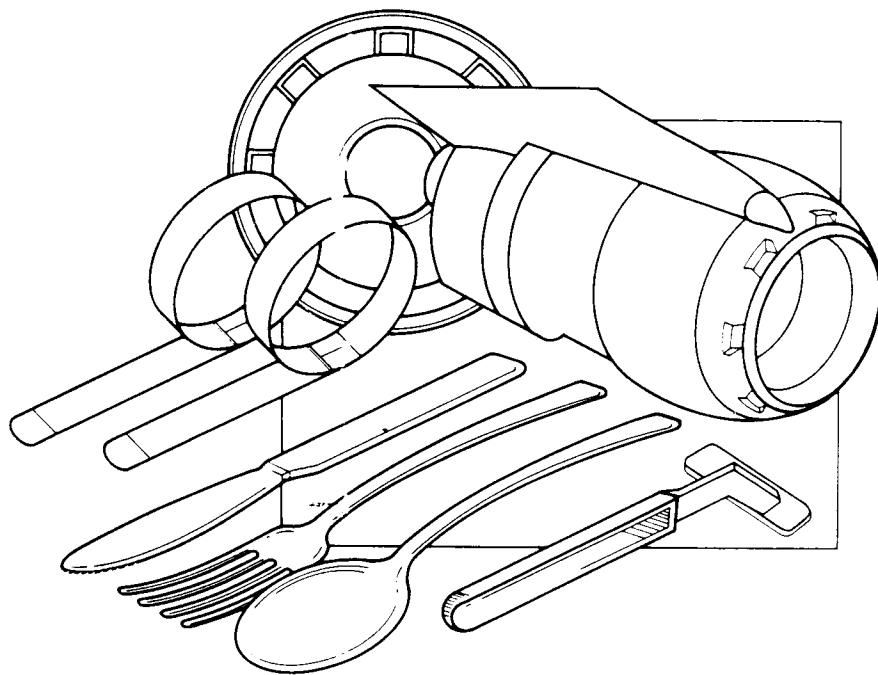


STEEL PRODUCTS MANUAL

Stainless Steels



March 1999

A PUBLICATION OF THE IRON AND STEEL SOCIETY

Stainless Steels



Warrendale, PA
March 1999

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Stainless Steels**
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FOREWORD

Herewith is presented the section of the Steel Products Manual covering Stainless Steels

It is the purpose of the Steel Products Manual to make available to purchasers, producers, and consumers information covering the major steel products.

The information contained in each section of the Steel Products Manual substantially represents the manufacturing practices and related scientific and technical information of steel producers. These practices have evolved from the utilization of available raw materials and manufacturing methods to produce steel products to meet the requirements of purchasers' specifications and standards.

The various sections of the Steel Products Manual primarily concern the manufacturing and testing of steel products, product properties and applications, commodity descriptions, dimensional tolerances, weight tolerances, inspection, sampling, chemical analysis and standards and specifications prepared by others which are pertinent to the identified steel products. The sections are revised from time to time and other sections may be issued.

It is hoped that the Steel Products Manual will be of service to consumers and producers of steel products, to professors of engineering and their students and to the general public. Comments, suggestions and criticism from any source are welcome and may be addressed to the Iron & Steel Society, 186 Thorn Hill Road, Warrendale, PA 15086-7528.

ACKNOWLEDGMENTS

Many persons have contributed suggestions and constructive criticism during the preparation of this edition of the Stainless Steel Manual.

I am especially indebted to the following individuals for their contributions and review of various sections of the manual:

Dr. Ralph M. Davison, Technical Marketing Resources, Inc.
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Dominic A. Sorace, Allegheny Ludlum Corporation

I am also indebted to George F. Vander Voort of Buehler, Ltd. for supplying the photomicrographs which appear in the "Overview of Stainless Steels."

—Harold M. Cobb
Editor

INTRODUCTION

The demand for stainless steels has increased dramatically in recent years as more and more companies specify these materials for their products. Industries which utilize stainless steels extensively include chemical and power, food and beverage, pharmaceutical, and transportation. Other major uses are in architecture, domestic appliances, household utensils and small electrical and electronic appliances.

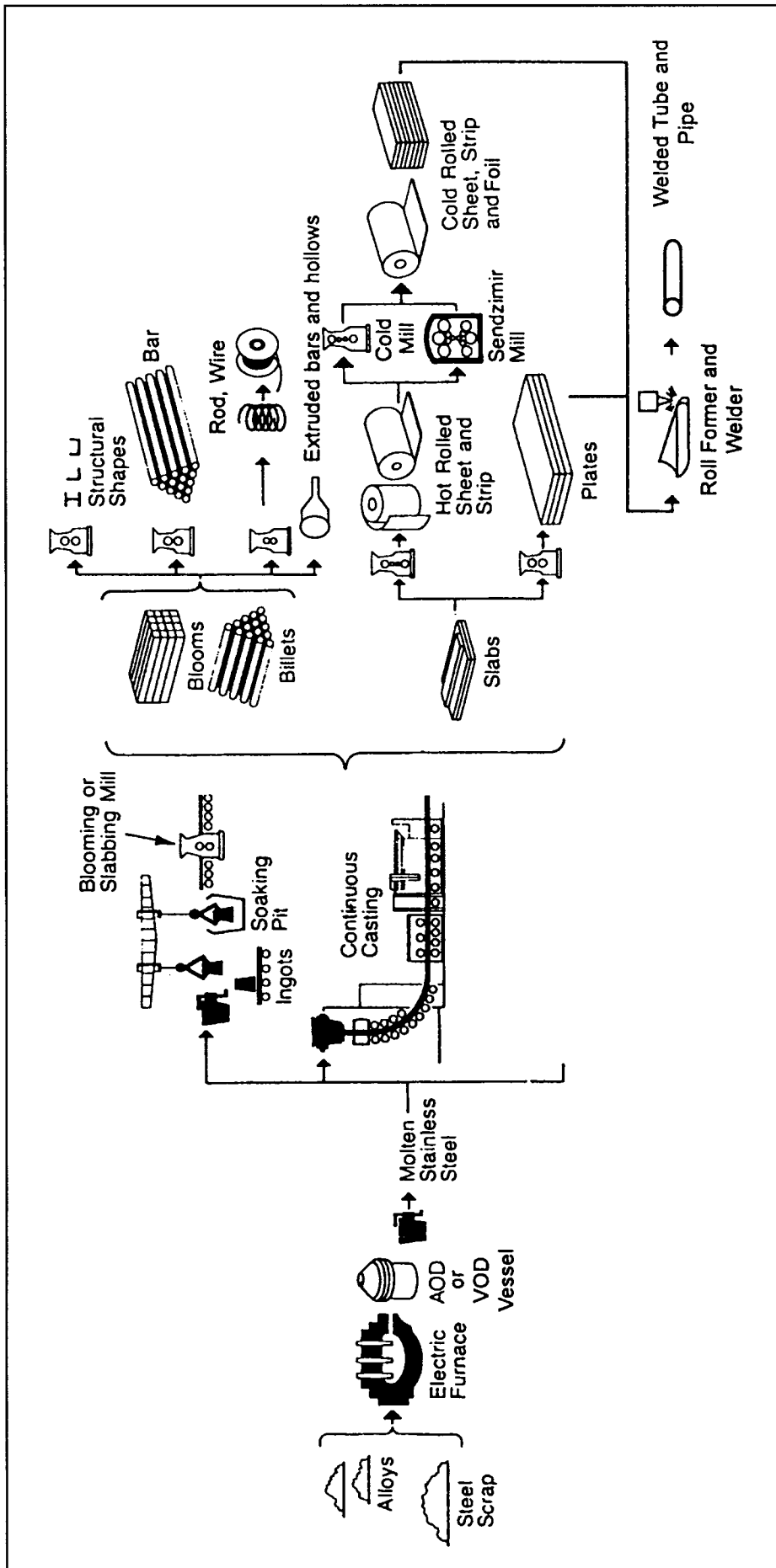
Stainless steels owe their widespread use to a combination of unique properties that have advantages over those of other steels and nonferrous metals for many applications. The principal outstanding characteristics are their resistance to corrosion in many environments, their good mechanical properties over an extremely wide range of temperatures, and their superior resistance to oxidation and scaling at very high temperatures.

These unique properties are achieved through substantial additions of chromium to iron and carbon, with or without the addition of other elements such as nickel, manganese, molybdenum, and nitrogen. Chromium, however, is the key ingredient since a dramatic increase in corrosion resistance occurs when a level of about 10.5% chromium is reached. Steels with at least 10.5% chromium have traditionally been designated as *stainless steels*.

These steels attain their *stainless* characteristics by virtue of their ability to form an invisible, adherent, chromium-rich oxide film which strongly resists attack by the atmosphere and many industrial gases and chemicals.

The chemical compositions of 225 alloys are listed in this manual, in addition to detailed information on 130 grades of steel which includes a general description of each alloy, its physical properties, its specified mechanical properties, and typical applications. Many of the recently developed duplex (austenitic-ferritic) and superaustenitic stainless steels are described as well as many modified versions of long-established grades.

This edition of the manual also includes a comprehensive stainless steel alloy index, a complete list of pertinent ASTM standards and specifications, an extensive guide to trade names and their origins, a cross index of national designations for similar stainless steels, a stainless steel products buyer's guide, and a list of typical applications.



The making of stainless steel.

Reproduced, with permission, from *Design Guidelines for the Selection and Use of Stainless Steel*, a publication of the Specialty Steel Industry of North America, and amended by the Allegheny Ludlum Steel Corporation.

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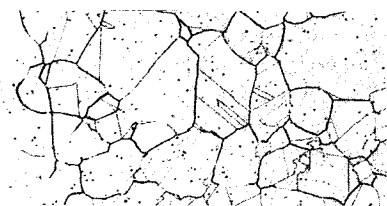
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OVERVIEW OF STAINLESS STEELS

General Description of Stainless Steels

Stainless steels may be divided into five main groups, the first four of which are based upon a common crystalline structure of the steels within the group. The fifth group, known as precipitation hardening steels, consists of alloys that can be hardened by an aging treatment.

Austenitic Stainless Steels. Austenitic stainless steels containing chromium and nickel are given a 300 Series classification and austenitic steels containing chromium, nickel and manganese are given a 200 Series classification. It should be noted, however, that some austenitic stainless steels do not have these 200 and 300 Series designations. The steels in this austenitic group have many compositions and properties, but they have many characteristics in common. They can be hardened by cold working but not by heat treatment. In the annealed condition all are essentially nonmagnetic, but some may become slightly magnetic by cold working. In the annealed condition they have excellent formability.



Highly magnified crystalline structure of austenitic stainless steel

The various grades of austenitic steels have excellent corrosion resistance in many environments, resisting attack by the atmosphere and by many industrial gases and many chemicals. They have a resistance to scaling at temperatures as high as 2000°F (1095°C). The resistance of an individual austenitic alloy to corrosion or oxidation in a particular environment will depend upon that steel's alloy content.

Many of these steels have good strength at high temperatures which accounts for their wide use at elevated temperatures. They are also among the primary materials selected for use at extremely low temperatures since they do not become brittle as with other types of steel. All austenitic stainless steels are sensitive, to some degree, to chloride stress corrosion cracking and fully austenitic types may be

sensitive to solidification cracking.

Some types are susceptible to carbide precipitation or intermetallic phase precipitation under adverse conditions of fabrication and use.

Type 304 stainless steel is the most widely used steel of the austenitic group. It has a nominal composition of 18% chromium and 8% nickel.

Ferritic Stainless Steels. Ferritic stainless steels are straight-chromium 400 Series steels that contain from 11 to 27% chromium and little or no nickel. They cannot be hardened by heat treatment and are only moderately hardened by cold working. These steels are magnetic. They have moderate ductility and resistance to corrosion and oxidation.



Highly magnified crystalline structure of ferritic stainless steel

Ferritic stainless steels are relatively weak at high temperature, and in heavier sections they may be lacking in toughness at below ambient temperatures.

Type 430 is the general purpose steel of the ferritic group. It has a nominal composition of 17% chromium and is used for highly-polished trim applications in mild atmospheres. It is also used in food processing and for consumer goods.

Type 409 and its recently-standardized variations are the most widely used ferritic grades of all the nickel-free stainless steels. They are among the least expensive of all stainless steels. These grades have a nominal composition of 11% chromium and their major use is in automotive exhaust systems.

Martensitic Stainless Steels. Martensitic stainless steels, like the ferritic steels, are straight-chromium types in the 400 Series. They have from 11 to 18% chromium with or without small additions of nickel or other elements. These steels are magnetic.

Unlike the austenitic and the ferritic steels, the martensitic steels are hardenable by heat treatment and are generally used in the hard-

ened and tempered condition.



Highly magnified crystalline structure of martensitic stainless steel

Type 410 stainless steel is the general-purpose grade in the martensitic group. It has a nominal chromium content of 12.5% and the carbon content is limited to a maximum of 0.15%. A tensile strength as high as 190 ksi (1380 MPa) can be obtained with Type 410 stainless steel after heat treatment, but with reduced ductility.

Duplex Stainless Steels. Duplex stainless steels have an annealed structure which typically consists of about equal parts of austenite and ferrite. These steels have 18 to 29% chromium, 3 to 8% nickel and various other elements, particularly nitrogen and molybdenum.



Highly magnified austenitic-ferritic structure of duplex stainless steel

This group of steels has several advantages over the austenitic steels. The duplex grades are highly resistant to chloride stress corrosion cracking, they have excellent pitting and crevice corrosion resistance and have about twice the yield strength of the common austenitic grades. Type 329 and Alloy 2205 are typical duplex steel grades.

Precipitation Hardening Stainless Steels. Precipitation hardening steels are not characterized by a single crystalline structure, but rather by a particular strengthening mechanism in one of the structures. They contain 11 to 18% chromium, 3 to 27% nickel and smaller amounts of other metals. They combine high strength and hardness with corrosion resistance which is superior to that of the martensitic chromium stainless steels. They can be hardened by solution treating and aging to develop tensile strengths as high as 240 ksi (1655 MPa) for the grade designated as UNS S17700 (17-7PH®), for example.



Highly magnified crystalline structure of precipitation hardening stainless steel

Melting and Refining

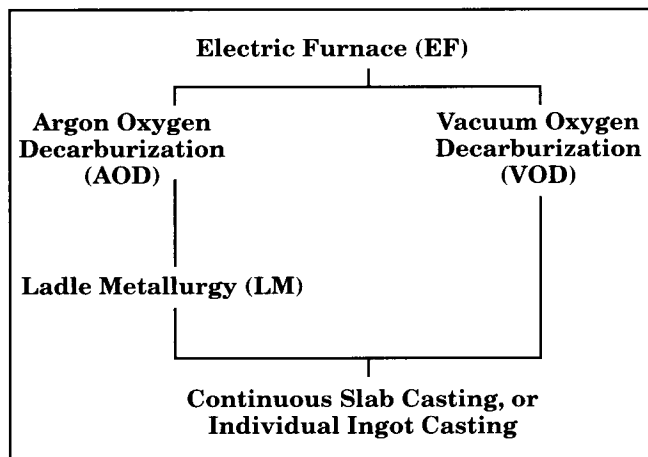
Stainless steels are normally melted by one of the following processes:

- (a) Electric furnace plus separate refining
- (b) Vacuum furnace
- (c) One of the former followed by vacuum arc, partial pressure inert gas arc or electroslag consumable remelting

Until the mid-1970s the primary melting method for stainless steels was the electric furnace process, where melting and refining were accomplished entirely in the furnace. The electric furnace process was typically slow, inefficient and metallurgically limited.

