Al2      | C 6870 T, C 6871 T, C 6872 T           | CuZn20Al2            |
| C70600                                                                           | CN 102        | CuNi10Fe1Mn    | C 7060 PC 7060 T                       | CuNi10Fe1Mn          |
| C71000                                                                           | ---           | ---            | C 7100 T                               | ---                  |
| C71500                                                                           | CN 107        | CuNi30Mn1Fe    | C 7150 P, C 7150 T                     | CuNi30Mn1Fe          |
| C71640                                                                           | CN 108        | ---            | C 7164 T                               | CuNi30Fe2Mn2         |
| C73500                                                                           | ---           | ---            | C 7351 P, C 7351 R                     | ---                  |
| C74500                                                                           | NS 103        | CuNi12Zn24     | C 7451 P, C 7451 R, C 7451 W           | CuNi10Zn27           |
| C75200                                                                           | NS 106        | CuNi18Zn20     | C 7521 P, C 7521 R, C 7521 B, C 7521 W | CuNi18Zn20           |
| ---                                                                              | NS 105        | CuNi12Zn24     | C 7541 P, C 7541 R, C 7541 B, C 7541 W | CuNi15Zn21           |
| C77000                                                                           | NS 107        | CuNi18Zn27     | C 7701 P, C 7701 R, C 7701 B, C 7701 W | CuNi18Zn27           |
| C83600                                                                           | LG 2          | CuSn5ZnPb      | BC 6, BC 6 C                           | CuPb5Sn5Zn5          |
| C85400                                                                           | SCB 3         | CuZn33Pb       | YBsC2                                  | CuZn33Pb2            |
| C85700                                                                           | DCB 3         | CuZn37Pb       | YBSC 3                                 | CuZn40Pb             |

| INTERNATIONAL CROSS REFERENCES - COPPER & COPPER ALLOYS <sup>a</sup> (Continued) |               |                |                  |                      |
|----------------------------------------------------------------------------------|---------------|----------------|------------------|----------------------|
| USA<br>UNS                                                                       | BRITAIN<br>BS | GERMANY<br>DIN | JAPAN<br>JIS     | INTERNATIONAL<br>ISO |
| C86200                                                                           | HTB 3         | CuZn25Al5      | HBsC 3, HBsC 3 C | CuZn26Al4Fe3Mn3      |
| C86300                                                                           | HTB 3         | CuZn25Al5      | HBsC 4, HBsC 4 C | CuZn25Al6Fe3Mn3      |
| C86400                                                                           | HTB 1         | CuZn34Al1      | HBsC 2, HBsC 2 C | CuZn35AlFeMn         |
| C86500                                                                           | HTB 1         | CuZn35Al1      | HBSC 1           | CuZn35AlFeMn         |
| C86500                                                                           | ---           | ---            | HBsC 1 C         | CuZn35AlFeMn         |
| C84400                                                                           | LG 1          | ---            | BC 1, BC 1 C     | ---                  |
| C87400                                                                           | ---           | ---            | SzBC 1           | ---                  |
| C87500                                                                           | ---           | CuZn15Si4      | SzBC 2           | ---                  |
| C90300                                                                           | ---           | ---            | BC 2, BC 2 C     | ---                  |
| C90500                                                                           | G 1           | CuSn10Zn       | BC 3, BC 3 C     | CuSn10Zn2            |
| C90700                                                                           | PB 2          | CuSn10         | PBC 2, PBC 2 C   | CuSn10               |
| C91000                                                                           | PB 2          | CuSn12         | PBC 3 B, PBC 3 C | CuSn12               |
| C92200                                                                           | LG 4          | ---            | BC 7, BC 7 C     | ---                  |
| C93700                                                                           | LB 2          | CuPb10Sn       | LBC 3, LBC 3 C   | CuPb10Sn10           |
| C93800                                                                           | LB 1          | CuPb15Sn       | LBC 4, LCB 4 C   | CuPb15Sn8            |
| C95200                                                                           | AB 1          | CuAl10Fe       | AIBC 1           | CuAl9                |
| C95400                                                                           | ---           | CuAl9Ni        | AIBC 2, AIBC 2 C | CuAl10Fe3            |
| C95800                                                                           | AB 2          | CuAl10Ni       | AIBC 3           | CuAl10Fe5Ni5         |
| C95700                                                                           | CMA 2         | ---            | AIBC 4           | ---                  |
| ---                                                                              | LB 5          | CuPb20Sn       | LBC 5            | CuPb20Sn5            |

a. It is not practical to directly correlate the various metal designations from country to country, let alone comparing several countries and their metal designations; from the view that chemical composition may be similar, but not identical, and that manufacturing technologies may differ greatly. Consequently, the cross references made in this table are, at best, only listed as a guide to assist in finding comparable metal designations, rather than equivalent metal designations. UNS - Unified Numbering System; BS - British Standards; DIN - Deutsches Institut für Normung; JIS - Japanese Industrial Standards; ISO - International Organization for Standardization.

# **Appendix**

# **1**

## ***HARDNESS CONVERSION TABLES***

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NICKEL & HIGH-NICKEL ALLOYS |                            |                                       |     |      |      |       |       |      |       |
|-------------------------------------------------------------------------|----------------------------|---------------------------------------|-----|------|------|-------|-------|------|-------|
| Vickers <sup>a</sup><br>HV                                              | Brinell <sup>b</sup><br>HB | Rockwell Hardness Number <sup>c</sup> |     |      |      |       |       |      |       |
|                                                                         |                            | HRA                                   | HRB | HRC  | HRD  | HRE   | HRF   | HRG  | HRK   |
| 513                                                                     | 479                        | 75.5                                  | --- | 50.0 | 63.0 | ---   | ---   | ---  | ---   |
| 481                                                                     | 450                        | 74.5                                  | --- | 48.0 | 61.5 | ---   | ---   | ---  | ---   |
| 452                                                                     | 425                        | 73.5                                  | --- | 46.0 | 60.0 | ---   | ---   | ---  | ---   |
| 427                                                                     | 403                        | 72.5                                  | --- | 44.0 | 58.5 | ---   | ---   | ---  | ---   |
| 404                                                                     | 382                        | 71.5                                  | --- | 42.0 | 57.0 | ---   | ---   | ---  | ---   |
| 382                                                                     | 363                        | 70.5                                  | --- | 40.0 | 55.5 | ---   | ---   | ---  | ---   |
| 362                                                                     | 346                        | 69.5                                  | --- | 38.0 | 54.0 | ---   | ---   | ---  | ---   |
| 344                                                                     | 329                        | 68.5                                  | --- | 36.0 | 52.5 | ---   | ---   | ---  | ---   |
| 326                                                                     | 313                        | 67.5                                  | --- | 34.0 | 50.5 | ---   | ---   | ---  | ---   |
| 309                                                                     | 298                        | 66.5                                  | 106 | 32.0 | 49.5 | ---   | 116.5 | 94.0 | ---   |
| 285                                                                     | 275                        | 64.5                                  | 104 | 28.5 | 46.5 | ---   | 115.5 | 91.0 | ---   |
| 266                                                                     | 258                        | 63.0                                  | 102 | 25.5 | 44.5 | ---   | 114.5 | 87.5 | ---   |
| 248                                                                     | 241                        | 61.5                                  | 100 | 22.5 | 42.0 | ---   | 113.0 | 84.5 | ---   |
| 234                                                                     | 228                        | 60.5                                  | 98  | 20.0 | 40.0 | ---   | 112.0 | 81.5 | ---   |
| 220                                                                     | 215                        | 59.0                                  | 96  | 17.0 | 38.0 | ---   | 111.0 | 78.5 | 100.0 |
| 209                                                                     | 204                        | 57.5                                  | 94  | 14.5 | 36.0 | ---   | 110.0 | 75.5 | 98.0  |
| 198                                                                     | 194                        | 56.5                                  | 92  | 12.0 | 34.0 | ---   | 108.5 | 72.0 | 96.5  |
| 188                                                                     | 184                        | 55.0                                  | 90  | 9.0  | 32.0 | 108.5 | 107.5 | 69.0 | 94.5  |
| 179                                                                     | 176                        | 53.5                                  | 88  | 6.5  | 30.0 | 107.0 | 106.5 | 65.5 | 93.0  |
| 171                                                                     | 168                        | 52.5                                  | 86  | 4.0  | 28.0 | 106.0 | 105.0 | 62.5 | 91.0  |
| 164                                                                     | 161                        | 51.5                                  | 84  | 2.0  | 26.5 | 104.5 | 104.0 | 59.5 | 89.0  |
| 157                                                                     | 155                        | 50.0                                  | 82  | ---  | 24.5 | 103.0 | 103.0 | 56.5 | 87.5  |
| 151                                                                     | 149                        | 49.0                                  | 80  | ---  | 22.5 | 102.0 | 101.5 | 53.0 | 85.5  |
| 145                                                                     | 144                        | 47.5                                  | 78  | ---  | 21.0 | 100.5 | 100.5 | 50.0 | 83.5  |
| 140                                                                     | 139                        | 46.5                                  | 76  | ---  | 19.0 | 99.5  | 99.5  | 47.0 | 82.0  |

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NICKEL & HIGH-NICKEL ALLOYS (Continued) |                            |                                       |     |     |      |      |      |      |      |
|-------------------------------------------------------------------------------------|----------------------------|---------------------------------------|-----|-----|------|------|------|------|------|
| Vickers <sup>a</sup><br>HV                                                          | Brinell <sup>b</sup><br>HB | Rockwell Hardness Number <sup>c</sup> |     |     |      |      |      |      |      |
|                                                                                     |                            | HRA                                   | HRB | HRC | HRD  | HRE  | HRF  | HRG  | HRK  |
| 135                                                                                 | 134                        | 45.5                                  | 74  | --- | 17.5 | 98.0 | 98.5 | 43.5 | 80.0 |
| 130                                                                                 | 129                        | 44.0                                  | 72  | --- | 16.0 | 97.0 | 97.0 | 40.5 | 78.0 |
| 126                                                                                 | 125                        | 43.0                                  | 70  | --- | 14.5 | 95.5 | 96.0 | 37.5 | 76.5 |
| 122                                                                                 | 121                        | 42.0                                  | 68  | --- | 13.0 | 94.5 | 95.0 | 34.5 | 74.5 |
| 119                                                                                 | 118                        | 41.0                                  | 66  | --- | 11.5 | 93.0 | 93.5 | 31.0 | 72.5 |
| 115                                                                                 | 114                        | 40.0                                  | 64  | --- | 10.0 | 91.5 | 92.5 | ---  | 71.0 |
| 112                                                                                 | 111                        | 39.0                                  | 62  | --- | 8.0  | 90.5 | 91.5 | ---  | 69.0 |
| 108                                                                                 | 108                        | ---                                   | 60  | --- | ---  | 89.0 | 90.0 | ---  | 67.5 |
| 106                                                                                 | 106                        | ---                                   | 58  | --- | ---  | 88.0 | 89.0 | ---  | 65.5 |
| 103                                                                                 | 103                        | ---                                   | 56  | --- | ---  | 86.5 | 88.0 | ---  | 63.5 |
| 100                                                                                 | 100                        | ---                                   | 54  | --- | ---  | 85.5 | 87.0 | ---  | 62.0 |
| 98                                                                                  | 98                         | ---                                   | 52  | --- | ---  | 84.0 | 85.5 | ---  | 60.0 |
| 95                                                                                  | 95                         | ---                                   | 50  | --- | ---  | 83.0 | 84.5 | ---  | 58.0 |
| 93                                                                                  | 93                         | ---                                   | 48  | --- | ---  | 81.5 | 83.5 | ---  | 56.5 |
| 91                                                                                  | 91                         | ---                                   | 46  | --- | ---  | 80.5 | 82.0 | ---  | 54.5 |
| 89                                                                                  | 89                         | ---                                   | 44  | --- | ---  | 79.0 | 81.0 | ---  | 52.5 |
| 87                                                                                  | 87                         | ---                                   | 42  | --- | ---  | 78.0 | 80.0 | ---  | 51.0 |
| 85                                                                                  | 85                         | ---                                   | 40  | --- | ---  | 76.5 | 79.0 | ---  | 49.0 |
| 83                                                                                  | 83                         | ---                                   | 38  | --- | ---  | 75.0 | 77.5 | ---  | 47.0 |
| 81                                                                                  | 81                         | ---                                   | 36  | --- | ---  | 74.0 | 76.5 | ---  | 45.5 |
| 79                                                                                  | 79                         | ---                                   | 34  | --- | ---  | 72.5 | 75.5 | ---  | 43.5 |
| 78                                                                                  | 78                         | ---                                   | 32  | --- | ---  | 71.5 | 74.0 | ---  | 42.0 |
| 77                                                                                  | 77                         | ---                                   | 30  | --- | ---  | 70.0 | 73.0 | ---  | 40.0 |

a. Vickers Hardness Number, Vickers indenter, 1.5, 10, 30-kgf load.  
b. Brinell Hardness Number, 10 mm ball, 3000 kgf load.

**APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NICKEL & HIGH-NICKEL ALLOYS (Continued)**

c. A Scale - 60-kgf load, diamond penetrator; B Scale - 100-kgf load, 1/16 in. (1.588 mm) ball; C Scale - 150-kgf load, diamond penetrator; D Scale - 100-kgf, diamond penetrator; E Scale - 100-kgf load, 1/8 in. (3.175 mm) ball; F Scale - 60-kgf load, 1/16 in. (1.588 mm ) ball; G Scale - 150-kgf load, 1/16 in. (1.588 mm) ball; K Scale - 150-kgf load, 1/8 in. (3.175 mm) ball.

Note that in Table 5 of ASTM Test Method E 10, the use of a 3000-kgf load is recommended (but not mandatory) for material in the hardness range 96 to 600 HV, and a 1500-kgf load is recommended (but not mandatory) for material in the hardness range 48 to 300 HV. These recommendations are designed to limit impression diameters to the range 2.50 to 6.0 mm. The Brinell hardness numbers in this conversion table are based on tests using a 3000-kgf load. When the 1500-kgf load is used for the softer nickel and high-nickel alloys, these conversion relationships do not apply.