Widespread adoption of the oxygen-inert-gas injection method of refining, or argon-oxygen decarburization (AOD) provided dramatic improvements in productivity, cost, efficiency, chemistry capabilities and microcleanliness. Another commonly used refining method is oxygen injection under vacuum, or vacuum oxygen decarburization (VOD). The AOD and VOD processes provide efficient decarburization and excellent mixing of the molten metal. The AOD and VOD refining vessels are usually fed metal from electric furnaces and the AOD refining process is normally followed by a ladle metallurgy (LM) treatment to further enhance the control of chemical composition, microcleanliness and casting temperature. The VOD process combines both refining and ladle metallurgy treatments in a single process. Ladle metallurgy treatment may be carried out under the cover of a protective slag or in a vacuum chamber where volatile impurities, such as hydrogen, may be removed. Further cost- and quality-enhancements are realized by the casting of continuous slab.

The melt process routing for most of the stainless steel production in the 1990s is shown in the following diagram:



These melting processes, in general, provide enhanced hot workability and product properties in contrast with the former electric-furnace-only method.

Several special melting methods can be used to produce stainless steels having higher pu-

urity and a lower nonmetallic inclusion content than the conventional product when the demands of an application justify the added cost. Selected charge materials may be melted entirely under high vacuum to prevent oxidation and nitrogen pickup and to remove any volatile impurities. Electric induction melting is the most common method, but electron beam melting may also be used. Conventionally-melted or vacuum-melted material may be refined further by consumable electrode remelting. In this process the starting stock is progressively melted and allowed to drip into a cooled metal mold where it progressively solidifies to form an ingot. This operation can be done under vacuum [vacuum arc remelting (VAR) or electron beam remelting (EBR)] or under a blanket of molten slag [that is, electroslag remelting (ESR)]. Either method substantially reduces inclusion content. The ESR process is usually designed to further reduce sulfur levels and to provide a cast microstructure that is more suitable for hot working compared to that of statically cast ingots. The ESR process typically operates at atmospheric pressure and is also capable of multiple ingot cross sections, such as round, square, rectangular, octagonal, and hollow round. The VAR process is normally limited to round ingots.

The brief description above is not intended to be limiting. Other melting methods can be used to produce stainless steel of satisfactory quality. The basic oxygen method, for example, has been used to produce substantial tonnages of some grades. The melting method is left to the discretion of the producer.

Fabrication and Cleaning

Stainless steels require care during fabrication. They are sensitive to thermal and mechanical operations, the control of which is complicated by the varying effects of different chemical combinations. To obtain the best results purchasers normally consult with the steel producer regarding the working, machining, heat treating and other operations to be employed in fabrication, the mechanical properties to be obtained, and the conditions of service for which the finished articles are intended. Particular attention should be given to informing the producer of the intended means of fabrication, the details of the first operation to which the steel will be subjected, and subsequent operations when significant.

Stainless steels can be readily fabricated by conventional manufacturing methods, but their fabrication characteristics are different from those of the carbon and alloy steels. Among the most important differences which must be recognized are the relatively high hot strengths of these high alloy steels, which affect forging, the high toughness and work hardening rates of

some types, which affect machining and cold forming, and the high thermal expansion of the austenitic types, which affects weldment distortion.

The two most common fabrication deficiencies which affect later service are surface contamination with carbon and alloy steels and improper post-fabrication cleaning. Stainless steels must have clean surfaces to provide optimum corrosion resistance. It is important to note that even minor, invisible contamination from non-stainless steels can later cause unsightly staining when exposed to moisture, and often may lead to more serious corrosion. Such contamination can come from high pressure contact with low alloy steels (forming dies, lifting and handling equipment), from wire brushing with non-stainless brushes, from grinding with wheels previously used for carbon steels or even from airborne particles in a shop which also fabricates carbon steel.

Contamination of stainless steel surfaces can be minimized by utilizing careful procedures, including the use of covered or plated dies and corrosion resisting handling equipment, but complete prevention of contamination is very difficult in shops which fabricate a variety of non-stainless metals. It is often the best practice to provide for an acid treatment to remove any contaminating particles after fabrication when staining or corrosion in service cannot be accepted.

Post-fabrication cleaning may be necessary for three basic purposes: (1) to remove oxide scale resulting from welding hot working or heat treating operations, (2) to remove contaminating metallic particles and (3) to remove general shop soils.

ASTM A380, Standard Recommended Practice for Descaling and Cleaning Stainless Steel Surfaces, provides excellent descriptions of procedures which can be used for all three purposes and the necessary precautions in their use. Careful adherence to this recommended practice will provide satisfactory cleaning and avoid the sometimes serious consequences of improper cleaning.

ASTM A967, Chemical Passivation Treatments for Stainless Steel Parts, provides valuable instructions for treating finished parts.

Oxide scales are most frequently removed by mechanical means (wire brushing with a stainless steel brush or blasting with clean sand or aluminum oxide grit) or by acid descaling (pickling). For faster descaling, pickling may be preceded by mechanical descaling.

Grease, oil, lubricants, paint and other soils may be removed from stainless steels by alkaline cleaners, emulsion or solvent cleaners, vapor degreasing or other suitable means, as described in ASTM A380. Such cleaning may be

required before processing steps, such as heat treatment or acid descaling, or as a final cleaning to prevent product contamination. Cleaning solutions containing chlorine or chlorides should be avoided, or used only with extreme caution. There are documented cases of serious service failures which resulted from cleaning with chloride-containing solutions.

The trend to the use of clean-in-place (CIP) systems is favorable if cleaning is done with good control, especially of the final rinsing operation. Failure to rinse thoroughly can lead to severe corrosion damage.

Heat Treatment

Stainless steels are rarely placed in service in the hot rolled or forged condition. Annealing or other forms of heat treatment are desirable to obtain the full advantages of the corrosion resistance and mechanical properties of the steels. Standard heat treating equipment may generally be used.

The 4xx series of ferritic and martensitic stainless steels are annealed (full annealed) by heating to above the critical temperature followed by slow cooling below this temperature to obtain minimum hardness and maximum ductility. These steels can also be annealed by an isothermal heat treatment below the critical temperature (process annealed).

Some steels of the 4xx series may be hardened by heating to above the critical temperature and rapidly cooling. This hardening operation is generally followed by a tempering or stress relieving treatment. See Table 3-1 for typical hardened and tempered properties.

The 2xx and 3xx series of austenitic stainless steels are annealed (solution annealed) by heating to a temperature sufficiently high to put the carbides into solution and rapidly cooling from that temperature to retain the carbides in solution. The austenitic types when maintained at (or cooled slowly through) the temperature range of 800 to 1650°F (425 to 900°C) may cause the precipitation of chromium carbides, as a separate phase, in the grain boundaries. Associated with such carbide precipitation is a severe loss of corrosion resistance in some corrosive media.

Cleaning and Maintenance

Routine cleaning and maintenance of stainless steel is often necessary to maintain corrosion resistance and appearance. Frequent cleaning on a routine scheduled basis is recommended to prevent initiation of crevice corrosion under deposits, and hardening of deposits. Accumulated materials while fresh and soft can often be easily removed by flushing with steam, hot water or warm detergent solution. A sponge, fiber brush or cloth can assist in the removal of residues from

low temperature operation. More resistant deposits, such as "baked-on" food residues, may require scouring with abrasive cleaning powder or fine stainless steel wool. Common steel wool, scouring pads, scrapers, wire brushes and other steel tools should never be used to clean stainless steel, because they can leave embedded iron particles which will eventually rust and stain the surface.

When stainless steel equipment is cleaned or sterilized, particular attention should be given to agents containing chlorine compounds, such as potassium hypochlorite. These compounds may decompose and release free chlorine, or hydrolyze to form hydrochloric acid. When these compounds or materials of unknown chlorine content must be used, contact time with stainless steel should be kept short and compounds should then be removed by thorough water flushing in order to avoid localized pitting corrosion.

Selection

The first and most important step toward successful use of a stainless steel is selection of the proper type for the application. This class of steels includes, as indicated earlier, a large number of standard types. These types differ greatly from one another in composition, corrosion resistance, physical properties and mechanical properties, and selection of the optimum type for a specific application is the key to satisfactory performance at a minimum total cost.

The individual type descriptions and property compilations given, and the following discussion, provide some information useful in steel selection. For more detailed discussion, the user is referred to "Design Guidelines for the Selection and Use of Stainless Steel," published by the Specialty Steel Industry of North America (SSINA).

Table 1-1 is a suggested checklist of properties to be considered in the selection of the proper type for a specific application. This table includes not only the obvious properties, but also some less frequently required, but occasionally overlooked, properties.

Table 1-1

PROPERTY CHECKLIST FOR TYPE SELECTION

Corrosion resistance
Oxidation and sulfidation resistance
Strength and ductility at service and ambient temperatures
Suitability for intended fabrication techniques
Suitability for intended cleaning procedures
Property stability in service
Toughness
Abrasion and erosion resistance

Galling and seizing resistance
 Reflectivity
 Magnetic properties
 Thermal conductivity
 Thermal expansion
 Electrical resistivity
 Sharpness (retention of cutting edge)
 Rigidity
 Dimensional stability

Corrosion resistance is frequently the most important characteristic of a stainless or heat resisting steel, but is often also the most difficult to assess for a specific application. General corrosion resistance to natural conditions and to pure chemical solutions is comparatively easy to determine, and Table 1-2 shows relative corrosion resistance of the standard types in various common media. However, general corrosion is often much less serious than localized forms, such as stress corrosion cracking, crevice corrosion in tight spaces or under deposits, pitting attack, intergranular attack in "sensitized" material, such as in weld heat affected zones, etc. Such localized corrosion can cause unexpected and sometimes catastrophic failures while most of a structure is unaffected, and must, therefore, be considered carefully in design and in steel selection. Corrosive attack can also be dramatically increased by seemingly minor impurities in the medium which may be difficult to anticipate, but can have major effects even in parts-per-million concentrations, by heat transfer through the steel to or from the corrosive medium, by contact with dissimilar metallic materials, by stray electrical currents and by many other subtle factors. At elevated temperatures, an attack on the metal can be significantly accelerated by seemingly minor changes in atmosphere which affect scaling rate, sulfidation or carburization.

Despite these complications, a suitable steel can be selected for most applications on the basis of experience, perhaps assisted by suggestions from the steel producer. However, it must be recognized that laboratory corrosion data can be misleading in predicting service performance of a particular type. Even service data have limitations, because "similar" corrosive media may differ substantially due to "slight" variations in some of the above corro-

sion factors. For difficult applications, extensive study of comparative data may be necessary, sometimes followed by pilot or service testing.

Mechanical properties at service temperature are an obvious consideration, but sometimes overlooked is the necessity for satisfactory properties at other temperatures which are likely to be experienced. Thus, a product for arctic service must have suitable properties at subzero temperatures even though the steady-state operating temperature may be much higher, and post-service room-temperature properties can be important for a structure which may be intermittently shut down after operating at an elevated temperature.

Selection must consider not only performance requirements, but also fabrication and cleaning requirements. Frequently, a particular type is chosen for a fabrication characteristic, such as formability or weldability over other types which would perform adequately, but cost more to fabricate. Even a required or preferred cleaning procedure may dictate steel selection. Sometimes overlooked is the fact that a welded fabrication, which is to be cleaned in a medium which attacks sensitized stainless steel, such as nitric-hydrofluoric acid, should be produced from stabilized or low-carbon types even though sensitization may be unimportant under service conditions.

Other properties listed in the checklist of Table 1-1 are of vital importance for some specialized applications, but are of little concern for many other applications.

Surface finish is important for many applications, and stainless steels are sometimes used because of the variety of attractive finishes available. Selection among the finishes described earlier may be made on the basis of characteristics, such as appearance, slideability or cleanability. Effect of finish on the cleanability is not as simple as sometimes thought, and tests of available finishes may be advisable. Selection of finish may in turn influence selection of type, because of differences in availability of the various finishes with grade or differences in finish durability. A more corrosion resistant type, for example, will maintain a bright finish in a corrosive environment which would dull a lower-alloy stainless steel.

Table 1-2

RELATIVE CORROSION RESISTANCE OF SELECTED STAINLESS STEELS

TYPE Number	UNS Number	Mild Atmospheric and Fresh Water	Atmospheric		Chemical		
			Industrial	Marine	Mild	Oxidizing	Reducing
201	S20100	x	x	x	x	x	
202	S20200	x	x	x	x	x	
205	S20500	x	x	x	x	x	
301	S30100	x	x	x	x	x	
302	S30200	x	x	x	x	x	

Table 1-2 (Continued)

RELATIVE CORROSION RESISTANCE OF SELECTED STAINLESS STEELS

TYPE Number	UNS Number	Mild Atmospheric and Fresh Water	Atmospheric		Chemical		
			Industrial	Marine	Mild	Oxidizing	Reducing
302B	S30215	x	x	x	x	x	
303	S30300	x	x		x		
303Se	S30323	x	x		x		
304	S30400	x	x	x	x	x	
304L	S30403	x	x	x	x	x	
	S30430	x	x	x	x	x	
304N	S30451	x	x	x	x	x	
305	S30500	x	x	x	x	x	
308	S30800	x	x	x	x	x	
309	S30900	x	x	x	x	x	
309S	S30908	x	x	x	x	x	
310	S31000	x	x	x	x	x	
310S	S31008	x	x	x	x	x	
314	S31400	x	x	x	x	x	
316	S31600	x	x	x	x	x	x
316F	S31620	x	x	x	x	x	x
316L	S31603	x	x	x	x	x	x
316N	S31651	x	x	x	x	x	x
317	S31700	x	x	x	x	x	x
317L	S31703	x	x	x	x	x	
321	S32100	x	x	x	x	x	
329	S32900	x	x	x	x	x	x
330	N08330	x	x	x	x	x	x
347	S34700	x	x	x	x	x	
348	S34800	x	x	x	x	x	
384	S38400	x	x	x	x	x	
403	S40300	x			x		
405	S40500	x			x		
409	S40900	x			x		
410	S41000	x			x		
414	S41400	x			x		
416	S41600	x					
416Se	S41623	x					
420	S42000	x					
420F	S42020	x					
422	S42200	x					
429	S42900	x	x		x	x	
430	S43000	x	x		x	x	
430F	S43020	x	x		x		
430F Se	S43023	x	x		x		
431	S43100	x	x	x	x		
434	S43400	x	x	x	x	x	
436	S43600	x	x	x	x	x	
440A	S44002	x			x		
440B	S44003	x					
440C	S44004	x					
442	S44200	x	x		x	x	
446	S44600	x	x	x	x	x	
	S13800	x	x		x	x	
	S15500	x	x	x	x	x	
	S17400	x	x	x	x	x	
	S17700	x	x	x	x	x	

The "X" notations indicate that a specific stainless steel type may be considered as resistant to the corrosive environment categories. When selecting a stainless steel for any corrosive environment, it is always best to consult with a corrosion engineer and, if possible, conduct tests in the environment involved under actual operating conditions.