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NICKEL & HIGH-NICKEL ALLOYS |                            |                                            |        |        |        |        |        |
|-------------------------------------------------------------------------|----------------------------|--------------------------------------------|--------|--------|--------|--------|--------|
| Vickers <sup>a</sup><br>HV                                              | Brinell <sup>b</sup><br>HB | Rockwell Superficial Hardness <sup>c</sup> |        |        |        |        |        |
|                                                                         |                            | HR15-N                                     | HR30-N | HR45-N | HR15-T | HR30-T | HR45-T |
| 513                                                                     | 479                        | 85.5                                       | 68.0   | 54.5   | ---    | ---    | ---    |
| 481                                                                     | 450                        | 84.5                                       | 66.5   | 52.5   | ---    | ---    | ---    |
| 452                                                                     | 425                        | 83.5                                       | 64.5   | 50.0   | ---    | ---    | ---    |
| 427                                                                     | 403                        | 82.5                                       | 63.0   | 47.5   | ---    | ---    | ---    |
| 404                                                                     | 382                        | 81.5                                       | 61.0   | 45.5   | ---    | ---    | ---    |
| 382                                                                     | 363                        | 80.5                                       | 59.5   | 43.0   | ---    | ---    | ---    |
| 362                                                                     | 346                        | 79.5                                       | 58.0   | 41.0   | ---    | ---    | ---    |
| 344                                                                     | 329                        | 78.5                                       | 56.0   | 38.5   | ---    | ---    | ---    |
| 326                                                                     | 313                        | 77.5                                       | 54.5   | 36.0   | ---    | ---    | ---    |
| 309                                                                     | 298                        | 76.5                                       | 52.5   | 34.0   | 94.5   | 85.5   | 77.0   |
| 285                                                                     | 275                        | 75.0                                       | 49.5   | 30.0   | 94.0   | 84.5   | 75.0   |
| 266                                                                     | 258                        | 73.5                                       | 47.0   | 26.5   | 93.0   | 83.0   | 73.0   |
| 248                                                                     | 241                        | 72.0                                       | 44.5   | 23.0   | 92.5   | 81.5   | 71.0   |
| 234                                                                     | 228                        | 70.5                                       | 42.0   | 20.0   | 92.0   | 80.5   | 69.0   |
| 220                                                                     | 215                        | 69.0                                       | 39.5   | 17.0   | 91.0   | 79.0   | 67.0   |
| 209                                                                     | 204                        | 68.0                                       | 37.5   | 14.0   | 90.5   | 77.5   | 65.0   |



| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NICKEL & HIGH-NICKEL ALLOYS (Continued) |                            |                                            |        |        |        |        |        |
|-------------------------------------------------------------------------------------|----------------------------|--------------------------------------------|--------|--------|--------|--------|--------|
| Vickers <sup>a</sup><br>HV                                                          | Brinell <sup>b</sup><br>HB | Rockwell Superficial Hardness <sup>c</sup> |        |        |        |        |        |
|                                                                                     |                            | HR15-N                                     | HR30-N | HR45-N | HR15-T | HR30-T | HR45-T |
| 198                                                                                 | 194                        | 66.5                                       | 35.5   | 11.0   | 89.5   | 76.0   | 63.0   |
| 188                                                                                 | 184                        | 65.0                                       | 32.5   | 7.5    | 89.0   | 75.0   | 61.0   |
| 179                                                                                 | 176                        | 64.0                                       | 30.5   | 5.0    | 88.0   | 73.5   | 59.5   |
| 171                                                                                 | 168                        | 62.5                                       | 28.5   | 2.0    | 87.5   | 72.0   | 57.5   |
| 164                                                                                 | 161                        | 61.5                                       | 26.5   | -0.5   | 87.0   | 70.5   | 55.5   |
| 157                                                                                 | 155                        | ---                                        | ---    | ---    | 86.0   | 69.5   | 53.5   |
| 151                                                                                 | 149                        | ---                                        | ---    | ---    | 85.5   | 68.0   | 51.5   |
| 145                                                                                 | 144                        | ---                                        | ---    | ---    | 84.5   | 66.5   | 49.5   |
| 140                                                                                 | 139                        | ---                                        | ---    | ---    | 84.0   | 65.5   | 47.5   |
| 135                                                                                 | 134                        | ---                                        | ---    | ---    | 83.0   | 64.0   | 45.5   |
| 130                                                                                 | 129                        | ---                                        | ---    | ---    | 82.5   | 62.5   | 43.5   |
| 126                                                                                 | 125                        | ---                                        | ---    | ---    | 82.0   | 61.0   | 41.5   |
| 122                                                                                 | 121                        | ---                                        | ---    | ---    | 81.0   | 60.0   | 39.5   |
| 119                                                                                 | 118                        | ---                                        | ---    | ---    | 80.5   | 58.5   | 37.5   |
| 115                                                                                 | 114                        | ---                                        | ---    | ---    | 79.5   | 57.0   | 35.5   |
| 112                                                                                 | 111                        | ---                                        | ---    | ---    | 79.0   | 56.0   | 33.5   |
| 108                                                                                 | 108                        | ---                                        | ---    | ---    | 78.5   | 54.5   | 31.5   |
| 106                                                                                 | 106                        | ---                                        | ---    | ---    | 77.5   | 53.0   | 29.5   |
| 103                                                                                 | 103                        | ---                                        | ---    | ---    | 77.0   | 51.5   | 27.5   |
| 100                                                                                 | 100                        | ---                                        | ---    | ---    | 76.0   | 50.5   | 25.5   |
| 98                                                                                  | 98                         | ---                                        | ---    | ---    | 75.5   | 49.0   | 23.5   |
| 95                                                                                  | 95                         | ---                                        | ---    | ---    | 74.5   | 47.5   | 21.5   |
| 93                                                                                  | 93                         | ---                                        | ---    | ---    | 74.0   | 46.5   | 19.5   |
| 91                                                                                  | 91                         | ---                                        | ---    | ---    | 73.5   | 45.0   | 17.0   |
| 89                                                                                  | 89                         | ---                                        | ---    | ---    | 72.5   | 43.5   | 14.5   |

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NICKEL & HIGH-NICKEL ALLOYS (Continued) |                            |                                            |        |        |        |        |        |
|-------------------------------------------------------------------------------------|----------------------------|--------------------------------------------|--------|--------|--------|--------|--------|
| Vickers <sup>a</sup><br>HV                                                          | Brinell <sup>b</sup><br>HB | Rockwell Superficial Hardness <sup>c</sup> |        |        |        |        |        |
|                                                                                     |                            | HR15-N                                     | HR30-N | HR45-N | HR15-T | HR30-T | HR45-T |
| 87                                                                                  | 87                         | ---                                        | ---    | ---    | 72.0   | 42.0   | 12.5   |
| 85                                                                                  | 85                         | ---                                        | ---    | ---    | 71.0   | 41.0   | 10.0   |
| 83                                                                                  | 83                         | ---                                        | ---    | ---    | 70.5   | 39.5   | 7.5    |
| 81                                                                                  | 81                         | ---                                        | ---    | ---    | 70.0   | 38.0   | 5.5    |
| 79                                                                                  | 79                         | ---                                        | ---    | ---    | 69.0   | 36.5   | 3.0    |
| 78                                                                                  | 78                         | ---                                        | ---    | ---    | 68.5   | 35.5   | 1.0    |
| 77                                                                                  | 77                         | ---                                        | ---    | ---    | 67.5   | 34.0   | -1.5   |

a. Vickers Hardness Number, Vickers indenter, 1.5, 10, 30-kgf load. b. Brinell Hardness Number, 10 mm ball, 3000 kgf load. Note that in Table 5 of ASTM Test Method E 10, the use of a 3000-kgf load is recommended (but not mandatory) for material in the hardness range 96 to 600 HV, and a 1500-kgf load is recommended (but not mandatory) for material in the hardness range 48 to 300 HV. These recommendations are designed to limit impression diameters to the range 2.50 to 6.0 mm. The Brinell hardness numbers in this conversion table are based on tests using a 3000-kgf load. When the 1500-kgf load is used for the softer nickel and high-nickel alloys, these conversion relationships do not apply. c. 15-N Scale - 15-kgf load, superficial diamond penetrator; 30-N Scale - 30-kgf load, superficial diamond penetrator; 45-N Scale - 45-kgf load, superficial diamond penetrator; 15-T Scale - 15-kgf load, 1/16 in. (1.588 mm) ball; 30-T Scale - 30-kgf load, 1/16 in. (1.588 mm) ball; 45-T Scale - 45-kgf load, 1/16 in. (1.588 mm) ball.

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR CARTRIDGE BRASS (70% COPPER - 30% ZINC ALLOY) |               |                                                   |       |        |        |        |
|-------------------------------------------------------------------------------------------|---------------|---------------------------------------------------|-------|--------|--------|--------|
| Vickers<br>HV                                                                             | Brinell<br>HB | Rockwell Superficial Hardness Number <sup>a</sup> |       |        |        |        |
|                                                                                           |               | HRB                                               | HRF   | HR15-T | HR30-T | HR45-T |
| 196                                                                                       | 169           | 93.5                                              | 110.0 | 90.0   | 77.5   | 66.0   |
| 194                                                                                       | 167           | ---                                               | 109.5 | ---    | ---    | 65.5   |
| 192                                                                                       | 166           | 93.0                                              | ---   | ---    | 77.0   | 65.0   |
| 190                                                                                       | 164           | 92.5                                              | 109.0 | ---    | 76.5   | 64.5   |
| 188                                                                                       | 162           | 92.0                                              | ---   | 89.5   | ---    | 64.0   |
| 186                                                                                       | 161           | 91.5                                              | 108.5 | ---    | 76.0   | 63.5   |
| 184                                                                                       | 159           | 91.0                                              | ---   | ---    | 75.5   | 63.0   |

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR CARTRIDGE BRASS (70% COPPER - 30% ZINC ALLOY) (Continued) |               |                                                   |       |        |        |        |
|-------------------------------------------------------------------------------------------------------|---------------|---------------------------------------------------|-------|--------|--------|--------|
| Vickers<br>HV                                                                                         | Brinell<br>HB | Rockwell Superficial Hardness Number <sup>a</sup> |       |        |        |        |
|                                                                                                       |               | HRB                                               | HRF   | HR15-T | HR30-T | HR45-T |
| 182                                                                                                   | 157           | 90.5                                              | 108.0 | 89.0   | ---    | 62.5   |
| 180                                                                                                   | 156           | 90.0                                              | 107.5 | ---    | 75.0   | 62.0   |
| 178                                                                                                   | 154           | 89.0                                              | ---   | ---    | 74.5   | 61.5   |
| 176                                                                                                   | 152           | 88.5                                              | 107.0 | ---    | ---    | 61.0   |
| 174                                                                                                   | 150           | 88.0                                              | ---   | 88.5   | 74.0   | 60.5   |
| 172                                                                                                   | 149           | 87.5                                              | 106.5 | ---    | 73.5   | 60.0   |
| 170                                                                                                   | 147           | 87.0                                              | ---   | ---    | ---    | 59.5   |
| 168                                                                                                   | 146           | 86.0                                              | 106.0 | 88.0   | 73.0   | 59.0   |
| 166                                                                                                   | 144           | 85.5                                              | ---   | ---    | 72.5   | 58.5   |
| 164                                                                                                   | 142           | 85.0                                              | 105.5 | ---    | 72.0   | 58.0   |
| 162                                                                                                   | 141           | 84.0                                              | 105.0 | 87.5   | ---    | 57.5   |
| 160                                                                                                   | 139           | 83.5                                              | ---   | ---    | 71.5   | 56.5   |
| 158                                                                                                   | 138           | 83.0                                              | 104.5 | ---    | 71.0   | 56.0   |
| 156                                                                                                   | 136           | 82.0                                              | 104.0 | 87.0   | 70.5   | 55.5   |
| 154                                                                                                   | 135           | 81.5                                              | 103.5 | ---    | 70.0   | 54.5   |
| 152                                                                                                   | 133           | 80.5                                              | 103.0 | ---    | ---    | 54.0   |
| 150                                                                                                   | 131           | 80.0                                              | ---   | 86.5   | 69.5   | 53.5   |
| 148                                                                                                   | 129           | 79.0                                              | 102.5 | ---    | 69.0   | 53.0   |
| 146                                                                                                   | 128           | 78.0                                              | 102.0 | ---    | 68.5   | 52.5   |
| 144                                                                                                   | 126           | 77.5                                              | 101.5 | 86.0   | 68.0   | 51.5   |
| 142                                                                                                   | 124           | 77.0                                              | 101.0 | ---    | 67.5   | 51.0   |
| 140                                                                                                   | 122           | 76.0                                              | 100.5 | 85.5   | 67.0   | 50.0   |
| 138                                                                                                   | 121           | 75.0                                              | 100.0 | ---    | 66.5   | 49.0   |
| 136                                                                                                   | 120           | 74.5                                              | 99.5  | 85.0   | 66.0   | 48.0   |
| 134                                                                                                   | 118           | 73.5                                              | 99.0  | ---    | 65.5   | 47.5   |

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR CARTRIDGE BRASS (70% COPPER - 30% ZINC ALLOY) (Continued) |               |                                                   |      |        |        |        |
|-------------------------------------------------------------------------------------------------------|---------------|---------------------------------------------------|------|--------|--------|--------|
| Vickers<br>HV                                                                                         | Brinell<br>HB | Rockwell Superficial Hardness Number <sup>a</sup> |      |        |        |        |
|                                                                                                       |               | HRB                                               | HRF  | HR15-T | HR30-T | HR45-T |
| 132                                                                                                   | 116           | 73.0                                              | 98.5 | 84.5   | 65.0   | 46.5   |
| 130                                                                                                   | 114           | 72.0                                              | 98.0 | 84.0   | 64.5   | 45.5   |
| 128                                                                                                   | 113           | 71.0                                              | 97.5 | ---    | 63.5   | 45.0   |
| 126                                                                                                   | 112           | 70.0                                              | 97.0 | 83.5   | 63.0   | 44.0   |
| 124                                                                                                   | 110           | 69.0                                              | 96.5 | ---    | 62.5   | 43.0   |
| 122                                                                                                   | 108           | 68.0                                              | 96.0 | 83.0   | 62.0   | 42.0   |
| 120                                                                                                   | 106           | 67.0                                              | 95.5 | ---    | 61.0   | 41.0   |
| 118                                                                                                   | 105           | 66.0                                              | 95.0 | 82.5   | 60.5   | 40.0   |
| 116                                                                                                   | 103           | 65.0                                              | 94.5 | 82.0   | 60.0   | 39.0   |
| 114                                                                                                   | 101           | 64.0                                              | 94.0 | 81.5   | 59.5   | 38.0   |
| 112                                                                                                   | 99            | 63.0                                              | 93.0 | 81.0   | 58.5   | 37.0   |
| 110                                                                                                   | 97            | 62.0                                              | 92.6 | 80.5   | 58.0   | 35.5   |
| 108                                                                                                   | 95            | 61.0                                              | 92.0 | ---    | 57.0   | 34.5   |
| 106                                                                                                   | 94            | 59.5                                              | 91.2 | 80.0   | 56.0   | 33.0   |
| 104                                                                                                   | 92            | 58.0                                              | 90.5 | 79.5   | 55.0   | 32.0   |
| 102                                                                                                   | 90            | 57.0                                              | 89.8 | 79.0   | 54.5   | 30.5   |
| 100                                                                                                   | 88            | 56.0                                              | 89.0 | 78.5   | 53.5   | 29.5   |
| 98                                                                                                    | 86            | 54.0                                              | 88.0 | 78.0   | 52.5   | 28.0   |
| 96                                                                                                    | 85            | 53.0                                              | 87.2 | 77.5   | 51.5   | 26.5   |
| 94                                                                                                    | 83            | 51.0                                              | 86.3 | 77.0   | 50.5   | 24.5   |
| 92                                                                                                    | 82            | 49.5                                              | 85.4 | 76.5   | 49.0   | 23.0   |
| 90                                                                                                    | 80            | 47.5                                              | 84.4 | 75.5   | 48.0   | 21.0   |
| 88                                                                                                    | 79            | 46.0                                              | 83.5 | 75.0   | 47.0   | 19.0   |
| 86                                                                                                    | 77            | 44.0                                              | 82.3 | 74.5   | 45.5   | 17.0   |
| 84                                                                                                    | 76            | 42.0                                              | 81.2 | 73.5   | 44.0   | 14.5   |