Common Classification of Products by Size, Shape, Condition and Finish

Plate. A flat rolled or forged product: 10 in (254 mm) and over in width, 0.1875 in (4.76 mm) and over in thickness.

Sheet. A flat rolled product in coils or cut lengths: 24 in (610 mm) and over in width, under 0.1875 in (4.76 mm) in thickness.

Strip. A flat rolled product in coils or cut lengths: under 24 in (610 mm) in width, under 0.1875 to 0.005 in (4.76 to 0.13 mm), inclusive, in thickness. Note: Cold finished product 0.005 in (0.13 mm) thick and under 24 in (610 mm) wide is sometimes identified as "foil."

Foil. Cold finished in coils: under 24 in (610 mm) in width; 0.005 in (0.13 mm) and under in thickness. Note: Cold finished product 0.005 in (0.13 mm) thick and under 24 in (610 mm) wide is sometimes identified as "strip."

Bars. Straight lengths either: hot rolled, forged, extruded, turned, cold drawn or ground. Also includes small shapes with all dimensions under 5 in (127 mm) and hot rolled flats from 0.25 to 10 in (6.35 to 254 mm), inclusive, in width and 0.125 in (3.18 mm) and over in thickness. All cold finished bars turned or ground in straight lengths produced from hot rolled bar or straightened and cut rod or wire. Note: All cold reduced flat material under 0.1875 in (4.76 mm) thick is classified as strip if 0.375 in (9.52 mm) and over in width.

Wire. A round or shaped cold reduced product in coils only produced by cold finishing coiled rod.

Rods. Hot rolled or hot rolled annealed and pickled: rounds, squares, octagons, hexagons and shapes, in coils, for subsequent cold drawing or cold rolling.

Blooms. A semifinished product (produced by hot rolling, forging or by continuous casting) that requires subsequent hot working or forging. Sizes are generally over 50 in² (32,258 mm) in square, rectangular or round cross sections with width less than twice the thickness.¹

Billets. A semifinished product (produced by hot rolling, forging or continuous casting machines) that requires subsequent hot rolling or hot forging. Sizes are generally up to 50 in² (32,258 mm) in cross section as squares, rectangles or round cross sections with width less than twice the thickness.¹

Slabs or Sheet Bars. The products of a primary mill such as blooming, slabbing or sheet bar mills, or continuous or pressure casting machines, which are shipped without further work other than cutting to length or surface conditioning used only for rerolling into sheet, strip or plate.

Tubing. A hollow product of round or any other cross section having a continuous periphery. It may be made in either a seamless or welded product form. It is manufactured to specified dimensions, usually outside dimension(s)

and wall thickness.

¹Rectangles with width twice the thickness or greater are classed as slabs or sheet bars.

Pipe. A round tubular product, generally of heavier wall thickness than tubing, conforming to the particular dimensions commercially known as "standard pipe sizes."

See Figures 1 through 6.

Inspection

When a purchaser's specification stipulates that inspection and tests (except product analysis) for acceptance of the steel be made prior to shipment from the mill, the producer affords the purchaser's inspector all reasonable facilities to determine that the steel is being furnished in accordance with the specification. Products subject to purchaser's inspection and sampling are customarily inspected and sampled in conjunction with the producer's inspection and sampling operations.

Limitations of Inspection, Testing and Certification

There are a number of intrinsic features of steelmaking and finishing processes that affect the properties or conditions of the finished products, and those effects cannot always be precisely known. Therefore, it is technically impossible to give unconditional certification of complete compliance with all prescribed requirements. That fact is manifest both to those having a technical knowledge of the subject and to those skilled in the art of steel manufacture, and is recognized in applying a factor of safety. For example, the phenomenon of segregation during solidification of alloy steels can affect the uniformity of chemical composition, mechanical test results and soundness. Variations in manufacturing practice such as control of temperatures, which cannot always be regulated with exactness, sometimes cause minor variations in mechanical properties in different parts of a heat or lots of steel.

Because of those and other conditions which are present in steel mill operations, it is not thought possible at the present time to point out any reasonable or practical methods of testing or inspection that will ensure the detection and rejection of every piece of steel that varies slightly from the specified requirements with regard to dimensional tolerances, chemical composition, mechanical properties, surface or internal conditions.

Inspection of Cut Lengths and Coils. Product in coil form (sheet and strip) may contain more imperfections than cut lengths because the producer does not have the same opportunity to remove the portions containing imperfections as is possible in the case of cut lengths.

Packaging, Marking and Loading

For information pertaining to this subject, please refer to ASTM A700, "Standard Recommended Practices for Packaging, Marking and Loading for Domestic Shipment."

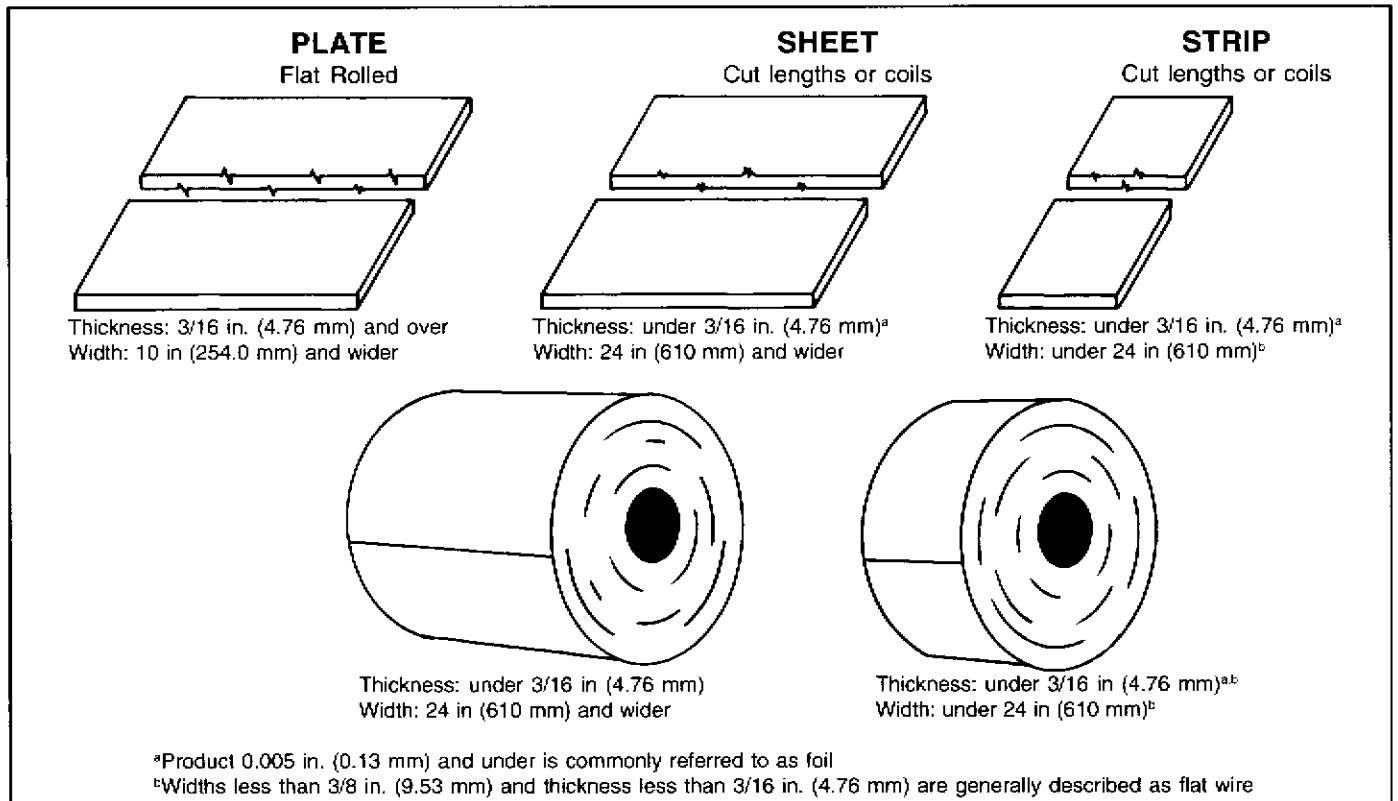


Fig. 1 - Schematic representation of common classification of product by size, shape, condition and finish: plates, sheets, and cold finished strip.

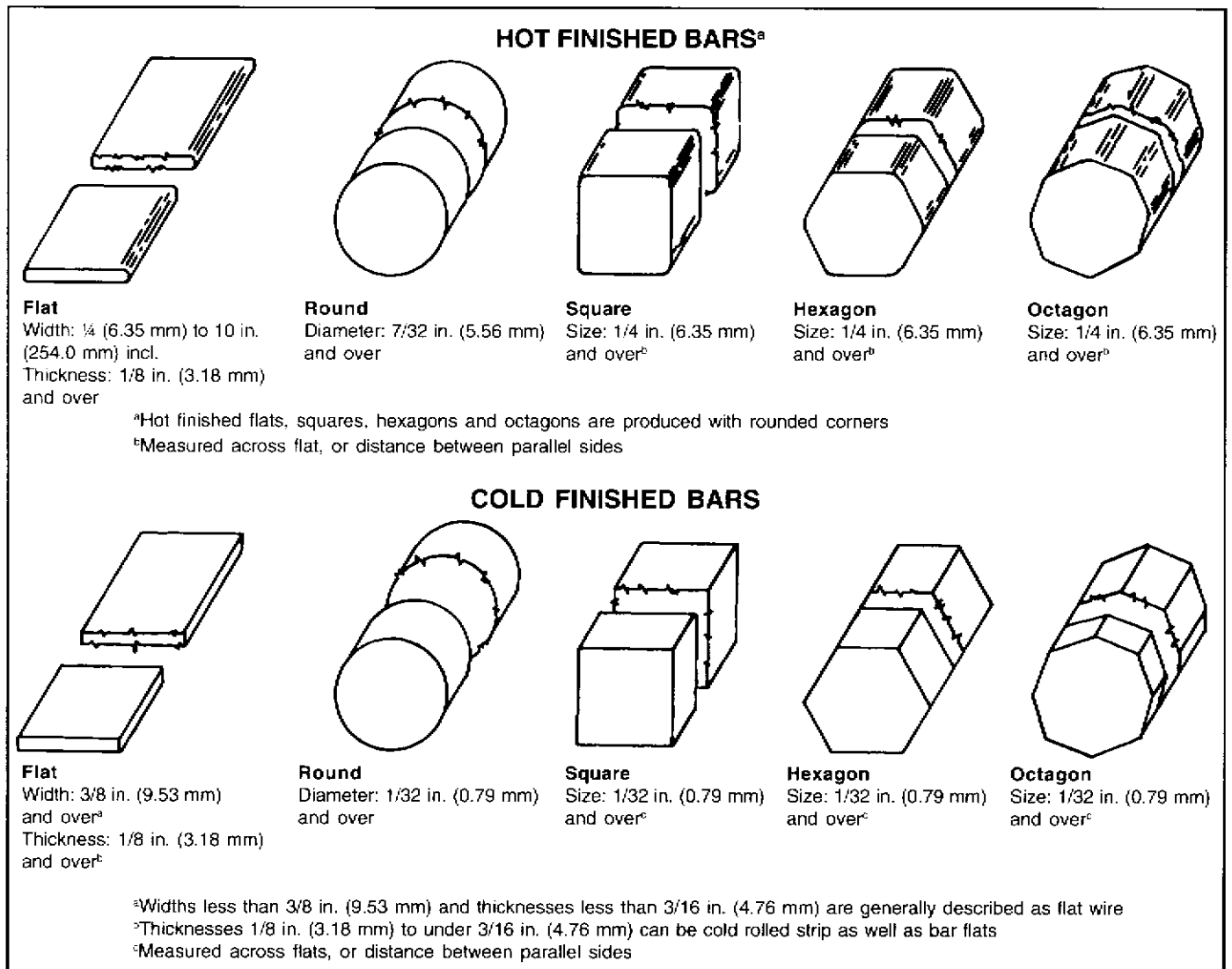


Fig. 2 - Schematic representation of common classification of product by size, shape, condition and finish: hot finished bars, cold finished bars.

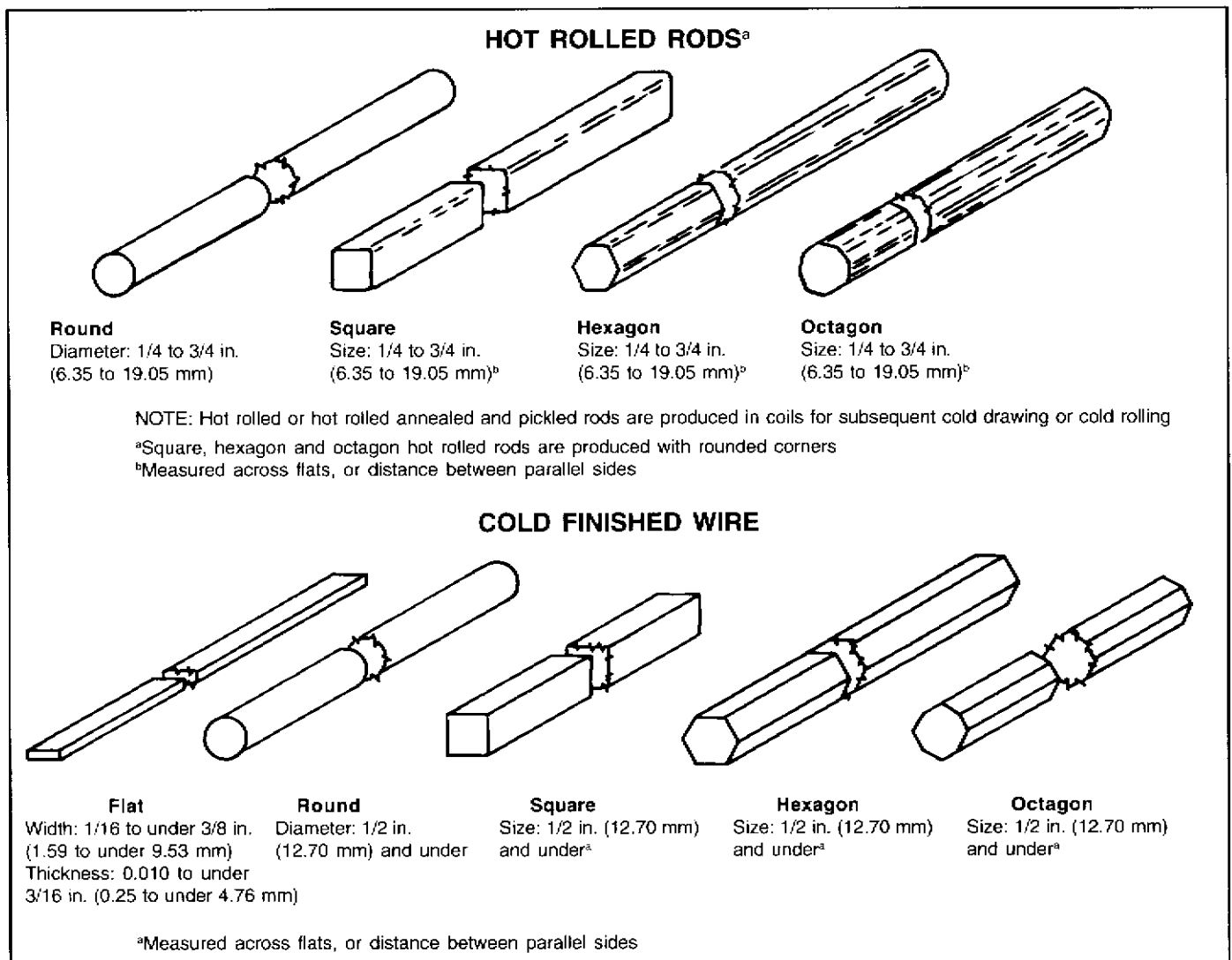


Fig. 3 - Schematic representation of common classification of product by size, shape, condition and finish: hot rolled rods, cold finished wire.

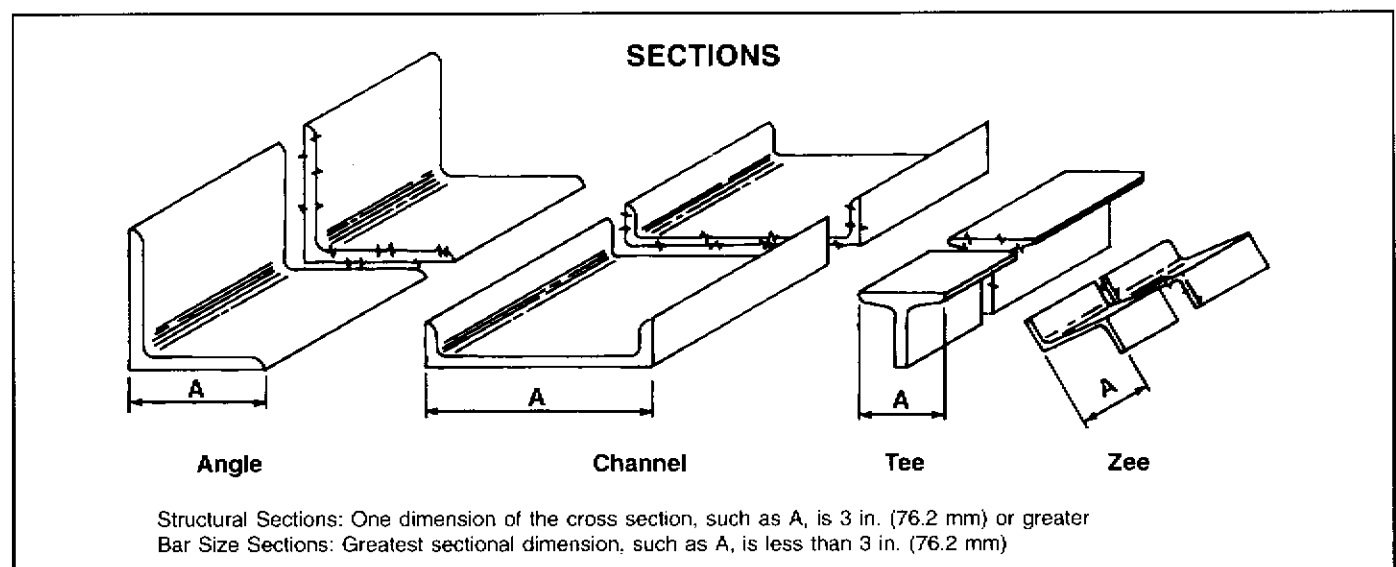


Fig. 4 - Schematic representation of common classification of product by size, shape, condition and finish: structural sections, bar size sections.

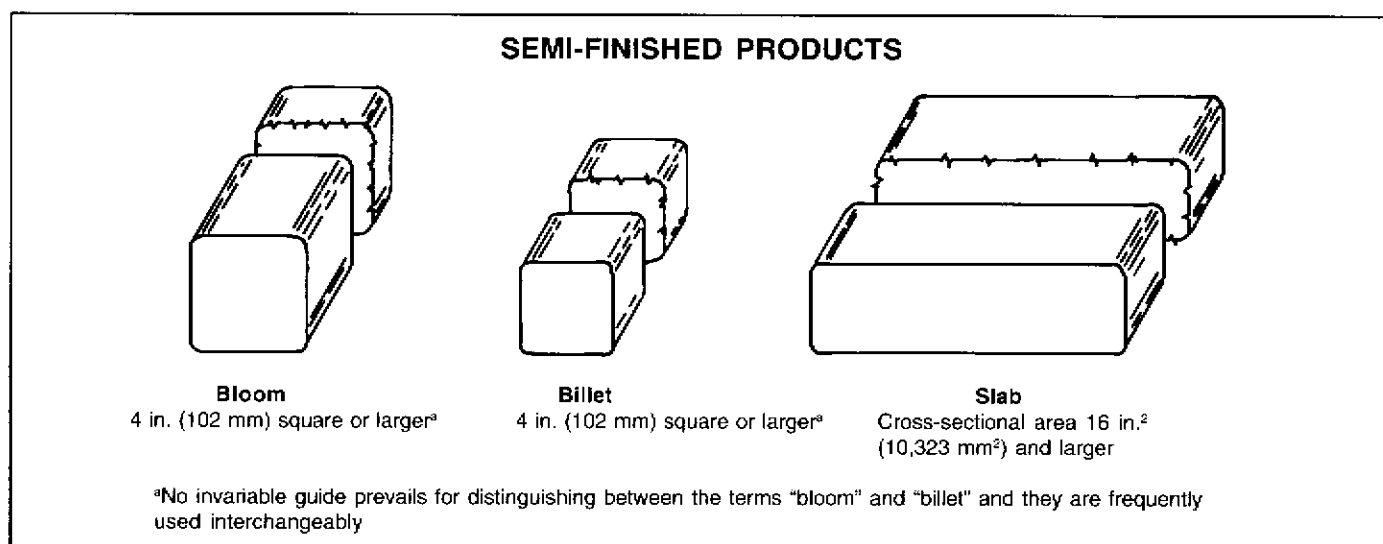


Fig. 5 - Schematic representation of common classification of product by size, shape, condition and finish: blooms, billets, slabs.

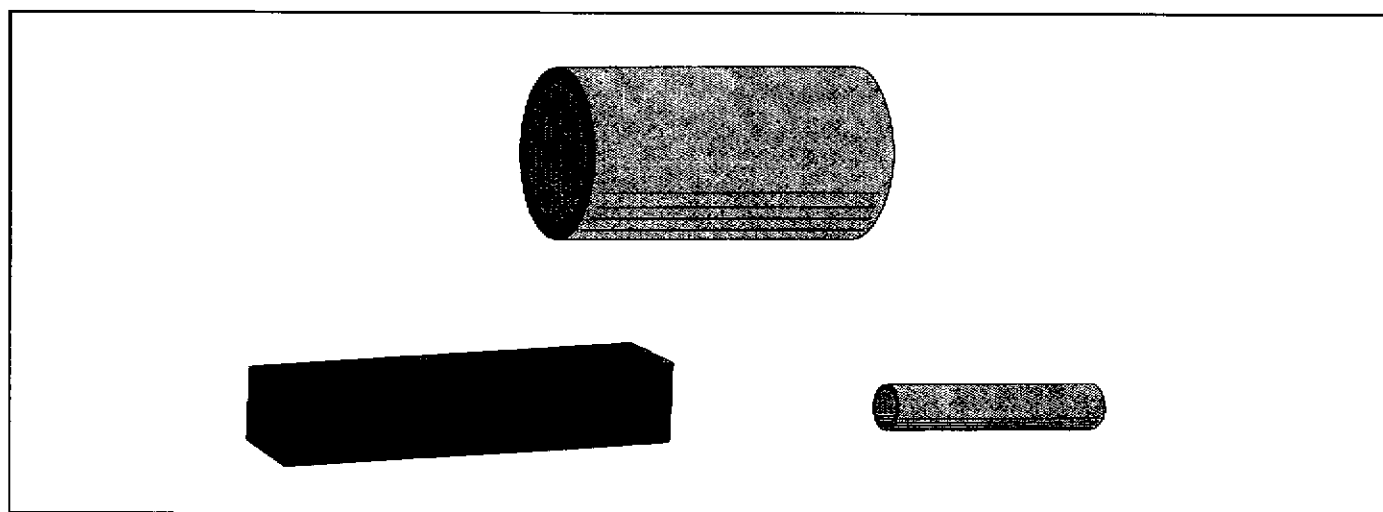


Fig. 6 - Schematic representation of common classification of product (these products are not classified by size, shape, condition and finish): pipe, tubing.

Chemical Ranges and Limits, Sampling and Analytical Procedures

The ranges and limits for the respective chemical elements shown in Table 2-1, based on cast or heat (formerly ladle) analysis, are the limits to which standard types of stainless steels are produced under normal manufacturing conditions.

Residual Elements. Residual elements are the unspecified elements present in small amounts as they occur naturally, or are added in minor quantities to assist in deoxidation, workability, etc. In either case, they may not be completely eliminated during the melting process.

Surface Contaminants. These contaminants, such as lead, zinc, copper, mercury, ferrous metals, carbonaceous materials, etc., are recognized to be potentially undesirable. All reasonable care is exerted by the producers to control all materials and operations that would be possible sources of contamination.

Heat Analysis

This term applies to the chemical analysis representative of a heat of steel as reported to the purchaser.

Heat analysis is determined by analyzing a test sample obtained during the pouring of the steel for such elements as have been specified. When this sample from the liquid steel is unobtainable or when it is evident that the sample does not truly represent the analysis of the melt, samples may be obtained from the solid steel. An analysis based on these representative samples may be used.

It is common practice in most melting operations to obtain more than one test sample from each heat; often three or more are taken representing the first, middle and last portion of the heat. These samples are used for a survey of uni-

formity and for control purposes.

When specified, the percentage of manganese, silicon, nickel, chromium, molybdenum, titanium, columbium plus tantalum, aluminum, nitrogen, cobalt and selenium is reported to two decimals; carbon up to 0.030 inclusive, phosphorus and sulfur up to 0.060 inclusive to three decimals; and higher values of carbon, phosphorus and sulfur to two decimals. Rounding off is in accordance with ASTM E29.

Product or Verification Analysis

Product Analysis. A product analysis is a chemical analysis on the semifinished or finished steel to determine conformance to the specification requirements. The range of the specified chemical composition is normally expanded to take into account deviations associated with analytical reproducibility and the heterogeneity of the steel. The permissible deviations or expanded limits should be stated in the product specification. When no product specification is cited, the limits are determined through reference to recognized compilations of standard steel grades. If several determinations of any element in the cast or heat are made, they may not vary both above and below the specified range.

Standard Methods for Sampling for Product Analysis. Sampling methods and sample preparation are as covered in ASTM E59, Standard Method of Sampling Steel, Cast Iron, Open-Hearth Iron and Wrought Iron.

Analytical Procedures. Methods of analysis commonly used are in accordance with methods of chemical analysis of metals, published by the American Society for Testing and Materials, or the methods approved by the National Institute of Standards and Technology (NIST), or methods of equivalent accuracy. Such methods include use of reagents in solutions, combustion methods, spectroscopic and X-ray analysis.

Table 1-3

PRODUCT ANALYSIS TOLERANCES^a STAINLESS AND HEAT RESISTING STEELS (ASTM A480)

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit	Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	to 0.010, incl.	0.002	Titanium	to 1.00, incl.	0.05
	over 0.010 to 0.030, incl.	0.005		over 1.00 to 3.00, incl.	0.07
	over 0.030 to 0.20, incl.	0.01	Cobalt	over 0.05 to 0.50, incl.	0.01 ^b
	over 0.20 to 0.60, incl.	0.02		over 0.50 to 2.00, incl.	0.02
	over 0.60 to 1.20, incl.	0.03		over 2.00 to 5.00, incl.	0.05

Table 1-3 (continued)

PRODUCT ANALYSIS TOLERANCES^A
STAINLESS AND HEAT RESISTING STEELS
(ASTM A 480)

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit	Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Manganese	to 1.00, incl.	0.03	Columbium plus tantalum	to 1.50, incl.	0.05
	over 1.00 to 3.00, incl.	0.04			
	over 3.00 to 6.00, incl.	0.05	Tantalum	to 0.10, incl.	0.02
	over 6.00 to 10.00, incl.	0.06			
	over 10.00 to 15.00, incl.	0.10	Copper	to 0.50, incl.	0.03
Phosphorus	over 15.00 to 20.00, incl.	0.15		over 0.50 to 1.00, incl.	0.05
				over 1.00 to 3.00, incl.	0.10
Sulfur	to 0.040, incl.	0.005		over 3.00 to 5.00, incl.	0.15
	over 0.040 to 0.20, incl.	0.010		over 5.00 to 10.00, incl.	0.20
			Aluminum	to 0.15, incl.	- 0.005,+0.01
Silicon	over 0.040 to 0.20, incl.	0.010		over 0.15 to 0.50, incl.	0.05
	over 0.20 to 0.50, incl.	0.020		over 0.50 to 2.00, incl.	0.10
			Nitrogen	to 0.02, incl.	0.005
Chromium	to 1.00, incl.	0.05		over 0.02 to 0.19, incl.	0.01
	over 1.00 to 3.00, incl.	0.10		over 0.19 to 0.25, incl.	0.02
	over 3.00 to 6.00, incl.	0.15		over 0.25 to 0.35, incl.	0.03
				over 0.35 to 0.45, incl.	0.04
Nickel	over 4.00 to 10.00, incl.	0.10	Tungsten	to 1.00, incl.	0.03
	over 10.00 to 15.00, incl.	0.15		over 1.00 to 2.00, incl.	0.05
	over 15.00 to 20.00, incl.	0.20	Vanadium	to 0.50, incl.	0.03
	over 20.00 to 30.00, incl.	0.25		over 0.50 to 1.50, incl.	0.05
Molybdenum	to 1.00, incl.	0.03	Selenium	all	0.03
	over 1.00 to 5.00, incl.	0.07			
	over 5.00 to 10.00, incl.	0.10			
	over 10.00 to 20.00, incl.	0.15			
	over 20.00 to 30.00, incl.	0.20			
Molybdenum	over 0.20 to 0.60, incl.	0.03			
	over 0.60 to 2.00, incl.	0.05			
	over 2.00 to 7.00, incl.	0.10			

^AThis table does not apply to heat analysis.

^BProduct analysis limits for cobalt under 0.05% have not been established, and the manufacturer should be consulted for those limits.

Quality Descriptions and Special Requirements

Stainless steels are available which are capable of meeting certain special quality tests or special requirements.

The production of such steels normally requires exacting steelmaking practices, extensive testing prior to shipment or both. The selection of heats or portions of heats, as well as additional discard, may be necessary.

The processing methods used to meet those tests and requirements may vary among the producers.

Magnetic Particle Inspection Quality. This quality designation, sometimes described as "Aircraft Quality," applies to steels for highly

stressed parts of aircraft and for other similar or corresponding purposes requiring steel of special quality.

A typical procedure for the magnetic particle method of inspection is described in ASTM E45. Recommended Practice for Determining Inclusion Content of Steel. It consists in suitably magnetizing the steel and applying a prepared magnetic powder which adheres to it along lines of flux leakage. On properly magnetized steel, flux leakage develops along surface or subsurface nonuniformities.