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR CARTRIDGE BRASS (70% COPPER - 30% ZINC ALLOY) (Continued) |               |                                                   |      |        |        |        |
|-------------------------------------------------------------------------------------------------------|---------------|---------------------------------------------------|------|--------|--------|--------|
| Vickers<br>HV                                                                                         | Brinell<br>HB | Rockwell Superficial Hardness Number <sup>a</sup> |      |        |        |        |
|                                                                                                       |               | HRB                                               | HRF  | HR15-T | HR30-T | HR45-T |
| 82                                                                                                    | 74            | 40.0                                              | 80.0 | 73.0   | 43.0   | 12.5   |
| 80                                                                                                    | 72            | 37.5                                              | 78.6 | 72.0   | 41.0   | 10.0   |
| 78                                                                                                    | 70            | 35.0                                              | 77.4 | 71.5   | 39.5   | 7.5    |
| 76                                                                                                    | 68            | 32.5                                              | 76.0 | 70.5   | 38.0   | 4.5    |
| 74                                                                                                    | 66            | 30.0                                              | 74.8 | 70.0   | 36.0   | 1.0    |
| 72                                                                                                    | 64            | 27.5                                              | 73.2 | 69.0   | 34.0   | ---    |
| 70                                                                                                    | 63            | 24.5                                              | 71.8 | 68.0   | 32.0   | ---    |
| 68                                                                                                    | 62            | 21.5                                              | 70.0 | 67.0   | 30.0   | ---    |
| 66                                                                                                    | 61            | 18.5                                              | 68.5 | 66.0   | 28.0   | ---    |
| 64                                                                                                    | 59            | 15.5                                              | 66.8 | 65.0   | 25.5   | ---    |
| 62                                                                                                    | 57            | 12.5                                              | 65.0 | 63.5   | 23.0   | ---    |
| 60                                                                                                    | 55            | 10.0                                              | 62.5 | 62.5   | ---    | ---    |
| 58                                                                                                    | 53            | ---                                               | 61.0 | 61.0   | 18.0   | ---    |
| 56                                                                                                    | 52            | ---                                               | 58.8 | 60.0   | 15.0   | ---    |
| 54                                                                                                    | 50            | ---                                               | 56.5 | 58.5   | 12.0   | ---    |
| 52                                                                                                    | 48            | ---                                               | 53.5 | 57.0   | ---    | ---    |
| 50                                                                                                    | 47            | ---                                               | 50.5 | 55.5   | ---    | ---    |
| 49                                                                                                    | 46            | ---                                               | 49.0 | 54.5   | ---    | ---    |
| 48                                                                                                    | 45            | ---                                               | 47.0 | 53.5   | ---    | ---    |
| 47                                                                                                    | 44            | ---                                               | 45.0 | ---    | ---    | ---    |
| 46                                                                                                    | 43            | ---                                               | 43.0 | ---    | ---    | ---    |
| 45                                                                                                    | 42            | ---                                               | 40.0 | ---    | ---    | ---    |

a. B Scale - 100-kgf load,  $\frac{1}{16}$  in. (1.588 mm) ball; F Scale - 60-kgf load,  $\frac{1}{16}$  in. (1.588 mm) ball; 15-T Scale - 15-kgf load,  $\frac{1}{16}$  in. (1.588 mm) ball; 30-T Scale - 30-kgf load,  $\frac{1}{16}$  in. (1.588 mm) ball; 45-T Scale - 45-kgf load,  $\frac{1}{16}$  in. (1.588 mm) ball.

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR COPPER, No. 102 to 142 Inclusive |           |          |           |                                      |                     |                     |                     |                     |
|------------------------------------------------------------------------------|-----------|----------|-----------|--------------------------------------|---------------------|---------------------|---------------------|---------------------|
| Vickers                                                                      |           | Knoop    |           | Rockwell Hardness Superficial Number |                     |                     |                     |                     |
| HV 1-kgf                                                                     | HV 100-gf | HK 1-kgf | HK 500-gf | HR15-T <sup>a</sup>                  | HR15-T <sup>b</sup> | HR15-T <sup>c</sup> | HR30-T <sup>c</sup> | HR45-T <sup>c</sup> |
| 130                                                                          | 127.0     | 138.7    | 133.8     | ---                                  | 85.0                | ---                 | 69.5                | 49.0                |
| 128                                                                          | 125.2     | 126.8    | 132.1     | 83.0                                 | 84.5                | 87.0                | 68.5                | 48.0                |
| 126                                                                          | 123.6     | 134.9    | 130.4     | ---                                  | 84.0                | ---                 | 67.5                | 46.5                |
| 124                                                                          | 121.9     | 133.0    | 128.7     | 82.5                                 | 83.5                | 86.0                | 66.5                | 45.0                |
| 122                                                                          | 121.1     | 131.0    | 127.0     | ---                                  | 83.0                | 85.5                | 66.0                | 44.0                |
| 120                                                                          | 118.5     | 129.0    | 125.2     | 82.0                                 | 82.5                | ---                 | 65.0                | 42.5                |
| 118                                                                          | 116.8     | 127.1    | 123.5     | 81.5                                 | ---                 | 85.0                | 64.0                | 41.0                |
| 116                                                                          | 115.0     | 125.1    | 121.7     | ---                                  | 82.0                | ---                 | 63.0                | 40.0                |
| 114                                                                          | 113.5     | 123.2    | 119.9     | 81.0                                 | 81.5                | 84.5                | 62.0                | 38.5                |
| 112                                                                          | 111.8     | 121.4    | 118.1     | 80.5                                 | 81.0                | ---                 | 61.0                | 37.0                |
| 110                                                                          | 109.9     | 119.5    | 116.3     | 80.0                                 | ---                 | 84.0                | 60.0                | 36.0                |
| 108                                                                          | 108.3     | 117.5    | 114.5     | ---                                  | 80.5                | 83.5                | 59.0                | 34.5                |
| 106                                                                          | 106.6     | 115.6    | 112.6     | 79.5                                 | 80.0                | ---                 | 58.0                | 33.0                |
| 104                                                                          | 104.9     | 113.5    | 110.1     | 79.0                                 | 79.5                | 83.0                | 57.0                | 32.0                |
| 102                                                                          | 103.2     | 111.5    | 108.0     | 78.5                                 | 79.0                | 82.5                | 56.0                | 30.0                |
| 100                                                                          | 101.5     | 109.4    | 106.0     | 78.0                                 | 78.0                | 82.0                | 55.0                | 28.5                |
| 98                                                                           | 99.8      | 107.3    | 104.0     | 77.5                                 | 77.5                | 81.0                | 53.5                | 26.5                |
| 96                                                                           | 98.0      | 105.3    | 102.1     | 77.0                                 | 77.0                | 80.5                | 52.0                | 25.5                |
| 94                                                                           | 96.4      | 103.2    | 100.0     | 76.5                                 | 76.5                | 80.0                | 51.0                | 23.0                |
| 92                                                                           | 94.7      | 101.0    | 98.0      | 76.0                                 | 75.5                | 79.0                | 49.0                | 21.0                |
| 90                                                                           | 93.0      | 98.9     | 96.0      | 75.5                                 | 75.0                | 78.0                | 47.5                | 19.0                |
| 88                                                                           | 91.2      | 96.9     | 94.0      | 75.0                                 | 74.5                | 77.0                | 46.0                | 16.5                |
| 86                                                                           | 89.7      | 95.5     | 92.0      | 74.5                                 | 73.5                | 76.0                | 44.0                | 14.0                |
| 84                                                                           | 87.9      | 92.3     | 90.0      | 74.0                                 | 73.0                | 75.0                | 43.0                | 12.0                |
| 82                                                                           | 86.1      | 90.1     | 87.9      | 73.5                                 | 72.0                | 74.5                | 41.0                | 9.5                 |

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR COPPER, No. 102 to 142 Inclusive (Continued) |           |          |           |                                      |                     |                     |                     |                     |
|------------------------------------------------------------------------------------------|-----------|----------|-----------|--------------------------------------|---------------------|---------------------|---------------------|---------------------|
| Vickers                                                                                  |           | Knoop    |           | Rockwell Hardness Superficial Number |                     |                     |                     |                     |
| HV 1-kgf                                                                                 | HV 100-gf | HK 1-kgf | HK 500-gf | HR15-T <sup>a</sup>                  | HR15-T <sup>b</sup> | HR15-T <sup>c</sup> | HR30-T <sup>c</sup> | HR45-T <sup>c</sup> |
| 80                                                                                       | 84.5      | 87.9     | 86.0      | 72.5                                 | 71.0                | 73.5                | 39.5                | 7.0                 |
| 78                                                                                       | 82.8      | 85.7     | 84.0      | 72.0                                 | 70.0                | 72.5                | 36.0                | 2.0                 |
| 76                                                                                       | 81.0      | 83.5     | 81.9      | 71.5                                 | 69.5                | 71.5                | 36.0                | 2.0                 |
| 74                                                                                       | 79.2      | 81.1     | 79.9      | 71.0                                 | 68.5                | 70.0                | 34.0                | ---                 |
| 72                                                                                       | 77.6      | 78.9     | 78.7      | 70.0                                 | 67.5                | 69.0                | 32.0                | ---                 |
| 70                                                                                       | 75.8      | 76.8     | 76.6      | 69.5                                 | 66.5                | 67.5                | 30.0                | ---                 |
| 68                                                                                       | 74.3      | 74.1     | 74.4      | 69.0                                 | 65.5                | 66.0                | 28.0                | ---                 |
| 66                                                                                       | 72.6      | 71.9     | 71.9      | 68.0                                 | 64.5                | 64.5                | 25.5                | ---                 |
| 64                                                                                       | 70.9      | 69.5     | 70.0      | 67.5                                 | 63.5                | 63.5                | 23.5                | ---                 |
| 62                                                                                       | 69.1      | 67.0     | 67.9      | 66.5                                 | 62.0                | 61.0                | 21.0                | ---                 |
| 60                                                                                       | 67.5      | 64.6     | 65.9      | 66.0                                 | 61.0                | 59.0                | 18.0                | ---                 |
| 58                                                                                       | 65.8      | 62.0     | 63.8      | 65.0                                 | 60.0                | 57.0                | 15.5                | ---                 |
| 56                                                                                       | 64.0      | 59.8     | 61.8      | 64.5                                 | 58.5                | 55.0                | 13.0                | ---                 |
| 54                                                                                       | 62.3      | 57.4     | 59.5      | 63.5                                 | 57.5                | 53.0                | 10.0                | ---                 |
| 52                                                                                       | 60.7      | 55.0     | 57.2      | 63.0                                 | 56.0                | 51.5                | 7.5                 | ---                 |
| 50                                                                                       | 58.9      | 52.8     | 55.0      | 62.0                                 | 55.0                | 49.5                | 4.5                 | ---                 |
| 48                                                                                       | 57.3      | 50.3     | 52.7      | 61.0                                 | 53.5                | 47.5                | 1.5                 | ---                 |
| 46                                                                                       | 55.8      | 48.0     | 50.2      | 60.5                                 | 52.0                | 45.0                | ---                 | ---                 |
| 44                                                                                       | 53.9      | 45.9     | 47.8      | 59.5                                 | 51.0                | 43.0                | ---                 | ---                 |
| 42                                                                                       | 52.2      | 43.7     | 45.2      | 58.5                                 | 49.5                | 41.0                | ---                 | ---                 |
| 40                                                                                       | 51.3      | 40.2     | 42.8      | 57.5                                 | 48.0                | 38.5                | ---                 | ---                 |

a. Strip 0.010 in. (0.25 mm).

b. Strip 0.020 in. (0.51 mm).

c. Strip 0.040 in. (1 mm) and greater. Rockwell superficial hardness: 15-T Scale - 15-kgf load,  $\frac{1}{16}$  in. (1.588 mm) ball; 30-T Scale - 30-kgf load,  $\frac{1}{16}$  in. (1.588 mm) ball; 45-T Scale - 45-kgf load,  $\frac{1}{16}$  in. (1.588 mm) ball.

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR COPPER, No. 102 to 142 Inclusive |           |          |           |                         |                        |                       |      |
|------------------------------------------------------------------------------|-----------|----------|-----------|-------------------------|------------------------|-----------------------|------|
| Vickers                                                                      |           | Knoop    |           | Brinell                 |                        | Rockwell <sup>c</sup> |      |
| HV 1-kgf                                                                     | HV 100-gf | HK 1-kgf | HK 500-gf | HB 500-kgf <sup>a</sup> | HB 20-kgf <sup>b</sup> | HRB                   | HRF  |
| 130                                                                          | 127.0     | 138.7    | 133.8     | ---                     | 119.0                  | 67.0                  | 99.0 |
| 128                                                                          | 125.2     | 126.8    | 132.1     | ---                     | 117.5                  | 66.0                  | 98.0 |
| 126                                                                          | 123.6     | 134.9    | 130.4     | 120.0                   | 115.0                  | 65.0                  | 97.0 |
| 124                                                                          | 121.9     | 133.0    | 128.7     | 117.5                   | 113.0                  | 64.0                  | 96.0 |
| 122                                                                          | 121.1     | 131.0    | 127.0     | 115.0                   | 111.0                  | 62.5                  | 95.5 |
| 120                                                                          | 118.5     | 129.0    | 125.2     | 112.0                   | 109.0                  | 61.0                  | 95.0 |
| 118                                                                          | 116.8     | 127.1    | 123.5     | 110.0                   | 107.5                  | 59.5                  | 94.0 |
| 116                                                                          | 115.0     | 125.1    | 121.7     | 107.0                   | 105.5                  | 58.5                  | 93.0 |
| 114                                                                          | 113.5     | 123.2    | 119.9     | 105.0                   | 103.5                  | 57.0                  | 92.5 |
| 112                                                                          | 111.8     | 121.4    | 118.1     | 102.0                   | 102.0                  | 55.0                  | 91.5 |
| 110                                                                          | 109.9     | 119.5    | 116.3     | 99.5                    | 100.0                  | 53.5                  | 91.0 |
| 108                                                                          | 108.3     | 117.5    | 114.5     | 97.0                    | 98.0                   | 52.0                  | 90.5 |
| 106                                                                          | 106.6     | 115.6    | 112.6     | 94.5                    | 96.0                   | 50.0                  | 89.5 |
| 104                                                                          | 104.9     | 113.5    | 110.1     | 92.0                    | 94.0                   | 48.0                  | 88.5 |
| 102                                                                          | 103.2     | 111.5    | 108.0     | 89.5                    | 92.0                   | 46.5                  | 87.5 |
| 100                                                                          | 101.5     | 109.4    | 106.0     | 87.0                    | 90.0                   | 44.5                  | 87.0 |
| 98                                                                           | 99.8      | 107.3    | 104.0     | 84.5                    | 88.0                   | 42.0                  | 85.5 |
| 96                                                                           | 98.0      | 105.3    | 102.1     | 82.0                    | 86.5                   | 40.0                  | 84.5 |
| 94                                                                           | 96.4      | 103.2    | 100.0     | 79.5                    | 85.0                   | 38.0                  | 83.0 |
| 92                                                                           | 94.7      | 101.0    | 98.0      | 77.0                    | 83.0                   | 35.5                  | 82.0 |
| 90                                                                           | 93.0      | 98.9     | 96.0      | 74.5                    | 81.0                   | 33.0                  | 81.0 |
| 88                                                                           | 91.2      | 96.9     | 94.0      | ---                     | 79.0                   | 30.5                  | 79.5 |
| 86                                                                           | 89.7      | 95.5     | 92.0      | ---                     | 77.0                   | 28.0                  | 78.0 |
| 84                                                                           | 87.9      | 92.3     | 90.0      | ---                     | 75.0                   | 25.5                  | 76.5 |
| 82                                                                           | 86.1      | 90.1     | 87.9      | ---                     | 73.0                   | 23.0                  | 74.5 |



| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR COPPER, No. 102 to 142 Inclusive (Continued) |           |          |           |                         |                        |                       |      |
|------------------------------------------------------------------------------------------|-----------|----------|-----------|-------------------------|------------------------|-----------------------|------|
| Vickers                                                                                  |           | Knoop    |           | Brinell                 |                        | Rockwell <sup>c</sup> |      |
| HV 1-kgf                                                                                 | HV 100-gf | HK 1-kgf | HK 500-gf | HB 500-kgf <sup>a</sup> | HB 20-kgf <sup>b</sup> | HRB                   | HRF  |
| 80                                                                                       | 84.5      | 87.9     | 86.0      | ---                     | 71.5                   | 20.0                  | 73.0 |
| 78                                                                                       | 82.8      | 85.7     | 84.0      | ---                     | 69.5                   | 17.0                  | 71.0 |
| 76                                                                                       | 81.0      | 83.5     | 81.9      | ---                     | 67.5                   | 14.5                  | 69.0 |
| 74                                                                                       | 79.2      | 81.1     | 79.9      | ---                     | 66.0                   | 11.5                  | 67.5 |
| 72                                                                                       | 77.6      | 78.9     | 78.7      | ---                     | 64.0                   | 8.5                   | 66.0 |
| 70                                                                                       | 75.8      | 76.8     | 76.6      | ---                     | 62.0                   | 5.0                   | 64.0 |
| 68                                                                                       | 74.3      | 74.1     | 74.4      | ---                     | 60.5                   | 2.0                   | 62.0 |
| 66                                                                                       | 72.6      | 71.9     | 71.9      | ---                     | 58.5                   | ---                   | 60.0 |
| 64                                                                                       | 70.9      | 69.5     | 70.0      | ---                     | 57.0                   | ---                   | 58.0 |
| 62                                                                                       | 69.1      | 67.0     | 67.9      | ---                     | 55.0                   | ---                   | 56.0 |
| 60                                                                                       | 67.5      | 64.6     | 65.9      | ---                     | 53.0                   | ---                   | 54.0 |
| 58                                                                                       | 65.8      | 62.0     | 63.8      | ---                     | 51.5                   | ---                   | 51.5 |
| 56                                                                                       | 64.0      | 59.8     | 61.8      | ---                     | 49.5                   | ---                   | 49.0 |
| 54                                                                                       | 62.3      | 57.4     | 59.5      | ---                     | 48.0                   | ---                   | 47.0 |
| 52                                                                                       | 60.7      | 55.0     | 57.2      | ---                     | 46.5                   | ---                   | 44.0 |
| 50                                                                                       | 58.9      | 52.8     | 55.0      | ---                     | 44.5                   | ---                   | 41.5 |
| 48                                                                                       | 57.3      | 50.3     | 52.7      | ---                     | 42.0                   | ---                   | 39.0 |
| 46                                                                                       | 55.8      | 48.0     | 50.2      | ---                     | 41.0                   | ---                   | 36.0 |
| 44                                                                                       | 53.9      | 45.9     | 47.8      | ---                     | ---                    | ---                   | 33.5 |
| 42                                                                                       | 52.2      | 43.7     | 45.2      | ---                     | ---                    | ---                   | 30.5 |
| 40                                                                                       | 51.3      | 40.2     | 42.8      | ---                     | ---                    | ---                   | 28.0 |

a. Strip 0.080 in. (2.03 mm), 10 mm diameter ball.

b. Strip 0.040 in. (1 mm), 2 mm ball.

c. Strip 0.040 in. (1 mm) and greater. Rockwell hardness: HRB - 100-kgf load, 1/16 in. (1.588 mm) ball; HRF - 60-kgf load, 1/16 in. (1.588 mm) ball.

| APPROXIMATE HARDNESS CONVERSION NUMBERS FOR WROUGHT ALUMINUM PRODUCTS |                      |                       |     |     |                                   |        |        |
|-----------------------------------------------------------------------|----------------------|-----------------------|-----|-----|-----------------------------------|--------|--------|
| Brinell<br>HB 500-kgf                                                 | Vickers<br>HV 15-kgf | Rockwell <sup>a</sup> |     |     | Rockwell Superficial <sup>b</sup> |        |        |
|                                                                       |                      | HRB                   | HRE | HRH | HR15-T                            | HR30-T | HR15-H |
| 160                                                                   | 189                  | 91                    | --- | --- | 89                                | 77     | 95     |
| 155                                                                   | 183                  | 90                    | --- | --- | 89                                | 76     | 95     |
| 150                                                                   | 177                  | 89                    | --- | --- | 89                                | 75     | 94     |
| 145                                                                   | 171                  | 87                    | --- | --- | 88                                | 74     | 94     |
| 140                                                                   | 165                  | 86                    | --- | --- | 88                                | 73     | 94     |
| 135                                                                   | 159                  | 84                    | --- | --- | 87                                | 71     | 93     |
| 130                                                                   | 153                  | 81                    | --- | --- | 87                                | 70     | 93     |
| 125                                                                   | 147                  | 79                    | --- | --- | 86                                | 68     | 92     |
| 120                                                                   | 141                  | 76                    | 101 | --- | 86                                | 67     | 92     |
| 115                                                                   | 135                  | 72                    | 100 | --- | 86                                | 65     | 91     |
| 110                                                                   | 129                  | 69                    | 99  | --- | 85                                | 63     | 91     |
| 105                                                                   | 123                  | 65                    | 98  | --- | 84                                | 61     | 91     |
| 100                                                                   | 117                  | 60                    | --- | --- | 83                                | 59     | 90     |
| 95                                                                    | 111                  | 56                    | 96  | --- | 82                                | 57     | 90     |
| 90                                                                    | 105                  | 51                    | 94  | 108 | 81                                | 54     | 89     |
| 85                                                                    | 98                   | 46                    | 91  | 107 | 80                                | 52     | 89     |
| 80                                                                    | 92                   | 40                    | 88  | 106 | 78                                | 50     | 88     |
| 75                                                                    | 86                   | 34                    | 84  | 104 | 76                                | 47     | 87     |
| 70                                                                    | 80                   | 28                    | 80  | 102 | 74                                | 44     | 86     |
| 65                                                                    | 74                   | ---                   | 75  | 100 | 72                                | ---    | 85     |
| 60                                                                    | 68                   | ---                   | 70  | 97  | 70                                | ---    | 83     |
| 55                                                                    | 62                   | ---                   | 65  | 94  | 67                                | ---    | 82     |
| 50                                                                    | 56                   | ---                   | 59  | 91  | 64                                | ---    | 80     |
| 45                                                                    | 50                   | ---                   | 53  | 87  | 62                                | ---    | 79     |
| 40                                                                    | 44                   | ---                   | 46  | 83  | 59                                | ---    | 77     |

**APPROXIMATE HARDNESS CONVERSION NUMBERS FOR WROUGHT ALUMINUM PRODUCTS (Continued)**

- a. Rockwell hardness: B Scale - 100-kgf load,  $\frac{1}{16}$  in. (1.588 mm) ball; E Scale - 100-kgf load,  $\frac{1}{8}$  in. (3.175 mm) ball; H Scale - 60-kgf  $\frac{1}{8}$  in. (3.175 mm) ball.
- b. Rockwell superficial hardness: 15-T Scale - 15-kgf load,  $\frac{1}{16}$  in. (1.588 mm) ball; 30-T Scale - 30-kgf load,  $\frac{1}{16}$  in. (1.588 mm) ball; 15-H Scale - 15-kgf load,  $\frac{1}{8}$  in. (3.175 mm) ball.

# **Appendix**

# **2**

## ***METRIC CONVERSIONS***

| <b>METRIC CONVERSION FACTORS</b>                |                   |                    |                                                |                   |                    |
|-------------------------------------------------|-------------------|--------------------|------------------------------------------------|-------------------|--------------------|
| <b>To Convert From</b>                          | <b>To</b>         | <b>Multiply By</b> | <b>To Convert From</b>                         | <b>To</b>         | <b>Multiply By</b> |
| <b>Angle</b>                                    |                   |                    | <b>Mass per unit length</b>                    |                   |                    |
| degree                                          | rad               | 1.745 329 E -02    | lb/ft                                          | kg/m              | 1.488 164 E + 00   |
| <b>Area</b>                                     |                   |                    | lb/ft                                          | kg/m              | 1.785 797 E + 01   |
| in. <sup>2</sup>                                | mm <sup>2</sup>   | 6.451 600 E + 02   | <b>Mass per unit time</b>                      |                   |                    |
| in. <sup>2</sup>                                | cm <sup>2</sup>   | 6.451 600 E + 00   | lb/h                                           | kg/s              | 1.259 979 E - 04   |
| in. <sup>2</sup>                                | m <sup>2</sup>    | 6.451 600 E - 04   | lb/min                                         | kg/s              | 7.559 873 E - 03   |
| ft <sup>2</sup>                                 | m <sup>2</sup>    | 9.290 304 E - 02   | lb/s                                           | kg/s              | 4.535 924 E - 01   |
| <b>Bending moment or torque</b>                 |                   |                    | <b>Mass per unit volume (includes density)</b> |                   |                    |
| lbf - in.                                       | N - m             | 1.129 848 E - 01   | g/cm <sup>3</sup>                              | kg/m <sup>3</sup> | 1.000 000 E + 03   |
| lbf - ft                                        | N - m             | 1.355 818 E + 00   | lb/ft <sup>3</sup>                             | g/cm <sup>3</sup> | 1.601 846 E - 02   |
| kgf - m                                         | N - m             | 9.806 650 E + 00   | lb/ft <sup>3</sup>                             | kg/m <sup>3</sup> | 1.601 846 E + 01   |
| ozf - in.                                       | N-m               | 7.061 552 E - 03   | lb/in. <sup>3</sup>                            | g/cm <sup>3</sup> | 2.767 990 E + 01   |
| <b>Bending moment or torque per unit length</b> |                   |                    | lb/in. <sup>3</sup>                            | kg/m <sup>3</sup> | 2.767 990 E + 04   |
| lbf - in./in.                                   | N - m/m           | 4.448 222 E + 00   | <b>Power</b>                                   |                   |                    |
| lbf - ft/in.                                    | N - m/m           | 5.337 866 E + 01   | Btu/s                                          | kW                | 1.055 056 E + 00   |
| <b>Corrosion rate</b>                           |                   |                    | Btu/min                                        | kW                | 1.758 426 E - 02   |
| mils/yr                                         | mm/yr             | 2.540 000 E - 02   | Btu/h                                          | W                 | 2.928 751 E - 01   |
| mils/yr                                         | μ/yr              | 2.540 000 E + 01   | erg/s                                          | W                 | 1.000 000 E - 07   |
| <b>Current density</b>                          |                   |                    | ft - lbf/s                                     | W                 | 1.355 818 E + 00   |
| A/in. <sup>2</sup>                              | A/cm <sup>2</sup> | 1.550 003 E - 01   | ft - lbf/min                                   | W                 | 2.259 697 E - 02   |
| A/in. <sup>2</sup>                              | A/mm <sup>2</sup> | 1.550 003 E - 03   | ft - lbf/h                                     | W                 | 3.766 161 E - 04   |
| A/ft <sup>2</sup>                               | A/m <sup>2</sup>  | 1.076 400 E + 01   | hp (550 ft - lbf/s)                            | kW                | 7.456 999 E - 01   |
| <b>Electricity and magnetism</b>                |                   |                    | hp (electric)                                  | kW                | 7.460 000 E - 01   |
| gauss                                           | T                 | 1.000 000 E - 04   |                                                |                   |                    |

| <b>METRIC CONVERSION FACTORS (Continued)</b> |           |                    |                                     |                  |                    |
|----------------------------------------------|-----------|--------------------|-------------------------------------|------------------|--------------------|
| <b>To Convert From</b>                       | <b>To</b> | <b>Multiply By</b> | <b>To Convert From</b>              | <b>To</b>        | <b>Multiply By</b> |
| <b>Electricity and magnetism (Continued)</b> |           |                    | <b>Power density</b>                |                  |                    |
| maxwell                                      | μWb       | 1.000 000 E - 02   | W/in. <sup>2</sup>                  | W/m <sup>2</sup> | 1.550 003 E + 03   |
| mho                                          | S         | 1.000 000 E + 00   | <b>Pressure (fluid)</b>             |                  |                    |
| Oersted                                      | A/m       | 7.957 700 E + 01   | atm (standard)                      | Pa               | 1.013 250 E + 05   |
| Ω - cm                                       | Ω - m     | 1.000 000 E - 02   | bar                                 | Pa               | 1.000 000 E + 05   |
| Ω circular - mil/ft                          | μΩ - m    | 1.662 426 E - 03   | in. Hg (32°F)                       | Pa               | 3.386 380 E + 03   |
| <b>Energy (impact other)</b>                 |           |                    | in. Hg (60°F)                       | Pa               | 3.376 850 E + 03   |
| ft - lbf                                     | J         | 1.355 818 E + 00   | lbf/in. <sup>2</sup> (psi)          | Pa               | 6.894 757 E + 03   |
| Btu (thermochemical)                         | J         | 1.054 350 E + 03   | torr (mm Hg, 0°C)                   | Pa               | 1.333 220 E + 02   |
| cal (thermochemical)                         | J         | 4.184 000 E + 00   | <b>Specific heat</b>                |                  |                    |
| kW - h                                       | J         | 3.600 000 E + 06   | Btu/lb - °F                         | J/kg - K         | 4.186 800 E + 03   |
| W - h                                        | J         | 3.600 000 E + 03   | cal/g - °C                          | J/kg - K         | 4.186 800 E + 03   |
| <b>Flow rate</b>                             |           |                    | <b>Stress (force per unit area)</b> |                  |                    |
| ft <sup>3</sup> /h                           | L/min     | 4.719 475 E - 01   | tonf/in. <sup>2</sup> (tsi)         | MPa              | 1.378 951 E + 01   |
| ft <sup>3</sup> /min                         | L/min     | 2.831 000 E + 01   | kgf/mm <sup>2</sup>                 | MPa              | 9.806 650 E + 00   |
| gal/h                                        | L/min     | 6.309 020 E - 02   | ksi                                 | MPa              | 6.894 757 E + 00   |
| gal/min                                      | L/min     | 3.785 412 E + 00   | lbf/in. <sup>2</sup> (psi)          | MPa              | 6.894 757 E - 03   |
| <b>Force</b>                                 |           |                    | MN/m <sup>2</sup>                   | MPa              | 1.000 000 E + 00   |
| lbf                                          | N         | 4.448 222 E + 00   | <b>Temperature</b>                  |                  |                    |
| kip (1000 lbf)                               | N         | 4.448 222 E + 03   | °F                                  | °C               | 5/9 (°F - 32)      |
| tonf                                         | kN        | 8.896 443 E + 00   | R                                   | K                | 5/9                |
| kgf                                          | N         | 9.806 650 E + 00   | <b>Temperature interval</b>         |                  |                    |
|                                              |           |                    | °F                                  | °C               | 5/9                |
| <b>Force per unit length</b>                 |           |                    | <b>Thermal conductivity</b>         |                  |                    |
| lbf/ft                                       | N/m       | 1.459 390 E + 01   | Btu - in./s - ft <sup>2</sup> - °F  | W/m - K          | 5.192 204 E + 02   |
| lbf/in.                                      | N/m       | 1.751 268 E + 02   | Btu/ft - h - °F                     | W/m - K          | 1.730 735 E + 00   |

| <b>METRIC CONVERSION FACTORS (Continued)</b> |                      |                    |                                         |                    |                    |
|----------------------------------------------|----------------------|--------------------|-----------------------------------------|--------------------|--------------------|
| <b>To Convert From</b>                       | <b>To</b>            | <b>Multiply By</b> | <b>To Convert From</b>                  | <b>To</b>          | <b>Multiply By</b> |
| <b>Fracture toughness</b>                    |                      |                    | <b>Thermal conductivity (Continued)</b> |                    |                    |
| ksi √in.                                     | MPa √m               | 1.098 800 E + 00   | Btu - in./h . ft <sup>2</sup> - °F      | W/m - K            | 1.442 279 E - 01   |
| <b>Heat content</b>                          |                      |                    | cal/cm - s - °C                         | W/m - K            | 4.184 000 E + 02   |
| Btu/lb                                       | kJ/kg                | 2.326 000 E + 00   | <b>Thermal expansion</b>                |                    |                    |
| cal/g                                        | kJ/kg                | 4.186 800 E + 00   | in./in. - °C                            | m/m - K            | 1.000 000 E + 00   |
| <b>Heat input</b>                            |                      |                    | in./in. - °F                            | m/m - K            | 1.800 000 E + 00   |
| J/in.                                        | J/m                  | 3.937 008 E + 01   | <b>Velocity</b>                         |                    |                    |
| kJ/in.                                       | kJ/m                 | 3.937 008 E + 01   | ft/h                                    | m/s                | 8.466 667 E - 05   |
| <b>Length</b>                                |                      |                    | ft/min                                  | m/s                | 5.080 000 E - 03   |
| A                                            | nm                   | 1.000 000 E - 01   | ft/s                                    | m/s                | 3.048 000 E - 01   |
| μin.                                         | μm                   | 2.540 000 E - 02   | in./s                                   | m/s                | 2.540 000 E - 02   |
| mil                                          | μm                   | 2.540 000 E + 01   | km/h                                    | m/s                | 2.777 778 E - 01   |
| in.                                          | mm                   | 2.540 000 E + 01   | mph                                     | km/h               | 1.609 344 E + 00   |
| in.                                          | cm                   | 2.540 000 E + 00   | <b>Velocity of rotation</b>             |                    |                    |
| ft                                           | m                    | 3.048 000 E - 01   | rev/min (rpm)                           | rad/s              | 1.047 164 E - 01   |
| yd                                           | m                    | 9.144 000 E - 01   | rev/s                                   | rad/s              | 6.283 185 E + 00   |
| mile                                         | km                   | 1.609 300 E + 00   | <b>Viscosity</b>                        |                    |                    |
| <b>Mass</b>                                  |                      |                    | poise                                   | Pa - s             | 1.000 000 E - 01   |
| oz                                           | kg                   | 2.834 952 E - 02   | stokes                                  | m <sup>2</sup> /S  | 1.000 000 E - 04   |
| lb                                           | kg                   | 4.535 924 E - 01   | ft <sup>2</sup> /s                      | m <sup>2</sup> /s  | 9.290 304 E - 02   |
| ton (short 2000 lb)                          | kg                   | 9.071 847 E + 02   | in. <sup>2</sup> /s                     | mm <sup>2</sup> /s | 6.451 600 E + 02   |
| ton (short 2000 lb)                          | kg x 10 <sup>3</sup> | 9.071 847 E - 01   | <b>Volume</b>                           |                    |                    |
| ton (long 2240 lb)                           | kg                   | 1.016 047 E + 03   | in. <sup>3</sup>                        | m <sup>3</sup>     | 1.638 706 E - 05   |
| kg x 10 <sup>3</sup> = 1 metric ton          |                      |                    | ft <sup>3</sup>                         | m <sup>3</sup>     | 2.831 685 E - 02   |
|                                              |                      |                    | fluid oz                                | m <sup>3</sup>     | 2.957 353 E - 05   |

| <b>METRIC CONVERSION FACTORS (Continued)</b> |                   |                  |                             |                   |                  |
|----------------------------------------------|-------------------|------------------|-----------------------------|-------------------|------------------|
| To Convert From                              | To                | Multiply By      | To Convert From             | To                | Multiply By      |
|                                              |                   |                  | <b>Volume (Continued)</b>   |                   |                  |
|                                              |                   |                  | gal (U.S. liquid)           | m <sup>3</sup>    | 3.785 412 E - 03 |
| <b>Mass per unit area</b>                    |                   |                  | <b>Volume per unit time</b> |                   |                  |
| oz/in. <sup>2</sup>                          | kg/m <sup>2</sup> | 4.395 000 E + 01 | ft <sup>3</sup> /min        | m <sup>3</sup> /S | 4.719 474 E - 04 |
| oz/ft <sup>2</sup>                           | kg/m <sup>2</sup> | 3.051 517 E - 01 | ft <sup>3</sup> /S          | m <sup>3</sup> /s | 2.831 685 E - 02 |
| oz/yd <sup>2</sup>                           | kg/m <sup>2</sup> | 3.390 575 E - 02 | in. <sup>3</sup> /min       | m <sup>3</sup> /S | 2.731 177 E - 07 |
| lb/ft <sup>2</sup>                           | kg/m <sup>2</sup> | 4.882 428 E + 00 | <b>Wavelength</b>           |                   |                  |
|                                              |                   |                  | A                           | nm                | 1.000 000 E - 01 |

| <b>THE GREEK ALPHABET</b> |                |                |
|---------------------------|----------------|----------------|
| A, α - Alpha              | I, ι - Iota    | P, ρ - Rho     |
| B, β - Beta               | K, κ - Kappa   | Σ, σ - Sigma   |
| Γ, γ - Gamma              | Λ, λ - Lambda  | T, τ - Tau     |
| Δ, δ - Delta              | M, μ - Mu      | Υ, υ - Upsilon |
| E, ε - Epsilon            | N, ν - Nu      | Φ, φ - Phi     |
| Z, ζ - Zeta               | Ξ, ξ - Xi      | X, χ - Chi     |
| H, η - Eta                | O, ο - Omicron | Ψ, ψ - Psi     |
| Θ, θ - Theta              | Π, π - Pi      | Ω, ω - Omega   |



| <b>SI PREFIXES</b> |        |                        |                           |
|--------------------|--------|------------------------|---------------------------|
| Prefix             | Symbol | Exponential Expression | Multiplication Factor     |
| exa                | E      | $10^{18}$              | 1 000 000 000 000 000 000 |
| peta               | P      | $10^{15}$              | 1 000 000 000 000 000     |
| tera               | T      | $10^{12}$              | 1 000 000 000 000         |
| giga               | G      | $10^9$                 | 1 000 000 000             |
| mega               | M      | $10^6$                 | 1 000 000                 |
| kilo               | k      | $10^3$                 | 1 000                     |
| hecto              | h      | $10^2$                 | 100                       |
| deka               | da     | $10^1$                 | 10                        |
| Base Unit          | ---    | $10^0$                 | 1                         |
| deci               | d      | $10^{-1}$              | 0.1                       |
| centi              | c      | $10^{-2}$              | 0.01                      |
| milli              | m      | $10^{-3}$              | 0.001                     |
| micro              |        | $10^{-6}$              | 0.000 001                 |
| nano               | n      | $10^{-9}$              | 0.000 000 001             |
| pico               | p      | $10^{-12}$             | 0.000 000 000 001         |
| femto              | f      | $10^{-15}$             | 0.000 000 000 000 001     |
| atto               | a      | $10^{-18}$             | 0.000 000 000 000 000 001 |

# **Appendix**

# **3**

## ***IMPERIAL UNITS***

| <b>DECIMAL EQUIVALENT OF FRACTIONS</b> |                      |                        |
|----------------------------------------|----------------------|------------------------|
| <b>Fraction (in.)</b>                  | <b>Decimal (in.)</b> | <b>Millimeter (mm)</b> |
| $\frac{1}{64}$                         | 0.015 625            | 0.396 875              |
| $\frac{1}{32}$                         | 0.031 250            | 0.793 750              |
| $\frac{3}{64}$                         | 0.046 875            | 1.190 625              |
| $\frac{1}{16}$                         | 0.062 500            | 1.587 500              |
| $\frac{5}{64}$                         | 0.078 125            | 1.984 375              |
| $\frac{3}{32}$                         | 0.093 750            | 2.381 250              |
| $\frac{7}{64}$                         | 0.109 375            | 2.778 125              |
| $\frac{1}{8}$                          | 0.125 000            | 3.175 000              |
| $\frac{9}{64}$                         | 0.140 625            | 3.571 875              |
| $\frac{5}{32}$                         | 0.156 250            | 3.968 750              |
| $\frac{11}{64}$                        | 0.171 875            | 4.365 625              |
| $\frac{3}{16}$                         | 0.187 500            | 4.762 500              |
| $\frac{13}{64}$                        | 0.203 125            | 5.159 375              |
| $\frac{7}{32}$                         | 0.218 750            | 5.556 250              |
| $\frac{15}{64}$                        | 0.234 375            | 5.953 125              |
| $\frac{1}{4}$                          | 0.250 000            | 6.350 000              |
| $\frac{17}{64}$                        | 0.265 625            | 6.746 875              |
| $\frac{9}{32}$                         | 0.281 250            | 7.143 750              |
| $\frac{19}{64}$                        | 0.296 875            | 7.540 625              |
| $\frac{15}{16}$                        | 0.312 500            | 7.937 500              |
| $\frac{21}{64}$                        | 0.328 125            | 8.334 375              |
| $\frac{11}{32}$                        | 0.343 750            | 8.731 250              |
| $\frac{23}{64}$                        | 0.359 375            | 9.128 125              |
| $\frac{3}{8}$                          | 0.375 000            | 9.525 000              |
| $\frac{25}{64}$                        | 0.390 625            | 9.921 875              |
| $\frac{13}{32}$                        | 0.406 250            | 10.318 750             |
| $\frac{27}{64}$                        | 0.421 875            | 10.715 625             |

| <b>DECIMAL EQUIVALENT OF FRACTIONS (Continued)</b> |                      |                        |
|----------------------------------------------------|----------------------|------------------------|
| <b>Fraction (in.)</b>                              | <b>Decimal (in.)</b> | <b>Millimeter (mm)</b> |
| $\frac{7}{16}$                                     | 0.437 500            | 11.112 500             |
| $\frac{29}{64}$                                    | 0.453 125            | 11.509 375             |
| $\frac{15}{32}$                                    | 0.468 750            | 11.906 250             |
| $\frac{31}{64}$                                    | 0.484 375            | 12.303 125             |
| $\frac{1}{2}$                                      | 0.500 000            | 12.700 000             |
| $\frac{33}{64}$                                    | 0.515 625            | 13.096 875             |
| $\frac{17}{32}$                                    | 0.531 250            | 13.493 750             |
| $\frac{35}{64}$                                    | 0.546 875            | 13.890 625             |
| $\frac{9}{16}$                                     | 0.562 500            | 14.287 500             |
| $\frac{37}{64}$                                    | 0.578 125            | 14.684 375             |
| $\frac{19}{32}$                                    | 0.593 750            | 15.081 250             |
| $\frac{39}{64}$                                    | 0.609 375            | 15.478 125             |
| $\frac{5}{8}$                                      | 0.625 000            | 15.875 000             |
| $\frac{41}{64}$                                    | 0.640 625            | 16.271 875             |
| $\frac{21}{32}$                                    | 0.656 250            | 16.668 750             |
| $\frac{43}{64}$                                    | 0.671 875            | 17.065 625             |
| $\frac{11}{16}$                                    | 0.687 500            | 17.462 500             |
| $\frac{45}{64}$                                    | 0.703 125            | 17.859 375             |
| $\frac{23}{32}$                                    | 0.718 750            | 18.256 250             |
| $\frac{47}{64}$                                    | 0.734 375            | 18.653 125             |
| $\frac{3}{4}$                                      | 0.750 000            | 19.050 000             |
| $\frac{49}{64}$                                    | 0.765 625            | 19.446 875             |
| $\frac{25}{32}$                                    | 0.781 250            | 19.843 750             |
| $\frac{51}{64}$                                    | 0.796 875            | 20.240 625             |
| $\frac{13}{16}$                                    | 0.812 500            | 20.637 500             |
| $\frac{53}{64}$                                    | 0.828 125            | 21.034 375             |
| $\frac{27}{32}$                                    | 0.843 750            | 21.431 250             |

| <b>DECIMAL EQUIVALENT OF FRACTIONS (Continued)</b> |                      |                        |
|----------------------------------------------------|----------------------|------------------------|
| <b>Fraction (in.)</b>                              | <b>Decimal (in.)</b> | <b>Millimeter (mm)</b> |
| $\frac{55}{64}$                                    | 0.859 375            | 21.828 125             |
| $\frac{7}{8}$                                      | 0.875 000            | 22.225 000             |
| $\frac{57}{64}$                                    | 0.890 625            | 22.621 875             |
| $\frac{29}{32}$                                    | 0.906 250            | 23.018 750             |
| $\frac{59}{64}$                                    | 0.921 875            | 23.415 625             |
| $\frac{15}{16}$                                    | 0.937 500            | 23.812 500             |
| $\frac{61}{64}$                                    | 0.953 125            | 24.209 375             |
| $\frac{31}{32}$                                    | 0.968 750            | 24.606 250             |
| $\frac{63}{64}$                                    | 0.984 375            | 25.003 125             |
| 1                                                  | 1.000 000            | 25.400 000             |