This method of inspection is applicable to most type numbers of the 4xx and 5xx series. It is not appropriate for use with the free machining types since those steels contain nonmetallic sulfide or selenide inclusions in large numbers. Steels of the 2xx and 3xx series do not re-

spond to magnetic particle inspection because they are essentially nonmagnetic.

The magnetic particle test was developed for and is used primarily on fully machined or ground surfaces or finished parts. When the magnetic particle test is to be applied to bar stock, short length samples should be completely machined or ground, as nearly as feasible, to the cross section and surface condition corresponding to the machined finished part they are to represent.

This method of inspection varies with the degree of magnetization, the procedure of conducting the inspection, including such conditions as relative location of surface tested, method and sequence of magnetizing and applying the powder, amperage and the interpretation of indications. The method of testing and the standard to be applied should be established in each instance.

Experience has shown that it is advisable for the purchaser to make adequate allowance for the removal from the surface of parts or bar stock of sufficient stock. The amount of removal varies with the size and to some extent with the grade and method of processing, and should be established in each instance.

Turbine Quality. This term is sometimes applied to Type 403, since this grade has been employed in the manufacture of blading for steam turbines, for compressor blading in gas turbines, as well as for other applications not related to turbines where parts are subject to high static or dynamic stresses.

Mirror-Finish Quality. This quality designation applies to stock for cutlery which must be capable of being polished to an extremely high mirror finish as a final operation. A sample of steel is either machined or forged to a flat, and then machined or ground and polished to simulate actual expected conditions of manufacture used in the finished part. The surface is then inspected for steel imperfections. There are various methods of testing and evaluating the test results. The location of tests, number of tests and interpretation of test results should be established in each instance.

Ultrasonic Quality. Stainless steel plates, bars, billets, blooms and slabs can be ultrasonically tested for quality when size, shape and grain size permit adequate transmission and reception of sound waves.

Some practices for ultrasonic nondestructive testing of stainless and heat resisting steel products are described in this section.

The test methods, calibration standards and interpretation of test results should be established in each instance.

Nuclear Quality. Nuclear quality relates to a high degree of verifiable assurance that the material was strictly produced under a quality assurance program meeting the requirements of 10CFR50 Appendix B and/or as defined by Section III of the American Society of Mechanical Engineers, Boiler and Pressure Vessel Code Committee or ANSI N45.2. These rules establish program requirements such as verifiable material identification, adherence to established processing procedures and compliance with specified chemical and material requirements. The rules do not establish superior material quality requirements from a metallurgical, dimensional or cosmetic point of view.

Special Requirements

Stainless and heat resisting steels can be produced to the following requirements:

Special Chemical Limits or Ranges. The composition ranges for the standard types shown in Table 2-1 have been developed over many years to provide the most useful combination in each instance of hot working, cold working, physical and mechanical properties, as well as corrosion resistance, high temperature properties and other properties characteristic of each type. It is recognized, however, that there are certain applications where some particular property or combination of properties is desired which may require composition ranges or limits more restrictive than those shown in Table 2-1. Where such restrictive limits or ranges are required, more exacting melting operations or selection may be involved.

Special Quenched or Tempered Hardness Requirements. The hardenable stainless steels of the 4xx series are sometimes required to attain certain minimum or maximum values or a range of hardness or other mechanical property after quenching from a specific hardening temperature, or hardening and tempering at some specific temperature. To meet those requirements usually necessitates a restricted chemical composition which should be established in each instance.

Macroetch Test. This test is generally applicable to blooms, billets, bars, structural shapes, plates and wire. It consists of immersing a properly prepared cross section of the steel in hot acid to evaluate the soundness and homogeneity of product being tested. The location of samples, number of tests, details of testing techniques and interpretation of test results should be established in each instance. ASTM A317, Standard Method of Macroetch Testing and Inspection of Steel Forgings, describes procedures for performing this test.

Nonmetallic Inclusions Test. A typical procedure for conducting the test is given in ASTM E45, Recommended Practice for Determining Inclusion Content of Steel. However, it may be difficult to obtain satisfactorily reproducible results on stainless and heat resisting steels, as shown in a Microcleanliness Survey of Type No. 304L Stainless Steel, April 1960, Contributions to the Metallurgy of Steel, published by the American Iron and Steel Institute.

The method of testing, the location of samples, number of tests and interpretation of test results should be established in each instance.

Special Mechanical and Physical Properties and Tests. Requirements for such properties and tests should be established in each instance.

Nondestructive Product Inspections

Ultrasonic Nondestructive Testing. This testing of stainless and heat resisting steel plates, bars, billets, blooms and slabs and tubular products is applicable in a wide range of sizes. Ultrasonic nondestructive testing, as used herein, is confined to the pulse echo reflection method employing either the direct contact or the immersion inspection technique.

The accuracy of ultrasonic inspection depends, to a large extent, on the surface condition of the piece to be inspected, particularly when the direct contact method is used. In general, surfaces should be clean and free from rough or loose scale. Semifinished products are often inspected after the surface has been conditioned by grinding. Finished products may be inspected with surfaces such as rolled, drawn, pickled, sand blasted, machined or ground.

The surface to be inspected is considered satisfactory if adequate transmission of the sound waves can be maintained during inspection. No further criteria of surface smoothness are required.

Internal conditions, such as grain size, segregation or structure, may impose restrictions which limit or prevent ultrasonic inspection.

Commercially available instruments of the pulse echo reflection type satisfying the following requirements are acceptable. The instrument should be capable of generating sound pulses at the frequencies and energy levels needed for the satisfactory performance of the test. It should be capable of receiving the reflected ultrasonic vibrations and suitably displaying their indications. A constant voltage regulator is generally incorporated either internally or externally in the ultrasonic instrument circuitry.

Commercially available transducers capable of transmitting and receiving sufficient ultrasonic energy, and having other characteristics

such as proper damping which result in the performance of a satisfactory inspection are considered acceptable.

Ultrasonic energy at the high frequencies employed in inspection cannot be transmitted satisfactorily through air. A fluid, such as oil, glycerin or water, is interposed between the search unit and the surface of the test piece as a transmission medium. The couplant chosen should not be injurious to the material being inspected, the equipment or the operator. Some couplants may require removal before subsequent operations.

The use of auxiliary equipment, such as automatic traversing and indexing devices, precision manipulators, collimators, monitors, recorders, flaw markers, signal alarms, special presentations, etc., may be helpful, but is not essential.

The reference standards are the benchmarks by which ultrasonic indications from discontinuities are evaluated to determine their acceptability. The exact dividing line between acceptance and rejection in terms of the reference standards is customarily given in the documents pertaining to the specific order. There are several generally used standards for evaluation of discrete indications. The standard selected depends upon the particular application and the dictates of the specific order.

There are numerous references to theory and practice of the application of ultrasonic inspection to stainless steel products. It is suggested that the stainless steel producer be consulted for further details and information and for the benefit of his experience.

Reference Documents

ASTM A388	Ultrasonic Examination of Heavy Steel Forgings
A435	Straight-Beam Ultrasonic Examination of Steel Plates for Pressure Vessels
A577	Ultrasonic Angle-Beam Examination of Steel Plates
A578	Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Application
E114	Ultrasonic Pulse-Echo Straight-Beam Testing by the Contact Method
E213	Ultrasonic Inspection of Metal Pipe and Tubing
E214	Immersed Ultrasonic Testing by the Reflecting Method Using Pulsed Longitudinal Waves
E273	Ultrasonic Inspection of Longitudinal and Spiral Welds of Welded Pipe and Tubing

Reference Documents (continued)

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|-----------|--|
| E317 | Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments |
| E409 | Description and Performance of the Microphotometer |
| E428 | Fabrication and Control of Steel Reference Blocks Used In Ultrasonic Inspection |
| E570 | Flux Leakage Examination of Ferromagnetic Steel Tubular Products |
| SNT-TC-1A | Personnel Qualification and Certification in Nondestructive Testing |

Liquid Penetrant Nondestructive Inspection. This is sometimes used as an aid to visual examination in detecting surface discontinuities on critical products. In this technique, a liquid penetrant which is either fluorescent or colored by a dye is applied to the surface, and enters any discontinuities by capillary action. After sufficient time has been allowed, excess penetrant is removed from the surface. A developer is then applied to draw penetrant from the discontinuities to the surface where it becomes visible either because of its intense color or its fluorescence under ultraviolet light.

Penetrant inspection can be very sensitive and thus readily detect discontinuities which might be overlooked in visual inspection. However, the penetrant cannot enter discontinuities not open to the surface, so the technique cannot be used to detect subsurface imperfections. Penetrant inspection can be used only to locate discontinuities and cannot determine depth. Even surface imperfections can be missed if they are scale filled; therefore, a light pickle or etch is strongly recommended. The inspection technique is not suited to surfaces so rough that excess penetrant cannot be completely removed, or to inspection of products such as hot rolled bars which are expected to contain some surface discontinuities.

Reference Documents

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|-----------|---|
| ASTM E165 | Liquid Penetrant Inspection |
| E270 | Definition of Terms Relating to Liquid Penetrant Inspection |

Eddy Current Nondestructive Testing. This testing of stainless and heat resisting steels is a method of electromagnetic testing

that uses induced electrical currents to indicate or measure certain characteristics, usually imperfections, in critical products. Applications are in one of three general categories: sorting, surface discontinuity detection or thickness measurement.

Eddy current testing has been used for detecting seams, laps, slivers, pits, cracks, voids, inclusions and cold shuts; for sorting by chemical composition on a qualitative basis; and for sorting by physical properties such as hardness, case depth and heat damage.

Eddy current tests may be absolute measurements relating only to the specified test piece of interest, or they may be comparison tests, comparing the properties of one segment with another segment of the same piece being tested, or by comparing with a similar but separate piece.

Factors that determine the minimum size of defect that can be detected include the surface condition (scale and roughness) of the product, the frequency of the magnetic field, the velocity of the product relative to the coil design, the test circuitry and the geometrical relationship of the coil or coils and the product. Most of these variables, along with the conductivity and magnetic permeability of the test piece, also govern the depth below the surface at which a defect may be detected.

A specimen of the product to be tested can be prepared to calibrate test instrumentation. The calibration standard is prepared from good material, but with artificial defects that will produce an indication in the test equivalent to the defects agreed upon by the purchaser and vendor and specified on the order.

During calibration, the equipment is adjusted so that the signal produced by the artificial defect is sufficient to cause a monitoring device to function, such as an alarm bell or light. Any product tested that does not activate the monitoring device is considered to have passed the test. Equipment calibration is checked against the artificial defect calibration standard at the start and completion of each run.

Reference Documents

- | | |
|-----------|---|
| ASTM E309 | Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation |
| E426 | Electromagnetic (Eddy-Current) Testing of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys |
| E571 | Electromagnetic (Eddy-Current) Examination of Nickel and Nickel Alloy Tubular Products |

CHEMICAL COMPOSITIONS

Table 2-1

STAINLESS STEELS

Cast or Heat Chemical Ranges and Limits

<i>Chemical Composition, Percent, Maximum Unless Otherwise Shown</i>									
UNS	Type	C	Mn	P	S	Si	Cr	Ni	Other Elements
Austenitic Stainless Steels									
N08020	—	0.06	2.00	0.035	0.035	1.00	19.0–21.0	32.5–35.0	Cu 3.0–4.0 Mo 2.00–3.00 Cb 8xC–1.00
N08024	—	0.03	1.00	0.035	0.035	0.50	22.5–25.0	35.0–40.0	Cb 0.15–0.35 Mo 3.5–5.0
N08026	—	0.03	1.00	0.03	0.03	0.50	22.0–26.0	33.0–37.0	Cu 2.0–4.0 Mo 5.0–6.7
N08330	—	0.08	2.00	0.040	0.030	0.75–1.50	17.0–20.0	34.0–37.0	Cu 1.00 Pb 0.005 Sn 0.025
N08366	—	0.03	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	Mo 6.0–7.0
N08367	—	0.03	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	Mo 6.0–7.0 Cu 0.75 N 0.18–0.25
N08700	—	0.04	2.00	0.04	0.03	1.00	19.0–23.0	24.0–26.0	Mo 4.3–5.0 Cb 8xC–0.40
N08800	—	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	Cu 0.75 Fe 39.5 min Al 0.15–0.60 Ti 0.15–0.60
N08810	—	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	Cu 0.75 Fe 39.5 min Al 0.15–0.60 Ti 0.15–0.60
N08811	—	0.06–0.10	1.50	0.040	0.015	1.00	19.0–23.0	30.0–35.0	Cu 0.75 Fe 39.5 min Al 0.15–0.60 Ti 0.15–0.60 (Al+Ti) 0.85–1.20
N08904	904L	0.02	2.00	0.045	0.035	1.00	19.0–23.0	23.0–28.0	Mo 4.0–5.0 Cu 1.00–2.00
N08926	—	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	Cu 0.5–1.5 Mo 6.0–7.0 N 0.15–0.25
S16800	—	0.05–0.10	2.00	0.040	0.030	0.75	14.5–16.5	7.5–9.5	Mo 1.50–2.00
S20100	201	0.15	5.5–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	N 0.25
S20103	201L	0.03	5.5–7.5	0.045	0.030	0.75	16.0–18.0	3.5–5.5	N 0.25
S20153	201LN	0.03	6.4–7.5	0.045	0.015	0.75	16.0–17.5	4.0–5.0	Cu 1.0 N 0.10–0.25
S20161	—	0.15	4.0–6.0	0.045	0.030	3.0–4.0	15.0–18.0	4.0–6.0	N 0.08–0.20
S20200	202	0.15	7.5–10.0	0.060	0.030	1.00	17.0–19.0	4.0–6.0	N 0.25
S20300	XM-1	0.08	5.0–6.5	0.040	0.18–0.35	1.0	16.0–18.0	5.0–6.0	Cu 1.75–2.25 Mo 0.50
S20400	—	0.030	7.0–9.0	0.040	0.030	1.00	15.0–17.0	1.50–3.00	N 0.15–0.30
S20500	205	0.12–0.25	14.0–15.5	0.060	0.030	1.00	16.0–18.0	1.00–1.75	N 0.32–0.40
S20910	XM-19	0.06	4.0–6.0	0.040	0.030	0.75	20.5–23.5	11.5–13.5	N 0.20–0.40 V 0.10–0.30 Cb 0.10–0.30 Mo 1.50–3.00
S21000	—	0.10	4.0–7.0	0.03	0.03	0.60	18.0–23.0	16.0–20.0	Cu 2.00 Mo 4.0–6.0 N 0.15
S21300	—	0.25	15.0–18.0	0.05	0.05	1.00	16.0–21.0	3.00	Cu 0.5–2.0 Mo 0.5–3.0 N 0.20–0.80
S21400	XM-31	0.12	14.0–16.0	0.045	0.030	0.30–1.00	17.0–18.5	1.00	N 0.35
S21460	XM-14	0.12	14.0–16.0	0.060	0.030	1.00	17.0–19.0	5.0–6.0	N 0.35–0.50
S21500	—	0.06–0.15	5.5–7.0	0.040	0.030	0.20–1.20	14.0–16.0	9.0–11.0	B 0.003–0.009 Cb 0.75–1.25 Mo 0.80–1.20 V 0.15–0.40
S21600	216, XM-17	0.08	7.5–9.0	0.045	0.030	0.75	17.5–22.0	5.0–7.0	Mo 2.00–3.00 N 0.25–0.50
S21603	216L, XM-18	0.03	7.5–9.0	0.045	0.030	0.75	17.5–22.0	5.0–7.0	Mo 2.00–3.00 N 0.25–0.50
S21800	—	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	N 0.08–0.18
S21900	XM-10	0.08	8.0–10.0	0.060	0.030	1.00	19.0–21.5	5.5–7.5	N 0.15–0.40
S21904	XM-11	0.040	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	N 0.15–0.40
S24000	XM-29	0.08	11.5–14.5	0.060	0.03	0.75	17.0–19.0	2.3–3.7	N 0.20–0.40
S24100	XM-28	0.15	11.0–14.0	0.060	0.030	1.00	16.5–19.5	0.5–2.5	N 0.20–0.45