# **Appendix**

# **4**

## ***PIPE DIMENSIONS***

| DIMENSIONS OF WELDED AND SEAMLESS PIPE |                     |                                 |                 |                |                |                |                      |                |
|----------------------------------------|---------------------|---------------------------------|-----------------|----------------|----------------|----------------|----------------------|----------------|
| Nominal<br>Pipe Size                   | Outside<br>Diameter | Nominal Wall Thickness (in) For |                 |                |                |                |                      |                |
|                                        |                     | Schedule<br>5S                  | Schedule<br>10S | Schedule<br>10 | Schedule<br>20 | Schedule<br>30 | Schedule<br>Standard | Schedule<br>40 |
| 1/8                                    | 0.405               | ---                             | 0.049           | ---            | ---            | ---            | 0.068                | 0.068          |
| 1/4                                    | 0.540               | ---                             | 0.065           | ---            | ---            | ---            | 0.088                | 0.088          |
| 3/8                                    | 0.675               | ---                             | 0.065           | ---            | ---            | ---            | 0.091                | 0.091          |
| 1/2                                    | 0.840               | 0.065                           | 0.083           | ---            | ---            | ---            | 0.109                | 0.109          |
| 3/4                                    | 1.050               | 0.065                           | 0.083           | ---            | ---            | ---            | 0.113                | 0.113          |
| 1                                      | 1.315               | 0.065                           | 0.109           | ---            | ---            | ---            | 0.133                | 0.133          |
| 1 1/4                                  | 1.660               | 0.065                           | 0.109           | ---            | ---            | ---            | 0.140                | 0.140          |
| 1 1/2                                  | 1.900               | 0.065                           | 0.109           | ---            | ---            | ---            | 0.145                | 0.145          |
| 2                                      | 2.375               | 0.065                           | 0.109           | ---            | ---            | ---            | 0.154                | 0.154          |
| 2 1/2                                  | 2.875               | 0.083                           | 0.120           | ---            | ---            | ---            | 0.203                | 0.203          |
| 3                                      | 3.5                 | 0.083                           | 0.120           | ---            | ---            | ---            | 0.216                | 0.216          |
| 3 1/2                                  | 4.0                 | 0.083                           | 0.120           | ---            | ---            | ---            | 0.226                | 0.226          |
| 4                                      | 4.5                 | 0.083                           | 0.120           | ---            | ---            | ---            | 0.237                | 0.237          |
| 5                                      | 5.563               | 0.109                           | 0.134           | ---            | ---            | ---            | 0.258                | 0.258          |
| 6                                      | 6.625               | 0.109                           | 0.134           | ---            | ---            | ---            | 0.280                | 0.280          |
| 8                                      | 8.625               | 0.109                           | 0.148           | ---            | 0.250          | 0.277          | 0.322                | 0.322          |
| 10                                     | 10.75               | 0.134                           | 0.165           | ---            | 0.250          | 0.307          | 0.365                | 0.365          |
| 12                                     | 12.75               | 0.156                           | 0.180           | ---            | 0.250          | 0.330          | 0.375                | 0.406          |
| 14 O.D.                                | 14.0                | 0.156                           | 0.188           | 0.250          | 0.312          | 0.375          | 0.375                | 0.438          |
| 16 O.D.                                | 16.0                | 0.165                           | 0.188           | 0.250          | 0.312          | 0.375          | 0.375                | 0.500          |
| 18 O.D.                                | 18.0                | 0.165                           | 0.188           | 0.250          | 0.312          | 0.438          | 0.375                | 0.562          |
| 20 O.D.                                | 20.0                | 0.188                           | 0.218           | 0.250          | 0.375          | 0.500          | 0.375                | 0.594          |
| 22 O.D.                                | 22.0                | 0.188                           | 0.218           | 0.250          | 0.375          | 0.500          | 0.375                | ---            |
| 24 O.D.                                | 24.0                | 0.218                           | 0.250           | 0.250          | 0.375          | 0.562          | 0.375                | 0.688          |
| 26 O.D.                                | 26.0                | ---                             | ---             | 0.312          | 0.500          | ---            | 0.375                | ---            |

| DIMENSIONS OF WELDED AND SEAMLESS PIPE (Continued) |                     |                                 |                 |                |                |                |                      |                |
|----------------------------------------------------|---------------------|---------------------------------|-----------------|----------------|----------------|----------------|----------------------|----------------|
| Nominal<br>Pipe Size                               | Outside<br>Diameter | Nominal Wall Thickness (in) For |                 |                |                |                |                      |                |
|                                                    |                     | Schedule<br>5S                  | Schedule<br>10S | Schedule<br>10 | Schedule<br>20 | Schedule<br>30 | Schedule<br>Standard | Schedule<br>40 |
| 28 O.D.                                            | 28.0                | ---                             | ---             | 0.312          | 0.500          | 0.625          | 0.375                | ---            |
| 30 O.D.                                            | 30.0                | 0.250                           | 0.312           | 0.312          | 0.500          | 0.625          | 0.375                | ---            |
| 32 O.D.                                            | 32.0                | ---                             | ---             | 0.312          | 0.500          | 0.625          | 0.375                | 0.688          |
| 34 O.D.                                            | 34.0                | ---                             | ---             | 0.312          | 0.500          | 0.625          | 0.375                | 0.688          |
| 36 O.D.                                            | 36.0                | ---                             | ---             | 0.312          | 0.500          | 0.625          | 0.375                | 0.750          |
| 42 O.D.                                            | 42.0                | ---                             | ---             | ---            | ---            | ---            | 0.375                | ---            |

See next page for heavier wall thicknesses; all units are inches.

| DIMENSIONS OF WELDED AND SEAMLESS PIPE |                     |                                 |                 |                |                 |                 |                 |                 |              |
|----------------------------------------|---------------------|---------------------------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|--------------|
| Nominal<br>Pipe<br>Size                | Outside<br>Diameter | Nominal Wall Thickness (in) For |                 |                |                 |                 |                 |                 |              |
|                                        |                     | Schedule<br>60                  | Extra<br>Strong | Schedule<br>80 | Schedule<br>100 | Schedule<br>120 | Schedule<br>140 | Schedule<br>160 | XX<br>Strong |
| 1/8                                    | 0.405               | ---                             | 0.095           | 0.095          | ---             | ---             | ---             | ---             | ---          |
| 1/4                                    | 0.540               | ---                             | 0.119           | 0.119          | ---             | ---             | ---             | ---             | ---          |
| 3/8                                    | 0.675               | ---                             | 0.126           | 0.126          | ---             | ---             | ---             | ---             | ---          |
| 1/2                                    | 0.840               | ---                             | 0.147           | 0.147          | ---             | ---             | ---             | 0.188           | 0.294        |
| 3/4                                    | 1.050               | ---                             | 0.154           | 0.154          | ---             | ---             | ---             | 0.219           | 0.308        |
| 1                                      | 1.315               | ---                             | 0.179           | 0.179          | ---             | ---             | ---             | 0.250           | 0.358        |
| 1 1/4                                  | 1.660               | ---                             | 0.191           | 0.191          | ---             | ---             | ---             | 0.250           | 0.382        |
| 1 1/2                                  | 1.900               | ---                             | 0.200           | 0.200          | ---             | ---             | ---             | 0.281           | 0.400        |
| 2                                      | 2.375               | ---                             | 0.218           | 0.218          | ---             | ---             | ---             | 0.344           | 0.436        |
| 2 1/2                                  | 2.875               | ---                             | 0.276           | 0.276          | ---             | ---             | ---             | 0.375           | 0.552        |
| 3                                      | 3.5                 | ---                             | 0.300           | 0.300          | ---             | ---             | ---             | 0.438           | 0.600        |
| 3 1/2                                  | 4.0                 | ---                             | 0.318           | 0.318          | ---             | ---             | ---             | ---             | ---          |



| DIMENSIONS OF WELDED AND SEAMLESS PIPE (Continued) |                     |                                 |                 |                |                 |                 |                 |                 |              |
|----------------------------------------------------|---------------------|---------------------------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|--------------|
| Nominal<br>Pipe<br>Size                            | Outside<br>Diameter | Nominal Wall Thickness (in) For |                 |                |                 |                 |                 |                 |              |
|                                                    |                     | Schedule<br>60                  | Extra<br>Strong | Schedule<br>80 | Schedule<br>100 | Schedule<br>120 | Schedule<br>140 | Schedule<br>160 | XX<br>Strong |
| 4                                                  | 4.5                 | ---                             | 0.337           | 0.337          | ---             | 0.438           | ---             | 0.531           | 0.674        |
| 5                                                  | 5.563               | ---                             | 0.375           | 0.375          | ---             | 0.500           | ---             | 0.625           | 0.750        |
| 6                                                  | 6.625               | ---                             | 0.432           | 0.432          | ---             | 0.562           | ---             | 0.719           | 0.864        |
| 8                                                  | 8.625               | 0.406                           | 0.500           | 0.500          | 0.594           | 0.719           | 0.812           | 0.906           | 0.875        |
| 10                                                 | 10.75               | 0.500                           | 0.500           | 0.594          | 0.719           | 0.844           | 1.000           | 1.125           | 1.000        |
| 12                                                 | 12.75               | 0.562                           | 0.500           | 0.688          | 0.844           | 1.000           | 1.125           | 1.312           | 1.000        |
| 14 O.D.                                            | 14.0                | 0.594                           | 0.500           | 0.750          | 0.938           | 1.094           | 1.250           | 1.406           | ---          |
| 16 O.D.                                            | 16.0                | 0.656                           | 0.500           | 0.844          | 1.031           | 1.219           | 1.438           | 1.594           | ---          |
| 18 O.D.                                            | 18.0                | 0.750                           | 0.500           | 0.938          | 1.156           | 1.375           | 1.562           | 1.781           | ---          |
| 20 O.D.                                            | 20.0                | 0.812                           | 0.500           | 1.031          | 1.281           | 1.500           | 1.750           | 1.969           | ---          |
| 22 O.D.                                            | 22.0                | 0.875                           | 0.500           | 1.125          | 1.375           | 1.625           | 1.875           | 2.125           | ---          |
| 24 O.D.                                            | 24.0                | 0.969                           | 0.500           | 1.218          | 1.531           | 1.812           | 2.062           | 2.344           | ---          |
| 26 O.D.                                            | 26.0                | ---                             | 0.500           | ---            | ---             | ---             | ---             | ---             | ---          |
| 28 O.D.                                            | 28.0                | ---                             | 0.500           | ---            | ---             | ---             | ---             | ---             | ---          |
| 30 O.D.                                            | 30.0                | ---                             | 0.500           | ---            | ---             | ---             | ---             | ---             | ---          |
| 32 O.D.                                            | 32.0                | ---                             | 0.500           | ---            | ---             | ---             | ---             | ---             | ---          |
| 34 O.D.                                            | 34.0                | ---                             | 0.500           | ---            | ---             | ---             | ---             | ---             | ---          |
| 36 O.D.                                            | 36.0                | ---                             | 0.500           | ---            | ---             | ---             | ---             | ---             | ---          |
| 42 O.D.                                            | 42.0                | ---                             | 0.500           | ---            | ---             | ---             | ---             | ---             | ---          |

All units are inches.

# Appendix

# 5

## ***PERIODIC TABLE***

Periodic Table of the Elements

| Metals                          |                                 |                                  |                                |                                 |                               |                                 |                                |                                 |                                |                                  |                                |                                |                                |                                 |                                | Nonmetals                       |                                | Orbit  |
|---------------------------------|---------------------------------|----------------------------------|--------------------------------|---------------------------------|-------------------------------|---------------------------------|--------------------------------|---------------------------------|--------------------------------|----------------------------------|--------------------------------|--------------------------------|--------------------------------|---------------------------------|--------------------------------|---------------------------------|--------------------------------|--------|
| I <sup>a</sup>                  | II <sup>a</sup>                 | III <sup>b</sup>                 | IV <sup>b</sup>                | V <sup>b</sup>                  | VI <sup>b</sup>               | VII <sup>b</sup>                | VIII                           |                                 |                                | I <sup>b</sup>                   | II <sup>b</sup>                | III <sup>a</sup>               | IV <sup>a</sup>                | V <sup>a</sup>                  | VI <sup>a</sup>                | VII <sup>a</sup>                | 0                              |        |
| 1<br>H<br>1.0079<br>1           |                                 |                                  |                                |                                 |                               |                                 |                                |                                 |                                |                                  |                                |                                |                                |                                 |                                |                                 | 2<br>He<br>4.00260<br>2        | K      |
| 3<br>Li<br>6.939<br>2-1         | 4<br>Be<br>9.0122<br>2-2        |                                  |                                |                                 |                               |                                 |                                |                                 |                                |                                  |                                | 5<br>B<br>10.81<br>2-3         | 6<br>C<br>12.011<br>2-4        | 7<br>N<br>14.0067<br>2-5        | 8<br>O<br>15.9994<br>2-6       | 9<br>F<br>18.998403<br>2-7      | 10<br>Ne<br>10.179<br>2-8      | K-L    |
| 11<br>Na<br>22.9898<br>2-8-1    | 12<br>Mg<br>24.312<br>2-8-2     |                                  |                                |                                 |                               |                                 |                                |                                 |                                |                                  |                                | 13<br>Al<br>26.98154<br>2-8-3  | 14<br>Si<br>28.08<br>2-8-4     | 15<br>P<br>30.97376<br>2-8-5    | 16<br>S<br>32.06<br>2-8-6      | 17<br>Cl<br>35.453<br>2-8-7     | 18<br>Ar<br>39.948<br>2-8-8    | K-L-M  |
| Transition Elements             |                                 |                                  |                                |                                 |                               |                                 |                                |                                 |                                |                                  |                                |                                |                                |                                 |                                |                                 |                                |        |
| 19<br>K<br>39.09<br>-8-8-1      | 20<br>Ca<br>40.08<br>-8-8-2     | 21<br>Sc<br>44.9559<br>-8-9-2    | 22<br>Ti<br>47.9<br>-8-10-2    | 23<br>V<br>50.941<br>-8-11-2    | 24<br>Cr<br>51.996<br>-8-13-1 | 25<br>Mn<br>54.9380<br>-8-13-2  | 26<br>Fe<br>55.847<br>-8-14-2  | 27<br>Co<br>58.9332<br>-8-15-2  | 28<br>Ni<br>58.71<br>-8-16-2   | 29<br>Cu<br>63.54<br>-8-18-1     | 30<br>Zn<br>65.38<br>-8-18-2   | 31<br>Ga<br>69.72<br>-8-18-3   | 32<br>Ge<br>72.59<br>-8-18-4   | 33<br>As<br>74.9216<br>-8-18-5  | 34<br>Se<br>78.96<br>-8-18-6   | 35<br>Br<br>79.904<br>-8-18-7   | 36<br>Kr<br>83.80<br>-8-18-8   | -L-M-N |
| 37<br>Rb<br>85.467<br>-18-8-1   | 38<br>Sr<br>87.62<br>-18-8-2    | 39<br>Y<br>88.9059<br>-18-9-2    | 40<br>Zr<br>91.22<br>-18-10-2  | 41<br>Nb<br>92.9064<br>-18-12-1 | 42<br>Mo<br>95.94<br>-18-13-1 | 43<br>Tc<br>98.9062<br>-18-13-2 | 44<br>Ru<br>101.07<br>-18-15-1 | 45<br>Rh<br>102.905<br>-18-16-1 | 46<br>Pd<br>106.4<br>-18-18-0  | 47<br>Ag<br>107.868<br>-18-18-1  | 48<br>Cd<br>112.40<br>-18-18-2 | 49<br>In<br>114.82<br>-18-18-3 | 50<br>Sn<br>118.69<br>-18-18-4 | 51<br>Sb<br>121.75<br>-18-18-5  | 52<br>Te<br>127.60<br>-18-18-6 | 53<br>I<br>126.9045<br>-18-18-7 | 54<br>Xe<br>131.30<br>-18-18-8 | -M-N-O |
| 55<br>Cs<br>132.9054<br>-18-8-1 | 56<br>Ba<br>137.3<br>-18-8-2    | 57*<br>La<br>138.9055<br>-18-9-2 | 72<br>Hf<br>178.49<br>-32-10-2 | 73<br>Ta<br>180.948<br>-32-11-2 | 74<br>W<br>183.85<br>-32-12-2 | 75<br>Re<br>186.207<br>-32-13-2 | 76<br>Os<br>190.2<br>-32-14-2  | 77<br>Ir<br>192.9<br>-32-15-2   | 78<br>Pt<br>195.09<br>-32-16-2 | 79<br>Au<br>196.9665<br>-32-18-1 | 80<br>Hg<br>200.59<br>-32-18-2 | 81<br>Tl<br>204.37<br>-32-19-3 | 82<br>Pb<br>207.19<br>-32-18-4 | 83<br>Bi<br>208.980<br>-32-18-5 | 84<br>Po<br>(209)<br>-32-18-6  | 85<br>At<br>(210)<br>-32-18-7   | 86<br>Rn<br>(222)<br>-32-18-8  | -N-O-P |
| 87<br>Fr<br>(223)<br>-18-8-1    | 88<br>Ra<br>226.0254<br>-18-8-2 | 89**<br>Ac<br>(227)<br>-18-9-2   | 104<br>Rf<br>(261)<br>-32-10-2 | 105<br>Ha<br>(262)<br>-32-11-2  | 106<br>(263)<br>-32-12-2      |                                 |                                |                                 |                                |                                  |                                |                                |                                |                                 |                                |                                 |                                | -O-P-Q |

Key to chart

Atomic Number → 50    +2    ← Oxidation States  
 Symbol → Sn    +4  
 Atomic Weight → 118.69  
 -18-18-4    ← Electron Configuration