Table 2-1 (Continued)

STAINLESS STEELS**Cast or Heat Chemical Ranges and Limits**

<i>Chemical Composition, Percent, Maximum Unless Otherwise Shown</i>									
UNS	Type	C	Mn	P	S	Si	Cr	Ni	Other Elements
Austenitic Stainless Steels									
S28200	—	0.15	17.0–19.0	0.045	0.030	1.00	17.0–19.0	—	Mo 0.50–1.50 N 0.40–0.60
S30100	301	0.15	2.00	0.045	0.030	0.75	16.0–18.0	6.0–8.0	N 0.10
S30103	301L	0.030	2.00	0.045	0.030	1.0	16.0–18.0	5.0–8.0	N 0.20
S30115	—	0.07–0.11	1.00–1.50	0.03	0.03	0.90–1.40	16.5–17.5	7.7–8.3	Mo 0.60–0.80
S30153	301LN	0.030	2.00	0.045	0.030	1.0	16.0–18.0	5.0–8.0	N 0.07–0.20
S30200	302	0.15	2.00	0.045	0.030	0.75	17.0–19.0	8.0–10.0	N 0.10
S30210	—	0.26–0.33	3.0–4.0	0.18–0.33	0.035	1.00	17.0–19.0	8.0–10.0	—
S30215	302B	0.15	2.00	0.045	0.030	2.00–3.00	17.0–19.0	8.0–10.0	—
S30260	—	0.15	1.00	0.20–0.40	0.040	1.00	16.0–18.0	9.5–12.0	—
S30300	303	0.15	2.00	0.20	0.15 min.	1.00	17.0–19.0	8.0–10.0	Mo 0.60 (Optional)
S30310	XM-5	0.15	2.5–4.5	0.20	0.25 min.	1.00	17.0–19.0	7.0–10.0	Mo 0.75
S30323	303Se	0.15	2.00	0.20	0.060	1.00	17.0–19.0	8.0–10.0	Se 0.15 min.
S30330	303Cu	0.15	2.00	0.15	0.10	1.00	17.0–19.0	6.0–10.0	Cu 2.5–4.0
S30345	XM-2	0.15	2.00	0.05	0.11–0.16	1.00	17.0–19.0	8.0–10.0	Al 0.60–1.00 Mo 0.40–0.60
S30360	303Pb	0.15	2.00	0.040	0.12–0.30	1.00	17.0–19.0	8.0–10.0	Mo 0.75 Pb 0.12–0.30
S30400	304	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–10.0	N 0.10
S30403	304L	0.03	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	N 0.10
S30409	304H	0.04–0.10	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	—
S30415	—	0.04–0.06	0.80	0.045	0.030	1.0–2.0	18.0–19.0	9.0–10.0	N 0.12–0.18 Ce 0.03–0.08
S30430	304 Cu, XM-7	0.10	2.00	0.045	0.030	1.00	17.0–19.0	8.0–10.0	Cu 3.0–4.0
S30451	304N	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	N 0.10–0.16
S30452	XM-21	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	N 0.16–0.30
S30453	304LN	0.03	2.00	0.045	0.030	0.75	18.0–20.0	8.0–12.0	N 0.10–0.16
S30454	304LHN	0.03	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	N 0.16–0.30
S30500	305	0.12	2.00	0.045	0.030	0.75	17.0–19.0	10.5–13.0	—
S30600	—	0.018	2.00	0.020	0.020	3.7–4.3	17.0–18.5	14.0–15.5	Mo 0.20
S30601	—	0.015	0.50–0.80	0.030	0.013	5.0–5.6	17.0–18.0	17.0–18.0	Mo 0.20 Cu 0.35 N 0.050
S30615	—	0.16–0.24	2.00	0.030	0.030	3.2–4.0	17.0–19.5	13.5–16.0	Al 0.8–1.5
S30800	308	0.08	2.00	0.045	0.030	1.00	18.0–21.0	10.0–12.0	—
S30815	—	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	N 0.14–0.20 Ce 0.03–0.08
S30900	309	0.20	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	—
S30908	309S	0.08	2.00	0.045	0.030	0.75	22.0–24.0	12.0–15.0	—
S30909	309H	0.04–0.10	2.00	0.045	0.030	0.75	22.0–24.0	12.0–15.0	—
S30940	309Cb	0.08	2.00	0.045	0.030	0.75	22.0–24.0	12.0–16.0	Cb 10xC–1.10
S30941	309HCb	0.04–0.10	2.00	0.045	0.030	0.75	22.0–24.0	12.0–16.0	Cb 10xC–1.10
S31000	310	0.25	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	—
S31008	310S	0.08	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	—
S31009	310H	0.04–0.10	2.00	0.045	0.030	0.75	24.0–26.0	19.0–22.0	—
S31040	310Cb	0.08	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	Cb 10xC–1.10
S31041	310HCb	0.04–0.10	2.00	0.045	0.030	0.75	24.0–26.0	19.0–22.0	Cb 10xC–1.10
S31042	310HCbN	0.04–0.10	2.00	0.030	0.030	0.75	17.0–23.0	24.0–26.0	Cb+Ta 0.20–0.60 N 0.15–0.35
S31050	310MoLN	0.030	2.00	0.030	0.010	0.50	24.0–26.0	21.0–23.0	Mo 2.00–3.00 N 0.10–0.16
S31254	—	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	Mo 6.00–6.50 Cu 0.50–1.00 N 0.18–0.22
S31266	—	0.030	2.0–4.0	0.035	0.020	1.00	23.0–25.0	21.0–24.0	Mo 5.2–6.2 N 0.35–0.60 Cu 1.00–2.50 W 1.50–2.50
S31272	—	0.08–0.12	1.50–2.00	0.030	0.015	0.30–0.70	14.0–16.0	14.0–16.0	Mo 1.0–1.4 Ti 0.3–0.6 B 0.004–0.008
S31400	314	0.25	2.00	0.045	0.030	1.50–3.00	23.0–26.0	19.0–22.0	—
S31600	316	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	Mo 2.0–3.0 N 0.10
S31603	316L	0.03	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	Mo 2.0–3.0 N 0.10
S31609	316H	0.04–0.10	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	Mo 2.0–3.0
S31620	316F	0.08	2.00	0.20	0.10 min.	1.00	17.0–19.0	12.0–14.0	Mo 1.75–2.50
S31635	316Ti	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	Ti 5x(C+N)–0.70 Mo 2.0–3.0 N 0.10
S31640	316Cb	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	Cb 10xC–1.10 Mo 2.0–3.0 N 0.10
S31651	316N	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	Mo 2.0–3.0 N 0.10–0.16
S31653	316LN	0.030	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	Mo 2.0–3.0 N 0.10–0.16
S31654	316LHN	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	Mo 2.00–3.00 N 0.16–0.30
S31700	317	0.08	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	Mo 3.0–4.0 N 0.10

Table 2-1 (Continued)

STAINLESS STEELS
Cast or Heat Chemical Ranges and Limits

<i>Chemical Composition, Percent, Maximum Unless Otherwise Shown</i>									
<i>UNS</i>	<i>Type</i>	<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Other Elements</i>
Austenitic Stainless Steels									
S31703	317L	0.030	2.00	0.045	0.030	0.75	18.0-20.0	11.0-15.0	Mo 3.0-4.0 N 0.10
S31725	-	0.030	2.00	0.045	0.030	0.75	18.0-20.0	13.5-17.5	Mo 4.0-5.0 N 0.10
S31726	-	0.030	2.00	0.045	0.030	0.75	18.0-20.0	13.5-17.5	Mo 4.0-5.0 N 0.10-0.20
S31753	317LN	0.030	2.00	0.045	0.030	0.75	18.0-20.0	11.0-15.0	Mo 3.0-4.0 N 0.10-0.22
S32100	321	0.08	2.00	0.045	0.030	0.75	17.0-19.0	9.0-12.0	Ti 5x(C+N)-0.70 N 0.10
S32109	321H	0.04-0.10	2.00	0.045	0.030	0.75	17.0-19.0	9.0-12.0	Ti 4x(C+N)-0.70
S32615	-	0.07	2.00	0.045	0.030	4.8-6.0	16.5-19.5	19.0-22.0	Cu 1.5-2.5 Mo 0.30-1.5
S32654	-	0.020	2.0-4.0	0.030	0.005	0.50	24.0-25.0	21.0-23.0	Mo 7.0-8.0 N 0.45-0.55 Cu 0.30-0.60
S33100	-	0.10-0.20	0.50-0.80	0.030	0.030	1.00-1.40	7.0-9.0	19.0-22.0	-
S33228	-	0.04-0.08	1.00	0.020	0.015	0.30	26.0-28.0	31.0-33.0	Ce 0.05-0.10 Cb 0.6-1.0 Al 0.025
-	332	0.08	2.00	0.040	0.030	0.75	19.0-23.0	30.0-34.0	Al 0.60 Ti 0.60
-	334	0.08	1.00	0.040	0.030	0.75	18.0-22.0	18.0-22.0	Al 0.60 Ti 0.60
S34565	-	0.030	5.0-7.0	0.030	0.010	1.00	23.0-25.0	16.0-18.0	Mo 4.0-5.0 Cb 0.10 N 0.40-0.60
S34700	347	0.080	2.00	0.045	0.030	0.75	17.0-19.0	9.0-13.0	Cb 10xC-1.00
S34709	347H	0.04-0.10	2.00	0.045	0.030	0.75	17.0-19.0	9.0-13.0	Cb 8xC-1.00
S34720	-	0.08	2.00	0.040	0.18-0.35	1.00	17.0-19.0	9.0-12.0	Cb 10xC-1.10
S34723	-	0.08	2.00	0.11-0.17	0.030	1.00	17.0-19.0	9.0-12.0	Cb 10xC-1.10 Se 0.15-0.35
S34800	348	0.08	2.00	0.045	0.030	0.75	17.0-19.0	9.0-13.0	(Cb+Ta) 10xC-1.00 Ta 0.10 Co 0.20
S34809	348H	0.04-0.10	2.00	0.045	0.030	0.75	17.0-19.0	9.0-13.0	(Cb+Ta) 8xC-1.00 Ta 0.10 Co 0.20
S35315	-	0.04-0.08	2.00	0.040	0.030	1.20-2.00	24.0-26.0	34.0-36.0	Ce 0.03-0.08 N 0.12-0.18
S38100	XM-15	0.08	2.00	0.030	0.030	1.50-2.50	17.0-19.0	17.5-18.5	-
S38400	384	0.08	2.00	0.045	0.030	1.00	15.0-17.0	17.0-19.0	-
S38660	-	0.08	1.65-2.35	0.040	0.010	0.50-1.0	12.50-14.50	14.5-16.5	Al 0.050 As 0.030 B 0.0020 Cb 0.050 Co 0.050 Cu 0.04 Mo 1.50-2.50 N 0.005 Ta 0.020 Ti 0.10-0.40 V 0.05 Mo 0.50
S70003	-	0.020	2.00	0.025	0.010	6.5-8.0	8.0-11.0	22.0-25.0	
Duplex (Austenitic-Ferritic) Stainless Steels									
S31100	XM-26	0.06	1.00	0.040	0.030	1.00	25.0-27.0	6.0-7.0	Ti 0.025
S31200	-	0.030	2.00	0.045	0.030	1.00	24.0-26.0	5.5-6.5	Mo 1.2-2.0 N 0.14-0.20
S31260	-	0.03	1.00	0.030	0.030	0.75	24.0-26.0	5.5-7.5	Mo 2.5-3.5 Cu 0.20-0.80 N 0.10-0.30 W 0.10-0.50
S31500	-	0.03	1.20-2.00	0.03	0.03	1.40-2.00	18.0-19.0	4.3-5.2	Mo 2.50-3.00
S31803	-	0.030	2.00	0.030	0.020	1.00	21.0-23.0	4.5-6.5	Mo 2.5-3.5 N 0.08-0.20
S32001	-	0.03	4.0-6.0	0.040	0.030	1.00	19.5-21.5	1.0-3.0	Cu 1.00 Mo 0.60 N 0.05-0.17
S32050	-	0.030	1.50	0.035	0.020	1.00	22.0-23.0	6.0-6.8	Cu 0.40 N 0.21-0.32
S32205	-	0.030	2.00	0.030	0.020	1.00	22.0-23.0	4.5-6.5	Mo 3.0-3.5 N 0.14-0.20
S32304	-	0.030	2.50	0.040	0.030	1.00	21.5-24.5	3.0-5.5	Mo 0.05-0.60 N 0.05-0.20
S32520	-	0.030	1.50	0.035	0.020	0.80	24.0-26.0	3.0-5.0	Cu 0.50-3.00 N 0.20-0.35
S32550	-	0.040	1.5	0.040	0.030	1.00	24.0-27.0	4.5-6.5	Cu 1.5-2.5 Mo 2.9-3.9 N 0.10-0.25
S32750	-	0.030	1.20	0.035	0.020	0.80	24.0-26.0	6.0-8.0	Mo 3.0-5.0 N 0.24-0.32 Cu 0.50
S32760	-	0.030	1.00	0.030	0.010	1.00	24.0-26.0	6.0-8.0	Mo 3.0-4.0 N 0.20-0.30 Cu 0.50-1.00 W 0.50-1.00 Cr+3.3xMo+16xN≥40
S32900	329	0.08	1.00	0.040	0.030	0.75	23.0-28.0	2.5-5.0	Mo 1.0-2.0
S32906	-	0.03	0.8-1.5	0.03	0.003	0.50	28-30	5.8-7.5	Cu 0.8 Mo 1.5-2.6 N 0.3-0.4
S32950	-	0.03	2.00	0.035	0.010	0.60	26.0-29.0	3.5-5.2	Mo 1.00-2.50
S39274	-	0.030	1.00	0.030	0.020	1.00	24.0-26.0	6.0-8.0	Mo 2.5-3.5 Cu 0.20-0.80 W 1.5-2.5 N 0.24-0.32
S39277	-	0.025	1.00	0.025	0.002	0.80	24.0-26.0	6.5-8.0	Mo 3.0-4.0 W 0.8-1.2 N 0.23-0.33 Cu 1.2-2.0

Table 2-1 (Continued)