## ***INTERNATIONAL STANDARDS ORGANIZATIONS, TECHNICAL ASSOCIATIONS & SOCIETIES***

### **International Standards Organizations**

|         |                                                                                                                               |
|---------|-------------------------------------------------------------------------------------------------------------------------------|
| AENOR   | Asoiación Española de Normalización y Cetificación (Spain)<br>tel +34 1 310 48 51, fax +34 1 310 49 76                        |
| AFNOR   | Association Française de Normalisation (France)<br>tel +33 1 42 91 55 55, fax +33 1 42 91 56 56                               |
| ANSI    | American National Standards Institute (USA)<br>tel +212 642 4900, fax +212 302 1286                                           |
| BSI     | British Standards Institution (England)<br>tel +44 181 996 70 00, fax +44 181 996 70 01                                       |
| CSA     | Canadian Standards Association (Canada)<br>tel +416 747 4044, fax +416 747 2475                                               |
| CSCE    | Canadian Society for Chemical Engineers (613) 526-4652                                                                        |
| DIN     | Deutches Institut für Normung e.V. (Germany)<br>tel +49 30 26 01 2260, fax +49 30 2601 1231                                   |
| DS      | Dansk Standard (Denmark)<br>tel +45 39 77 01 01, fax +45 39 77 02 02                                                          |
| ELOT    | Hellenic Organization for Standardization (Greece)<br>tel +30 1 201 50 25, fax +30 1 202 07 76                                |
| IBN/BIN | Institut Belge de Normalisation/Belgisch Instituut voor<br>Normalisatie (Belgium)<br>tel +32 2 738 01 11, fax +32 2 733 42 64 |
| IPQ     | Instituto Português da Qualidade (Potugal)<br>tel +351 1 294 81 00, fax +351 1 294 81 01                                      |
| ISO     | International Organization for Standardization (Switzerland)<br>tel +41 22 749 01 11, fax +41 22 733 34 30                    |

**International Standards Organizations (Continued)**

|      |                                                                                              |
|------|----------------------------------------------------------------------------------------------|
| ITM  | Inspection du Travail et des Mines (Luxembourg)<br>tel +352 478 61 54, fax +352 49 14 47     |
| JSA  | Japanese Standards Association (Japan)<br>tel +03 3583 8074, fax + 033582 2390               |
| NNI  | Nederlands NormalisatieInstituut (Netherlands)<br>tel +31 15 69 03 90, fax +31 15 69 01 90   |
| NSAI | National Standards Authority of Ireland<br>tel +353 1 837 01 01, fax +353 1 836 98 21        |
| NFS  | Norges Standardiseringsforbund (Norway)<br>tel +47 22 46 60 94, fax +47 22 46 44 57          |
| ON   | Österreichisches Normungsintitut (Austria)<br>tel +43 1 213 00, fax +43 1 213 00 650         |
| SA   | Standards Australia<br>tel +08 373 1540, fax +08 373 1051                                    |
| SCC  | Standards Council of Canada<br>tel +800 267 8220, fax +613 995 4564                          |
| SIS  | Standardiseringskommissionen i Sverige (Sweden)<br>tel +46 8 613 52 00, fax +46 8 411 70 35  |
| SFS  | Suomen Standardisoimisliitto r.y. (Finland)<br>tel +358 0 149 93 31, fax +358 0 146 49 25    |
| SNV  | Schweizerische Normen-Vereinigung (Switzerland)<br>tel +41 1 254 54 54, fax +41 1 254 54 74  |
| STRI | Technological Institute of Iceland<br>tel +354 587 70 02, fax +354 587 74 09                 |
| UNI  | Ente Nazionale Italiano di Unificazione (Italy)<br>tel +39 2 70 02 41, fax +39 2 70 10 61 06 |

**Technical Associations & Societies<sup>a</sup>**

|       |                                                                                           |
|-------|-------------------------------------------------------------------------------------------|
| AA    | The Aluminum Association (202) 862-5100                                                   |
| AEE   | The Association of Energy Engineers (404) 447-5083                                        |
| AFS   | American Foundrymen's Society (312) 824-0181                                              |
| AISI  | Association of Iron and Steel Engineers (412) 281-6323                                    |
| AIChE | American Institute of Chemical Engineers (212) 705-7338                                   |
| AMEC  | Advanced Materials Engineering Centre (902) 425-4500                                      |
| ASEE  | American Society for Engineering Education (202) 331-3500                                 |
| ASM   | ASM International - The Materials Information Society<br>(800) 336-5152 or (216) 338-5151 |
| ASME  | American Society of Mechanical Engineers (212) 705-7722                                   |
| ASNT  | American Society for Nondestructive Testing (614) 274-6003                                |
| ASQC  | American Society for Quality Control (414) 272-8575                                       |
| ASTM  | American Society for Testing and Materials (215) 299-5400                                 |

**Technical Associations & Societies<sup>a</sup> (Continued)**

|        |                                                                                                                    |
|--------|--------------------------------------------------------------------------------------------------------------------|
| AWS    | American Welding Society (305) 443-9353 or (800) 443-9353                                                          |
| CAIMF  | Canadian Advanced Industrial Materials Forum<br>(416) 798-8055                                                     |
| CASI   | Canadian Aeronautic & Space Institute (613) 234-0191                                                               |
| CCA    | Canadian Construction Association (613) 236-9455                                                                   |
| CCPE   | Canadian Council of Professional Engineers (613) 232-2474                                                          |
| CCS    | Canadian Ceramics Society (416) 491-2886                                                                           |
| CDA    | Copper Development Association (212) 251-7200                                                                      |
| CEN    | European Committee for Standardization<br>+32 2 550 08 11                                                          |
| CIE    | Canadian Institute of Energy (403) 262-6969                                                                        |
| CIM    | Canadian Institute for Mining and Metallurgy (514) 939-2710                                                        |
| CMA    | Canadian Manufacturing Association (416) 363-7261                                                                  |
| CNS    | Canadian Nuclear Society (416) 977-6152                                                                            |
| CPI    | Canadian Plastics Institute (416) 441-3222                                                                         |
| CPIC   | Canadian Professional Information Centre (905) 624-1058                                                            |
| CSEE   | Canadian Society of Electronic Engineers (514) 651-6710                                                            |
| CSME   | Canadian Society of Mechanical Engineers (514) 842-8121                                                            |
| CSNDT  | Canadian Society for Nondestructive Testing (416) 676-0785                                                         |
| El     | Engineering Information Inc. (212) 705-7600                                                                        |
| FED    | Federal & Military Standards (215) 697-2000                                                                        |
| IEEE   | Institute of Electrical & Electronic Engineers (212) 705-7900                                                      |
| IES    | Institute of Environmental Sciences (312) 255-1561                                                                 |
| IIE    | Institute of Industrial Engineers (404) 449-0460                                                                   |
| IMMS   | International Material Management Society (705) 525-4667                                                           |
| ISA    | Instrument Society of America (919) 549-8411                                                                       |
| ISA    | Instrument Society of America (919) 549-8411                                                                       |
| ISS    | Iron and Steel Society (412) 776-1535                                                                              |
| ITI    | International Technology Institute (412) 795-5300                                                                  |
| ITRI   | International Tin Research Institute (614) 424-6200                                                                |
| MSS    | Manufactures Standardization Society of Valves & Fittings<br>Industry (703) 281-6613                               |
| MTS    | Marine Technology Society (202) 775-5966                                                                           |
| NACE   | National Association of Corrosion Engineers (713) 492-0535                                                         |
| NAPE   | National Association of Power Engineers (212) 298-0600                                                             |
| NAPEGG | Association of Professional Engineers, Geologists and<br>Geophysicists of the Northwest Territories (403) 920-4055 |
| NiDI   | Nickel Development Institute (416) 591-7999                                                                        |
| PIA    | Plastics Institute of America (201) 420-5553                                                                       |
| RIA    | Robotic Industries Association (313) 994-6088                                                                      |
| SAE    | Society of Automotive Engineers (412) 776-4841                                                                     |
| SAME   | Society of American Military Engineers (703) 549-3800                                                              |

**Technical Associations & Societies<sup>a</sup> (Continued)**

|       |                                                                                    |
|-------|------------------------------------------------------------------------------------|
| SAMPE | Society for the Advancement of Materials and Processing Engineering (818) 331-0616 |
| SCC   | Standards Council of Canada (800) 267-8220                                         |
| SCTE  | Society of Carbide & Tool Engineers (216) 338 5151                                 |
| SDCE  | Society of Die Casting Engineers (312) 452-0700                                    |
| SME   | Society of Manufacturing Engineers (313) 271-1500                                  |
| SPE   | Society of Petroleum Engineers (214) 669-3377                                      |
| SSIUS | Specialty Steel Industry of the United States<br>(202) 342-8630                    |
| SSPC  | Steel Structures Painting Council (412) 268-3327                                   |
| STC   | Society for Technical Communications (202) 737-0035                                |
| STLE  | Society of Tribologists and Lubrication Engineers<br>(312) 825-5536                |
| TDA   | Titanium Development Association (303) 443-7515                                    |
| TMS   | The Minerals, Metals, and Materials Society (412) 776-9000                         |
| WIC   | Welding Institute of Canada (905) 257-9881                                         |

a. Telephone numbers only.

# **Appendix**

# **7**

## ***TRADE NAMES & TRADEMARKS***



| <b>TRADEMARK</b>                        | <b>COMPANY</b>                        |
|-----------------------------------------|---------------------------------------|
| <b>ALCOA</b>                            | <b>Aluminum Company of America</b>    |
| <b>AL 6XN, AL 6X</b>                    | <b>Allegheny Ludlum Corp</b>          |
| <b>ALUMEL</b>                           | <b>Hoskins Manufacturing Co.</b>      |
| <b>ARMCO 20-45-5</b>                    | <b>Armco Steel Corp.</b>              |
| <b>CARPENTER, 20Cb3, 20Mo6</b>          | <b>Carpenter Technology Corp.</b>     |
| <b>PYROMET</b>                          | <b>Carpenter Technology Corp.</b>     |
| <b>CHROMEL</b>                          | <b>Hoskin Manufacturing Co.</b>       |
| <b>COLMONOY</b>                         | <b>Wall Colmonoy Corp.</b>            |
| <b>CREUSOT UR SB 8</b>                  | <b>Creusot-Loire</b>                  |
| <b>DURATHERM</b>                        | <b>Vacuumschmelze GmbH</b>            |
| <b>EATONITE</b>                         | <b>Eaton Corp.</b>                    |
| <b>ELGILOY</b>                          | <b>Elgiloy Limited Partnership</b>    |
| <b>EVERDUR</b>                          | <b>Anaconda Co.</b>                   |
| <b>HASTELLOY, HAYNES, 242, 214, 230</b> | <b>Haynes International Inc.</b>      |
| <b>230W, 556, B-3, C-22, G-30, G-50</b> | <b>Haynes International Inc.</b>      |
| <b>H-9M, HR-120, HR-160</b>             | <b>Haynes International Inc.</b>      |
| <b>HAVAR</b>                            | <b>Hamilton Technology Inc.</b>       |
| <b>IN-100, IN-102, RENE 41</b>          | <b>Cannon-Muskegon Corp.</b>          |
| <b>INCO, INCOLOY, INCONEL, NIMONIC</b>  | <b>Inco Alloys International Inc.</b> |
| <b>MAR-M Alloy</b>                      | <b>Martin-Marietta Corp.</b>          |
| <b>NICHROME</b>                         | <b>Harrison Alloys</b>                |
| <b>RA330, RA330-04, RA-333</b>          | <b>Rolled Alloys Inc.</b>             |
| <b>SANICRO 28</b>                       | <b>Sandvik Steel Corp.</b>            |
| <b>SM-2060</b>                          | <b>Svenska Metallverken A.B.</b>      |
| <b>STELLITE, TRIBALLOY</b>              | <b>Stoody Deloro Stellite Inc.</b>    |
| <b>TPM</b>                              | <b>American Manufacture</b>           |
| <b>UDIMET</b>                           | <b>Specialty Metals inc.</b>          |
| <b>VITALIUM</b>                         | <b>Howmet Corp.</b>                   |
| <b>WASPALOY</b>                         | <b>United Technologies</b>            |

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# USING ACROBAT® READER WITH SEARCH

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Working with Large Pages (Hand Tool)

Choosing a Page Layout for Scrolling Ease

A rectangular button with a 3D effect, featuring a black background and the text "Main Menu" in white, bold, sans-serif font.A rectangular button with a 3D effect, featuring a black background and the text "Next Page" in white, bold, sans-serif font.

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# Navigating

## Tool Bar Icons (Continued)



Use the **Zoom** tools to magnify and reduce the page display by a factor of 2.



This function is not available with this CD-ROM.



The **Browse** icons (arrows) with the vertical line, advances the document to the first or last page of a document, whereas the browse icons without vertical lines move the document forward or back one page at a time.



Use the **Go Back** and **Go Forward** icons to retrace your steps in a document, moving to each view in the order visited. Go Back also returns you to the original document after you click a link to another document.



Click the **Actual Size** icon to display the page at 100 percent.

## Tool Bar Icons (Continued)



Click the **Fit Page** icon to scale the page to fit within the window.



Click the **Fit Width** icon to scale the page width to fill the width of the window.



The **Find** tool searches for part of a word, a complete word, or multiple words in a document.



The **Search** tool searches indexed PDF documents for single words, phrases, parts of words, or combinations of words.



The **Search/Results** tool displays the results of your cross document search.

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## Paging Through a Document

Acrobat Reader provides a number of ways to page through a document.

### Go to the Next Page

Choose one of the following:

- Click the **Next Page** button ► in the tool bar.
- Press the **Right Arrow** or **Down Arrow**.
- Choose *View, Next Page*.

### Return to the Previous Page

Choose one of the following:

- Click the **Previous Page** button ◀ in the tool bar.
- Press the **Left Arrow** or **Up Arrow**.
- Choose *View, Previous Page*.

A rectangular button with a 3D effect, containing the text "Main Menu".A rectangular button with a 3D effect, containing the text "Using Acrobat Reader".A rectangular button with a 3D effect, containing the text "Next Page".

## Move One Screenful at a Time

- Press the **PageDown** key, **Enter**, or **Return** to move forward.
- Press the **PageUp** key, **Shift+ Enter**, or **Shift+ Return** to go back. Use the horizontal scroll bar in the status bar to scroll the page right or left.

## Browsing with Thumbnails

A thumbnail is a miniature view of each document page which you can display in the overview area. You can use a thumbnail to jump quickly to a page and to adjust the view of the current page.

## Jump to a Page Using its Thumbnail

Click the **Thumbnails and Page** button  or choose *View, Thumbnails and Page* to display thumbnail images. Click a thumbnail to move to the page it represents. The point you click determines the center of the page display.

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## Browsing with Bookmarks

Bookmarks can mark parts of a document for quick access.

### Jump to a Topic by its Bookmark

1. Click the **Bookmarks and Page** button  or choose *View, Bookmarks and Page* to display bookmarks in the overview area. If a triangle appears to the left of the bookmark, click the triangle to show or hide subordinate bookmarks.
2. To go to the destination specified by a bookmark, click the bookmark text or double-click the page icon to the left of the bookmark name. A bookmark can also change the page view, play a movie, reset a form, or perform other actions.

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## Following Links

Links can connect parts of a document, jump to other PDF documents, open another application file, play a movie or sound, enter an article, hide or show an annotation, import form data, and reset or submit a form.

1. Move the pointer over a linked area. The pointer changes to a pointing finger  when positioned over a link.
2. Click to follow the link. Clicking a link can also change the page view, play a movie, reset a form, or perform other actions.