STAINLESS STEELS
Cast or Heat Chemical Ranges and Limits

<i>Chemical Composition, Percent, Maximum Unless Otherwise Shown</i>									
<i>UNS</i>	<i>Type</i>	<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Other Elements</i>
Ferritic Chromium Stainless Steels									
S18200	XM-34	0.08	1.25-2.50	0.040	0.15 min.	1.00	17.5-19.5	—	Mo 1.50-2.50
S18235	—	0.025	0.50	0.030	0.15-0.35	1.00	17.5-18.5	1.00	Mo 2.00-2.50 Ti 0.30-1.00
S32803	—	0.015	0.50	0.020	0.0035	0.55	28.0-29.0	3.0-4.0	Mo 1.8-2.5 N 0.020 Cb 0.15-0.50 and 12(C+N) Min. (C+N) 0.030
S40500	405	0.08	1.00	0.040	0.030	1.00	11.5-14.5	0.60	Al 0.10-0.30
S40800	—	0.08	1.00	0.045	0.045	1.00	11.5-13.0	0.80	Ti 12xC-1.10
S40900	409	0.08	1.00	0.045	0.030	1.00	10.50-11.75	0.50	Ti 6xC-0.75
S40910	—	0.030	1.00	0.040	0.020	1.00	10.5-11.7	0.50	Ti 6x(C+N) Min.-0.50 Max Cb 0.17 N 0.030
S40920	—	0.030	1.00	0.040	0.020	1.00	10.5-11.7	0.50	Ti 8x(C+N) Min. 0.15-0.5 Cb 0.10 N 0.030
S40930	—	0.030	1.00	0.040	0.020	1.00	10.5-11.7	0.50	(Cb+Ti)0.08+8(C+N) Min.-0.75 Max N 0.030
S40940	409Cb	0.06	1.00	0.045	0.040	1.00	10.5-11.7	0.50	Cb 10xC Min.-0.75 Max
S40945	—	0.030	1.00	0.040	0.030	1.00	10.50-11.75	0.50	Cb 0.18-0.40 N 0.030
S40975	—	0.030	1.00	0.040	0.030	1.00	10.5-11.7	0.50-1.00	Ti 6(C+N) Min.-0.75 Max N 0.030
S40976	409Ni-Cb	0.030	1.00	0.040	0.030	1.00	10.5-11.7	0.75-1.00	Cb 10x(C+N)-0.80 N 0.040
S41045	—	0.030	1.00	0.040	0.030	1.00	12.0-13.0	0.50	Cb 9(C+N) Min.-0.60 Max N 0.030
S41050	—	0.040	1.00	0.045	0.030	1.00	10.5-12.5	0.60-1.10	N 0.10
S41603	—	0.08	1.25	0.06	0.15 Min	1.00	12.0-14.0	—	—
S42400	—	0.06	0.50-1.00	0.030	0.030	0.30-0.60	12.0-14.0	3.5-4.5	Mo 0.30-0.70
S42900	429	0.12	1.00	0.040	0.030	1.00	14.0-16.0	0.75	—
S43000	430	0.12	1.00	0.040	0.030	1.00	16.0-18.0	0.75	—
S43020	430F	0.12	1.25	0.060	0.15 min.	1.00	16.0-18.0	—	Mo 0.60 (Optional)
S43023	430FSe	0.12	1.00	0.060	0.060	1.00	16.0-18.0	—	Se 0.15 Min.
S43035	439	0.07	1.00	0.040	0.030	1.00	17.0-19.0	0.50	Ti 0.20+4(C+N)-1.10 Al 0.15 N 0.04
S43036	430Ti	0.10	1.00	0.040	0.030	1.00	16.0-19.5	0.60	Ti 5xC-0.75
S43400	434	0.12	1.00	0.040	0.030	1.00	16.0-18.0	—	Mo 0.75-1.25
S43600	436	0.12	1.00	0.040	0.030	1.00	16.0-18.0	—	Mo 0.75-1.25 (Cb+Ta) 5xC-0.70
S43932	—	0.030	1.00	0.040	0.030	1.00	17.0-19.0	0.50	N 0.030 Al 0.15 Ti+Cb 0.20+4(C+N) Min-0.75 Max.
S44200	442	0.20	1.00	0.040	0.030	1.00	18.0-23.0	—	—
S44300	443	0.20	1.00	0.040	0.030	1.00	18.0-23.0	0.50	Cu 0.90-1.25
S44400	444	0.025	1.00	0.040	0.030	1.00	17.5-19.5	1.00	(Ti+Cb) {0.20+4(C+N)}-0.80 Mo 1.75-2.50 N 0.035
S44500	—	0.020	1.00	0.040	0.012	1.00	19.0-21.0	0.60	Cu 0.30-0.60 N 0.03 Cb 10x(C+N)-0.80
S44600	446	0.20	1.50	0.040	0.030	1.00	23.0-27.0	0.25	—
S44626	XM-33	0.06	0.75	0.040	0.020	0.75	25.0-27.0	0.50	Mo 0.75-1.50 N 0.04 Cu 0.20 Ti 0.20-1.00 Ti 7x(C+N) Min.
S44627	XM-27	0.010	0.40	0.020	0.020	0.40	25.0-27.5	0.50	Mo 0.75-1.50 Cb 0.05-0.20 N 0.015 (Ni+Cu) 0.50
S44635	—	0.025	1.00	0.040	0.030	0.75	24.5-26.0	3.5-4.5	Mo 3.5-4.5 N 0.035 (Cb+Ti) 0.20+4 (C+N)-0.80
S44660	—	0.030	1.00	0.040	0.030	1.00	25.0-28.0	1.0-3.50	Mo 3.0-4.0 N 0.040 (Ti+Cb) 0.20-1.00 and 6(C+N) Min.
S44700	—	0.010	0.30	0.025	0.020	0.20	28.0-30.0	0.15	Mo 3.5-4.2 N 0.020 (C+N) 0.025 Cu 0.15
S44735	—	0.030	1.00	0.040	0.030	1.00	28.0-30.0	1.00	Mo 3.6-4.2 N 0.045 (Ti+Cb) 0.20-1.00 and 6(C+N) Min.
S44800	—	0.010	0.30	0.025	0.020	0.20	28.0-30.0	2.0-2.5	Mo 3.5-4.2 Cu 0.15 N 0.020 (C+N) 0.025
S46800	—	0.030	1.00	0.040	0.030	1.00	18.0-20.0	0.50	Ti 0.07-0.30 Cb 0.10-0.60 Ti+Cb=0.20+4(C+N)Min. and 0.80 Max. N 0.030

Table 2-1 (Continued)

STAINLESS STEELS**Cast or Heat Chemical Ranges and Limits**

<i>Chemical Composition, Percent, Maximum Unless Otherwise Shown</i>									
UNS	Type	C	Mn	P	S	Si	Cr	Ni	Other Elements
Martensitic Chromium Stainless Steels									
S40300	403	0.15	1.00	0.04	0.03	0.50	11.50-13.0	0.60	—
S41000	410	0.15	1.00	0.04	0.03	1.00	11.5-13.0	0.75	—
S41001	—	0.15	1.00	0.025	0.025	1.00	11.5-13.5	0.75	Al 0.05 Cu 0.05 Mo 0.50 Sn 0.05
S41003	—	0.030	1.50	0.040	0.030	1.00	10.5-12.5	1.50	N 0.030
S41008	410S	0.08	1.00	0.040	0.030	1.00	11.5-13.5	0.60	—
S41025	—	0.15	1.00	0.040	0.030	1.00	11.5-13.5	0.60	Mo 0.40-0.60
S41026	—	0.15	1.00	0.02	0.02	1.00	11.5-13.5	1.0-2.0	Cu 0.50 Mo 0.40-0.60
S41040	XM-30, 410 Cb	0.15	1.00	0.040	0.030	1.00	11.5-13.5	—	Cb 0.05-0.20
S41041	—	0.13-0.18	0.40-0.60	0.030	0.030	0.50	11.5-13.0	0.50	Al 0.05 Cb 0.15-0.45 Mo 0.20
S41045	—	0.030	1.00	0.040	0.030	1.00	12.0-13.0	0.50	Cb 9(C+N)-0.60 N 0.030
S41050	—	0.040	1.00	0.045	0.030	1.00	10.5-12.5	0.60-1.10	N 0.10
S41400	414	0.15	1.00	0.040	0.030	1.00	11.5-13.5	1.25-2.50	—
S41425	—	0.05	0.50-1.00	0.020	0.005	0.50	12.0-15.0	4.0-7.0	Mo 1.5-2.0 N 0.06-0.12 Cu 0.30
S41426	—	0.03	0.50	0.02	0.005	0.50	11.5-13.5	4.5-6.5	Mo 1.5-3.0 Ti 0.01-0.50 V 0.50
S41500 ^a	—	0.050	0.5-1.0	0.030	0.030	0.60	11.5-14.0	3.5-5.5	Mo 0.50-1.00
S41600	416	0.15	1.25	0.060	0.15 Min.	1.00	12.0-14.0	—	Mo 0.60 (Optional)
S41603	—	0.08	1.25	0.06	0.15 Min.	1.00	12.0-14.0	—	—
S41610	XM-6	0.15	1.50-2.50	0.060	0.15 Min.	1.00	12.0-14.0	—	Mo 0.60
S41623	416 Se	0.15	1.25	0.060	0.060	1.00	12.0-14.0	—	Se 0.15 min.
S41800	615	0.15-0.20	0.50	0.040	0.030	0.50	12.0-14.0	1.80-2.20	W 2.5-3.5
S42000	420	0.15 min.	1.00	0.040	0.030	1.00	12.0-14.0	—	—
S42010	—	0.15-0.30	1.00	0.040	0.030	1.00	13.5-15.0	0.25-1.00	Mo 0.40-1.00
S42020	420F	0.15 min.	1.25	0.06	0.15 min.	1.25	12.0-14.0	—	Mo 0.60
S42023	420FSe	0.30-0.40	1.25	0.06	0.060	1.25	12.0-14.0	—	Mo 0.60 Se 0.15 Min. Zr or Cu 0.60
S42200	422	0.20-0.25	1.00	0.040	0.030	0.75	11.5-13.5	0.50-1.00	Mo 0.75-1.25
S42201	—	0.20-0.25	0.50-1.00	0.025	0.025	0.20-0.60	11.0-13.5	0.75-1.25	Al 0.05 Co 0.25 Mo 0.75-1.25 Ti 0.05 V 0.20-0.30 W 0.75-1.25
S42300	619	0.27-0.32	0.95-1.35	0.025	0.025	0.50	11.0-12.0	0.50	Mo 2.50-3.00 V 0.20-0.30
S42390	—	0.18-0.25	1.00	0.030	0.030	1.00	11.5-12.5	0.30-0.80	Mo 0.80-1.20 Cb 0.08-0.15 N 0.03-0.08 V 0.25-0.35 Cu 0.35 Mo 3.7-4.2 V 1.10-1.30
S42700	—	1.05-1.15	0.25-0.50	0.015	0.010	0.20-0.40	13.7-14.8	0.40	Cb 0.25-0.35 Cu 0.35 Mo 1.90-2.25 V 0.90-1.15
S42800	—	1.05-1.15	0.25-0.50	0.015	0.010	0.20-0.40	13.7-14.8	0.35	—
S43100	431	0.20	1.00	0.040	0.030	1.00	15.0-17.0	1.25-2.50	—
S44002	440A	0.60-0.75	1.00	0.040	0.030	1.00	16.0-18.0	—	Mo 0.75
S44003	440B	0.75-0.95	1.00	0.040	0.030	1.00	16.0-18.0	—	Mo 0.75
S44004	440C	0.95-1.20	1.00	0.040	0.030	1.00	16.0-18.0	—	Mo 0.75
S44020	440F	0.95-1.20	1.25	0.040	0.10-0.35	1.00	16.0-18.0	0.08	Mo 0.40-0.60
S44023	440FSe	0.95-1.10	1.25	0.040	0.030	1.00	16.0-18.0	0.08	Mo 0.60 Se 0.15 Min.
S44025	—	0.95-1.10	1.00	0.025	0.025	1.00	16.0-18.0	0.75	Mo 0.40-0.65
S50100	501	0.10 min.	1.00	0.040	0.030	1.00	4.0-6.0	—	Mo 0.40-0.65
—	501A	0.15	0.30-0.60	0.030	0.030	0.50-1.00	6.0-8.0	—	Mo 0.45-0.65
—	501B	0.15	0.30-0.60	0.030	0.030	0.50-1.00	8.0-10.0	—	Mo 0.90-1.10
S50200	502	0.10	1.00	0.040	0.030	1.00	4.0-6.0	—	Mo 0.40-0.65
S50300	—	0.15	1.00	0.040	0.040	1.00	6.0-8.0	—	Mo 0.45-0.65
S50400	—	0.15	1.00	0.040	0.040	1.00	8.0-10.0	—	Mo 0.90-1.10
S64152	XM-32	0.08-0.15	0.50-0.90	0.025	0.025	0.35	11.0-12.5	2.00-3.00	N 0.01-0.05
Precipitation Hardening Stainless Steels									
S13800	XM-13	0.05	0.20	0.01	0.008	0.10	12.3-13.2	7.5-8.5	Mo 2.0-2.5 Al 0.90-1.35 N 0.01
S14800	—	0.05	1.00	0.015	0.010	1.00	13.75-15.0	7.75-8.75	Al 0.75-1.5 Mo 2.0-3.0
S15500	XM-12	0.07	1.00	0.04	0.03	1.00	14.0-15.5	3.5-5.5	Cu 2.5-4.5 (Cb+Ta) 0.15-0.45
S15700	632	0.09	1.00	0.04	0.03	1.00	14.0-16.0	6.5-7.75	Mo 2.0-3.0 Al 0.75-1.5
S17400	630	0.07	1.00	0.04	0.03	1.00	15.0-17.5	3.0-5.0	Cu 3.0-5.0 (Cb+Ta) 0.15-0.45

^aWrought version of CA6NM

Table 2-1 (Continued)

STAINLESS STEELS**Cast or Heat Chemical Ranges and Limits**

<i>Chemical Composition, Percent, Maximum Unless Otherwise Shown</i>									
<i>UNS</i>	<i>Type</i>	<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Other Elements</i>
S17600	635	0.08	1.00	0.04	0.03	1.00	16.0-17.5	6.0-7.5	Ti 0.4-1.2 Al 0.4
S17700	631	0.09	1.00	0.04	0.03	1.00	16.0-18.0	6.5-7.75	Al 0.75-1.50
S35000	633	0.07-0.11	0.5-1.25	0.04	0.03	0.50	16.0-17.0	4.0-5.0	Mo 2.50-3.25 N 0.07-0.13
S35500	634	0.10-0.15	0.5-1.25	0.04	0.03	0.50	15.0-16.0	4.0-5.0	Mo 2.50-3.25
S36200	XM-9	0.05	0.50	0.04	0.03	0.30	14.0-14.5	6.25-7.0	Ti 0.55-0.90
S45000	XM-25	0.05	1.00	0.03	0.03	1.00	14.0-16.0	5.0-7.0	Cu 1.25-1.75 Mo 0.5-1.0 Cb 8xC min.
S45500	XM-16	0.05	0.50	0.04	0.03	0.50	11.0-12.5	7.5-9.5	Cu 1.5-2.5 Mo 0.5 Ti 0.8-1.4 (Cb+Ta) 0.01-0.05
S63198	651	0.28-0.35	0.40-1.00	0.040	0.030	0.30-0.80	18.0-21.0	8.0-11.0	Mo 1.00-1.75 Cu 0.50 W 1.00-1.75 Ti 0.10-0.35 Cb 0.25-0.60
S66220	662	0.08	0.40-1.00	0.040	0.030	0.40-1.00	12.0-15.0	24.0-28.0	Mo 2.0-3.5 Cu 0.50 Al 0.35 Ti 1.80-2.10 B 0.001-0.010
S66286	660	0.08	2.00	0.04	0.03	1.00	13.5-16.0	24.0-27.0	Al 0.35 B 0.0010-0.010 Mo 1.00-1.50
S66545	665	0.08	1.25-2.00	0.040	0.030	0.10-0.80	12.0-15.0	24.0-28.0	Ti 1.90-2.35 V 0.10-0.50 Mo 1.25-2.25 Cu 0.25 Al 0.25 Ti 2.7-3.3 B 0.01-0.07

DESCRIPTIONS OF ALLOYS, THEIR PROPERTIES AND APPLICATIONS

This section provides data on 130 of the most commonly used stainless steels. There are specifications for most of these steels in the ASTM Book of Standards.