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## Retracing Your Steps

The **Go Back** button traces your viewing path through a document or series of documents. You can go back up to 64 views. **Go Back** will reopen closed documents if necessary.

### Retrace Your Viewing Path

- Click the **Go Back** button ◀ or choose *View, Go Back* to return to the previous page, document, or magnification level.
- Click the **Go Forward** button ▶ or choose *View, Go Forward* to reverse direction and return, one view at a time, to the view where you first used *Go Back*.



## Magnifying the Page View

You can use the **Zoom** tool, the **Magnification Box** in the status bar, or the **Actual Size**, **Fit Page**, and **Fit Width** tool bar buttons to change the screen magnification. The maximum magnification level is 800%. The minimum magnification level is 12%. If you zoom in on a large document, use the hand tool to move the page around on-screen or in a thumbnail . Acrobat Reader also offers magnification level choices that are not related to a specific percentage, but to the look of the page on-screen:

- **Fit Page**  scales the page to fit within the main window.
- **Fit Width**  scales the page to fit the width of the main window.
- **Fit Visible** fills the window with the page's imaged area only (text and graphics).

## Magnifying the Page View (Continued)

When you select any of the **Fit** options, the magnification level resulting from the selection is displayed in the status bar.

The Fit options, **Fit Page**, **Fit Width**, and **Fit Visible**, are in a *sticky state*, which means they don't change as you page through a document unless you change the zoom level.

### Increase Magnification

Choose one of the following:

- Select the **Zoom** tool  and click on the document page to double the current magnification.
- Select the **Zoom** tool  and drag to draw a rectangle, called a *marquee*, around the area you want to magnify.
- Click the **magnification box** in the status bar, and choose a magnification level. If you choose **Zoom To**, type in the magnification level and click *OK*.

## Decrease Magnification

Choose one of the following:

- Select the **Zoom** tool  while holding down Ctrl (Windows and UNIX) or Option (Macintosh), and click at the center of the area you want to reduce.
- Select the **Zoom** tool  while holding down Ctrl (Windows and UNIX) or Option (Macintosh), and drag to draw a rectangle, called a marquee , around the area you want to reduce.
- Click the **Magnification Box** in the status bar, and choose a magnification level. If you choose **Zoom To**, type in the magnification level and click *OK*.

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## Working with Large Page Sizes

If you need to magnify a page to a size larger than the Reader window, you can use the **Hand** tool to move the page around so that you can view all the areas on it. Moving a page around with the **Hand** tool is like moving a piece of paper around on a desk with your hand.

A rectangular button with a 3D effect, featuring a dark gray border and a lighter gray background. The text "Main Menu" is written in a bold, black, sans-serif font.A rectangular button with a 3D effect, featuring a dark gray border and a lighter gray background. The text "Using Acrobat Reader" is written in a bold, black, sans-serif font.A rectangular button with a 3D effect, featuring a dark gray border and a lighter gray background. The text "Next Page" is written in a bold, black, sans-serif font.

## Choosing a Page Layout for Scrolling Ease

Acrobat Reader has three page layout options: Single Page, Continuous, and Continuous-Facing Pages. Continuous and Continuous-Facing Pages facilitate page scrolling so that you can see the bottom of one page and the top of another.

- **Single Page layout** displays one page in the document window at a time.
- **Continuous layout** arranges the pages in a continuous vertical column.
- **Continuous-Facing Pages layout** arranges the pages to appear side by side. This configuration accommodates two-page spread display and multiple-page viewing in the viewer window. If the total page count of a document is greater than two pages, the first page is displayed on the right to ensure proper display of two-page spreads. To see two-page spreads most efficiently in this page layout, choose *View, Fit Width*.



## Choosing a Page Layout for Scrolling Ease (Continued)

Choose one of the following:

- Click the **Page Size Box** in the status bar, and choose one of the page layouts from the menu.
- Choose *Single Page*, *Continuous*, or *Continuous-Facing Pages* from the *View* menu.



## **Search**

Use the Search command to perform full-text searches of indexed PDF document collections.

The Search command has powerful tools for limiting and expanding the definition of the term you are searching for.

A full-text index is a searchable database of all text in a document or collection of documents. Searches of full-text indexes are very quick.

The Find command works with a single document and reads every word on every page, and is slower than the Search command.

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# Searching

## Perform a Full-Text Search

1. From the Main Menu click on Search, or at any time from the menu bar you may choose *Tools, Search, Query* or click the *Search Query* button  on the tool bar to open the Search window. Type the text you want to find in the *Find Results Containing Text* box, and click *Search*. The text can be a single word, a number, a term, or a phrase. When you click *Search*, the Search window is hidden, however, the search results can be seen by clicking on the  icon located on the tool bar. The Search Results window displays the number of hits for the search.

2. Use the *Search Next* button  and *Search Previous* button  to go to other matches in the document. Alternatively, redefine the query by typing new text or by using other techniques to expand the search to more documents or to limit the search to fewer hits. If you want to do this without having to redisplay the Search windows, change the default preference that hides it “on view.”

## Defining Search Queries

You can search for a word, a number, a term, or a phrase made up of several terms. You can also use the other techniques listed below to define a search query.

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## Searching for a Term or Phrase

To find matches for a single term, type the term in the text box labeled *Find Results Containing Text* and click *Search*. The term can be a word, a word with wild-card characters, or any combination of letters, numbers, and symbols.

- If the phrase includes the word *and*, *or*, or *not* used in its ordinary sense (not as a Boolean operator), put the phrase in quotes. The search phrase “*rock or mineral*” finds all occurrences of the phrase *rock or mineral*, not all occurrences of *rock* and all occurrences of *mineral* as it would without the quotes.
- If the phrase includes punctuation (other than the apostrophe) or special characters such as @ and \*, they are ignored. For example, either of the terms *up-todate*, *up to date* finds all occurrences of both *up-to-date* and *up to date*.

## Expanding a Search

If a search returns too few hits or no hits at all, make sure you are searching the appropriate key words. Also, make sure that settings left over from a previous search aren't limiting the current one.

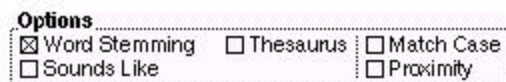
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# Using Search Options

## Query Techniques

- The **Word Stemming** option finds words that share a stem with a search word.
- The **Sounds Like** option finds different spellings of proper names.
- The **Thesaurus** option finds words that have meanings similar to the meaning of a search word.
- **Match Case** finds text only when it has the same capitalization as the text you type.
- **Proximity** limits AND searches so that words must be within three pages of each other.
- **Boolean OR, AND, NOT** operators between key words can narrow or expand searches.
- Using **Operator Names** and **Symbols Literally**
- **Wild-card** characters, such as \* or ?, in the search text increase the number of matches for the text.

The options in the Search window expand or limit the results of searches with single terms and phrases and with Boolean expressions. All options are initially disabled in the window by default.



The **Word Stemming**, **Thesaurus**, and **Sounds Like** options expand searches. (Before you perform a search with one of these options, you can see the effects of using it with the **Word Assistant**.)

The **Match Case** and **Proximity** options limit searches.





## Word Stemming Option

The **Word Stemming** option expands the search by finding words that share a word stem with the search word you type.

**Example:** with Word Stemming selected, searching for *engineering* finds *engineer* and *engineers* as well as *engineering*.

Before searching with the **Word Stemming** option, consider using the **Word Assistant** to see whether the option would find too many irrelevant words to be practical.

The Word Stemming option:

- Applies to single words, not phrases.
- Does not apply to words that contain wild-card characters.
- Finds words that end in **ing**, **ed**, **s**, **ion**, and so on (but not **er**).
- Cannot be used with the **Match Case** option.

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## Sounds Like Option

The **Sounds Like** option expands the search for a proper name by finding words that begin with the same letter as a search word and that share some phonetic feature with it.

**Example:** with Sounds Like selected, searching for *color* also finds *colour* and *colore*.

Searching for *color* with the **Sounds Like** option also finds *clear* and *chaleur*. Before searching with the option, try using the **Word Assistant** to see whether the option will find relevant words.

The Sounds Like option:

- Applies to single words, not phrases.
- Does not apply to words that contain wild-card characters.
- Cannot be used with the **Match Case** option.

## Thesaurus Option

The **Thesaurus** option expands the search by finding words with meanings similar to the meaning of the search word.

**Example:** with **Thesaurus** selected, searching for *begin* finds *start*.

Searching for *begin* with the **Thesaurus** option also finds *attack* and *produce*. Before searching with the option, try using the **Word Assistant** to see whether the option will find relevant words.

The Thesaurus option:

- Applies to single words, not phrases.
- Does not apply to words that contain wild-card characters.
- Cannot be used with the **Match Case** option.
- Finds only the similar words that appear in the documents you are searching, not all the similar words you might find in a complete Thesaurus.

## Match Case Option

The **Match Case** option limits the results of the search by finding only those documents that contain words with the same capitalization as the search word or phrase you type.

**Example:** with Match Case selected, searching for *Metal* finds all occurrences of *Metal*, but not occurrences of *metal*.

You can use the **Match Case** option with a Boolean expression or with terms that use wild-card characters. Characters matched by wild-card characters can be either uppercase or lowercase. You cannot use the **Match Case** option with the **Word Stemming**, **Thesaurus**, or **Sounds Like** option.

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## Proximity Option

The **Proximity** option limits the results of simple AND searches to one pair of matches closest together. The two matches must be within three pages or fewer of each other. The option is useful for locating a search that concentrates on some topic of interest.

**Example:** searching for information about *arc welding* with *arc* AND *welding* would be less likely to locate information about *mig welding* or *circle arcs* if the **Proximity** option was used.

**Proximity** will not work with complex AND searches, for example, *welding* AND (*arc* OR *mig*).

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## Searching with Boolean AND

Use AND to find two or more search terms.

**Example:** *installation AND instructions*  
finds only those hits that contain both  
*installation* and *instructions*.

You can also use the ampersand (&) to specify an AND search.

**Example:** *installation & instructions*.

Choosing the **Proximity** option changes the way AND searches work. Without the **Proximity** option, items in an AND search can be anywhere in a document.

With the **Proximity** option, items in an AND search must be within three pages of each other to be found.

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## Searching with Boolean OR

Use OR to find hits containing any of two or more search terms.

**Example:** *metal* OR *alloy* finds all hits that contain either or both *metal* and *alloy*.

You can also use a comma (,) or a vertical bar (|) to separate items in an OR search.

**Example:** *metal, alloy* and *metal | alloy*.

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## Combining Boolean Operators

Be careful when combining operators to build Boolean expressions because it is easy to build an expression that does not mean what you think it means.

When you combine AND and OR in the same expression, AND is evaluated before OR.

**Example:** *alloy OR metallurgy AND stainless* finds all documents that contain *alloy* or that contain both *metallurgy* and *stainless*.

You can use parentheses to change the default order of evaluation for Boolean operators.

**Example:** *(alloy OR metallurgy) AND stainless* finds all documents that contain either *alloy* and *stainless* or that contain *metallurgy* and *stainless*. Parentheses can be nested, i.e., parentheses can be placed within parentheses.



## Using Operator Names and Symbols Literally

When you use a literal phrase that contains an operator name, a symbol for an operator name (such as & for AND), or parentheses, the phrase must be enclosed in quotation marks.

**Example:** “*salt and rock*” finds all hits that contain the phrase *salt and rock*, not all hits that contain either the word *salt* or the word *rock*. The phrase *salt & rock* also needs quotes to be interpreted literally.

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## Searching with Wild-Card Characters

You can use **wild-card** characters to find words that contain a word fragment or all the terms that match a character pattern:

- \* asterisk, matches zero, one, or more characters
- ? question mark, matches any one character

You can use wild-card characters in a term that is part of a Boolean expression. You cannot use wild cards to represent separator characters such as the hyphen (-) and the slash (/).

### Examples:

geo\* matches geodesic, Geoffrey, and geothermal

\*tic matches austenitic and ferritic

?ight matches light and might but not bright

S3???? matches all six-digit alphanumerical sets with the S3 prefix, e.g., S30403, S30400

pr?m\* matches prime, primary, and primed

## Limiting a Search

If a search returns too many hits or provides too many matches in individual searches, try any of these query techniques:

- A **Boolean AND operator** between two words returns only hits containing both words.
- The **Proximity** option limits AND searches so that words must be close to each other – within three pages or fewer.
- The **Match Case** option finds text only when it has the same capitalization as the text you type.

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## Word Assistant

Use the **Word Assistant** to build a list of terms that will appear when the search of a document uses the **Sounds Like**, **Word Stemming**, or **Thesaurus** option. The list will show you whether the option you are using is likely to be helpful in the search. If the list is too long or full of irrelevant words, you can quickly construct a list of words to find with the option turned off by copying words from the **Word Assistant** dialog box and pasting them into the Search window.

Look up the effects of a search option on a search word:

1. Choose *Tools, Search, Word Assistant*.
2. Enter the search word in the **Word text** box.
3. Select the **Search** option from the **Assist** menu.
4. Click on **Look Up**. All the words that will be found in a search for this word with this option are listed.

## Word Assistant (Continued)

Search with words copied from the Word Assistant dialog box:

1. If the **Search** window is closed, click the **Search Query** button  on the tool bar to open it.
2. Use the **Word Assistant** to look up the effects of a search option on a search word and to display a list of related words.
3. Double-click a word in the list that you want to use in a search. The word appears in the **Word** text box.
4. Double-click the word to select it, and copy it to the clipboard (Ctrl + C).
5. In the **Search** window, click the **Find Results Containing Text** box and paste (Ctrl + V) the selected word into the text box.
6. Repeat steps 3 through 5 for each word you want to use and separate each pair of words in the **Find Results Containing Text** box with AND or OR.

## Changing Search Preferences

You may need to change the default settings in the **Search Preferences** dialog box.

1. Choose *File, Preferences, Search*.
2. Change preferences in the dialog box as necessary.
3. Click *OK*.



## Selecting Indexes to Search

If you use Acrobat Reader to view and search documents other than this CD-ROM, you will need to understand how **Indexes** work. Otherwise, each time you start a search while using this CD-ROM, the appropriate **Index** will automatically be installed. If the search function does not work or the Search button is grayed-out, read the following information about **Indexes**.

Choosing *Tools, Search, Indexes* lists the available indexes. On a Macintosh, the list may also include indexes on currently unavailable file server volumes or CD-ROMs.

To be searchable, an index must be in the search list and it must be selected. When you add an index to the list, it is automatically selected. You can deselect or reselect it for specific searches or remove it from the list altogether. You can view a description of any index in the list.

## Add an Index to the Search List

1. Choose *Tools, Search, Indexes*. (If the Search window is open, click the *Indexes* button in it instead.)
2. Click on *Add*.
3. Locate and select the appropriate index for this CD-ROM (e.g., blackcd for The Metals Black Book - on CD-ROM, or redcd, bluecd, etc.). Acrobat index-definition filenames usually end with the extension .pdx.
4. Double-click the name of the index you want to use.

The new index is added to the search list.

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## Select or Deselect an Index

In the **Index Selection** dialog box, click the box of any index whose status you want to change and click *OK*.

## Remove an Index from the Search List

1. In the **Index Selection** dialog box, highlight the name of the index you want to remove.
2. Click on *Remove*.
3. Click *OK*.

## View a Description of an Index

1. In the **Index Selection** dialog box, highlight the name of the index you want information about.
2. Click on *Info* to view the information.
3. Click *OK*.

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