The physical property data, for the most part, consist of typical values which may be used as a guide in the selection of a particular type of steel for a specific purpose, but if a specific physical property is critical to the intended application it is recommended that more specific and more detailed information should be obtained from the steel producer.

The mechanical property data are generally based on requirements listed in ASTM specifications for the various steel product forms. Since these specifications are subject to peri-

odic revision, the most recent issue of the referenced ASTM specification should be consulted.

The mechanical properties of selected martensitic stainless steels after hardening and tempering are shown in Table 3-1.

Additional information on the properties of stainless steels may be found in many publications such as *Design Guidelines for the Selection and Use of Stainless Steels*, a publication of the Specialty Steel Industry of North America, 3050 K Street NW, Washington, DC 20007, tel. 800-982-0355; fax 202-338-5534; and *ASM Specialty Handbook®—Stainless Steels*, a publication of ASM International, Materials Park, OH 44073-0002, tel. 440-338-5151; fax 440-338-4634.

Table 3-1

NOMINAL MECHANICAL PROPERTIES OF SELECTED MARTENSITIC STAINLESS STEELS As Quenched Hardness and Properties After Hardening and Tempering 1 in. (25.4 mm) Diameter Bars

Type	UNS	Hardening Temp. °F (°C)		As Quenched Hardness HB HR		Tempering Temp. °F (°C)		Tensile Strength ksi (MPa)	Yield Strength 0.2% Offset ksi (MPa)	Elongation in 2 in. (50.8 mm)	Red. of Area (50.8 mm)	Izod Impact V-Notch Ft · lbf (J)	Tempered Hardness HB HR	
403 and 410	S40300 S41000	1800	(981)	410	C43	400 (204)		190 (1310)	145 (1000)	15	55	35 (47)	390	C41
						600 (315)		180 (1241)	140 (965)	15	55	35 (47)	375	C39
						*800 (426)		195 (1344)	150 (1034)	17	55		390	C41
						*1000 (538)		145 (1000)	115 (793)	20	65		300	C31
						1200 (648)		110 (758)	85 (586)	23	65	75 (102)	225	B97
						1400 (760)		90 (621)	60 (414)	30	70	100 (136)	180	B89
416 and 416 Se	S41600 S41623	1800	(981)	410	C43	400 (204)		190 (1310)	145 (1000)	12	45	20 (27)	390	C41
						600 (315)		180 (1241)	140 (965)	13	45	20 (27)	375	C39
						*800 (426)		195 (1344)	150 (1034)	13	50		390	C41
						*1000 (538)		145 (1000)	115 (793)	15	50		300	C31
						1200 (648)		110 (758)	85 (586)	18	55	30 (41)	225	B97
						1400 (760)		90 (621)	60 (414)	25	60	60 (81)	180	B89
414	S41400	1800	(981)	425	C44	400 (204)		100 (1379)	150 (1034)	15	55	45 (61)	410	C43
						600 (315)		190 (1310)	145 (1000)	15	55	45 (61)	400	C41
						800 (426)		200 (1379)	150 (1034)	16	58		415	C43
						*1000 (538)		145 (1000)	120 (827)	20	60		290	C30
						1200 (760)		120 (827)	105 (724)	20	65	50 (68)	250	C22
431	S43100	1900	(1036)	440	C45	400 (204)		205 (1413)	155 (1069)	15	55	30 (41)	415	C43
						600 (315)		195 (1344)	150 (1034)	15	55	45 (61)	400	C41
						*800 (426)		205 (1413)	155 (1069)	15	60		415	C43
						*1000 (538)		150 (1034)	130 (896)	18	60		325	C34
						1200 (760)		125 (862)	95 (655)	20	60	50 (68)	260	C24
420	S42000	1900	(1036)	540	C54	600 (315)		230 (1586)	195 (1344)	8	25	10 (14)	500	C50
440A	S44002	1900	(1036)	570	C56	600 (315)		260 (1793)	240 (1655)	5	20	4 (5)	510	C51
440B	S44003	1900	(1036)	590	C58	600 (315)		280 (1931)	270 (1862)	3	15	3 (4)	555	C55
440C	S44004	1900	(1036)	610	C60	600 (315)		285 (1965)	275 (1896)	2	10	2 (3)	580	C57

*Tempering within the range of 750 to 1050°F (399 to 565°C) is not recommended because such treatment will result in low and erratic impact properties and loss of corrosion resistance. Variations in chemical composition within the individual type ranges may affect the mechanical properties.

UNS N08020—20Cb-3®; Alloy 20; 3620Nb

Austenitic

20Cb-3 is an austenitic stainless steel with excellent resistance to hot sulfuric acid and many aggressive environments which readily attack Type 316 stainless steel. It has excellent resistance to stress-corrosion cracking. It is weldable, machineable and formable. Assemblies are usually placed in service in the as-welded condition.

Applications are found in the processing of synthetic rubber, high-octane gasoline, solvents, explosives, plastics, synthetic fibers, heavy chemicals, organic chemicals, pharmaceuticals and agrichemicals. Where purity must be maintained in the processing of products such as foodstuffs or dyes, the alloy has been used to protect end products from the danger of metallic contamination.

UNS N08020
Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Cb
0.07	2.00	0.045	0.035	1.00	19.0	32.0	2.0	3.0	8 × C
Max	Max	Max	Max	Max	21.0	38.0	3.0	4.0	1.0

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0 × 10 ⁶	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.292	8,080

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
1.082

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
212°F	100°C
7.57	13.1

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
77-212°F	25-100°C
8.6 × 10 ⁻⁶	14.69 × 10 ⁻⁶
77-842°F	25-450°C
8.84 × 10 ⁻⁶	15.91 × 10 ⁻⁶
77-1652°F	25-900°C
9.53 × 10 ⁻⁶	17.15 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2500-2600	1371-1427

Magnetic Permeability

<i>H/m Annealed</i>
1.002

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2250	1149-1232

Annealing

<i>°F</i>	<i>°C</i>
1725-1850	941-1010

Annealing

Heat to above temperature for ½ h/in of thickness and water quench.

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS N08020

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Stabilized- annealed	B463	80(551)	35(241)	30 ^a	—	217	95B
Bar							
Stabilized- annealed, hot or cold finished	B473	80(551)	35(241)	30	50	—	—
Stabilized- annealed, strain hardened [up to 2 in (50.8 mm) diameter]	B473	90(620)	60(415)	15	40	—	—
Wire							
Cold finished	B473	90-120 (620-830)	—	—	—	—	—

^aFor thickness less than 0.015 in (0.38 mm) the minimum elongation is 20% in 1 in (25.4 mm).

UNS N08024—Alloy 20Mo-4®

Austenitic

20Mo-4 is a highly corrosion-resistant austenitic stainless steel which complements 20Cb-3 and 20Mo-6. It is designed for applications requiring improved resistance to pitting and crevice corrosion in acid environments. For applications requiring maximum resistance to pitting and crevice corrosion 20Mo-6 should be considered.

Potential applications for 20Mo-4 include heat exchangers, chemical process piping and equipment, mixing tanks and metal cleaning and pickling tanks. Other possible applications include flue gas scrubbing systems and in wet process phosphoric acid environment.

UNS N08024
Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	Cb
0.03	1.00	0.035	0.035	0.50	22.5	35.0	3.5	0.15
Max	Max	Max	Max	Max	25.0	40.0	5.0	0.35

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
27.0 × 10 ⁶	186,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.293	8,106

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
1,056

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.109	0.458

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F	100°C
7.51	13.0

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
77-392°F	8.29 × 10 ⁻⁶	25-200°C	14.92 × 10 ⁻⁶
77-572°F	8.66 × 10 ⁻⁶	25-300°C	15.58 × 10 ⁻⁶
77-572°F	8.96 × 10 ⁻⁶	25-400°C	16.12 × 10 ⁻⁶
77-932°F	9.17 × 10 ⁻⁶	25-500°C	16.50 × 10 ⁻⁶
77-1112°F	9.44 × 10 ⁻⁶	25-600°C	17.0 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2480	1360

Magnetic Permeability

<i>H/m Annealed</i>
No Data

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2200-2250	1204-1232

Annealing

<i>°F</i>	<i>°C</i>
1925-1975	1052-1079

Annealing

Heat to above temperature for ½ h/in of thickness and water quench.

Hardening

Hardenable by cold work only.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNSN08024
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	B463	80(550)	35(240)	30.0	—	217	B95
Welded Pipe	B464	80(550)	35(240)	30.0	—	—	—

UNS N08026—20Mo-6³

Austenitic

20Mo-6 is an austenitic stainless steel which is resistant to corrosion in hot chloride environments with low pH. It has good resistance to pitting and stress-corrosion cracking in chloride environments and is also resistant to oxidizing media.

The alloy complements alloy 20Cb-3. It is designed for applications where better pitting and crevice corrosion resistance are required than that provided by 20Cb-3.

UNS N08026

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>Cu</i>
0.03	1.00	0.03	0.03	0.50	22.0	33.0	5.0	2.0
Max	Max	Max	Max	Max	26.0	37.0	6.7	4.0

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
27.0 × 10 ⁶	186,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.294	8,133

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
1,082

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.45

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F	100°C
7.51	13.0

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
212°F	100° C
392°F	200° C
572°F	300° C
752°F	400° C
932°F	500° C
1112°F	600° C
1292°F	700° C
1472°F	800° C
1652°F	900° C
8.22 × 10 ⁻⁶	14.80 × 10 ⁻⁶
8.29 × 10 ⁻⁶	14.92 × 10 ⁻⁶
8.52 × 10 ⁻⁶	15.34 × 10 ⁻⁶
8.73 × 10 ⁻⁶	15.71 × 10 ⁻⁶
8.89 × 10 ⁻⁶	16.01 × 10 ⁻⁶
9.29 × 10 ⁻⁶	16.72 × 10 ⁻⁶
9.55 × 10 ⁻⁶	17.19 × 10 ⁻⁶
9.76 × 10 ⁻⁶	17.57 × 10 ⁻⁶
9.86 × 10 ⁻⁶	17.74 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
~2520	1380

Magnetic Permeability

<i>H/m Annealed</i>
1.0056

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2200-2250	1204-1232

Annealing

<i>°F</i>	<i>°C</i>
2050-2200	1121-1204

Annealing

Heat to above temperature for ½ h/in of thickness and water quench.

Hardening

Hardenable by cold work only.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS N08026

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip Solution-Annealed	B463	80(551)	35(241)	30 ^a	—	217	95B
Bar Solution-Annealed, hot or cold finished	B473	80(551)	35(241)	30	50	—	—
Solution-Annealed, strain hardened [up to 2 in. (50.8 mm) diameter]	B473	90(620)	60(415)	15	40	—	—
Wire Cold finished	B473	90-120 (620-830)	—	—	—	—	—

^a For thickness less than 0.015 in (0.38 mm) the minimum elongation is 20% in 1 in (25.4 mm).

RA 330 is an austenitic heat- and corrosion-resistant alloy offering an exceptional combination of strength and resistance to carburization, oxidation and thermal shock. Carburization and oxidation resistance to 2200°F (1205°C) are enhanced by a nominal addition of 1.25% silicon. The alloy is widely used in high temperature industrial environments where good resistance to the combined effects of carburization and thermal cycling is a prime requisite.

The alloy remains austenitic at all temperatures and is not subject to sigma formation.

Applications include furnace containers for carburizing, carbonitriding, annealing and malleablizing; muffles and retorts; quenching fixtures; bar frame heat treating baskets; radiant tubes; salt pots, both neutral and cyanide; gas turbine parts; petrochemical furnace components; furnace fans and shafts; conveyors; and hot pressing platens.

UNS N08330

Chemical Composition Limits Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Pb	Sn	Cu
0.08	2.00	0.030	0.03	<u>0.75</u>	<u>17.0</u>	<u>34.0</u>	0.005	0.025	1.00
Max	Max	Max	Max	1.50	20.0	37.0	Max	Max	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
28.5×10^6	196,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.287	7,944

Electrical Resistivity

Microhm — mm

75 F	(24 C)	1020
1000 F	(538 C)	1110
1200 F	(649 C)	1130
1400 F	(760 C)	1200
1600 F	(871 C)	1240
1800 F	(982 C)	1270
2000 F	(1093 C)	1390

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.117	0.490

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
75°F	7.2
1000°F	12.8
1200°F	13.2
1400°F	13.7
1600°F	14
1800°F	14.7
2000°F	15.1
24°C	12.5
538°C	22.1
648°C	22.9
760°C	23.8
871°C	24.6
981°C	25.4
1093°C	26.2

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
77-200°F	8.3×10^{-6}
77-400°F	8.6×10^{-6}
77-600°F	8.9×10^{-6}
77-1000°F	9.3×10^{-6}
77-1250°F	9.6×10^{-6}
77-1500°F	9.7×10^{-6}
77-1800°F	10.0×10^{-6}
25-93°C	14.9×10^{-6}
25-204°C	15.5×10^{-6}
25-315°C	16.0×10^{-6}
25-538°C	16.7×10^{-6}
25-677°C	17.3×10^{-6}
25-816°C	17.5×10^{-6}
25-981°C	18.0×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2590	1400-1420

Magnetic Permeability

<i>H/m Annealed</i>
1.009

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2050-2150	1120-1180

Full Annealing

<i>°F</i>	<i>°C</i>
1925-1975	1052-1079

Rapid air cool or quench to below 800°F (425°C)

Process Annealing

<i>°F</i>	<i>°C</i>
1850-1900	1010-1040

Hardening

Not hardenable by heat treatment.

UNS N08330

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>	
						<i>HB, Max</i>	<i>HR, Typical</i>
Plate, Sheet & Strip							
Annealed	B536	70(483)	30(207)	30	—	—	B70-90
Bar							
Annealed	B511	70(483)	30(207)	30	—	—	—
Pipe							
Annealed	B535, B546	70(483)	30(207)	30	—	—	B70-90
Solution Treated	B535	65(448)	25(172)	30	—	—	—

This superaustenitic stainless steel has a very high resistance to chloride ion pitting and high

resistance to general corrosion in a variety of environments. It is being supplanted by AL-6XN®(N08367).

UNS N08366

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>
0.03	2.0	0.040	0.030	1.0	<u>20.0</u>	<u>23.5</u>	<u>6.0</u>
Max	Max	Max	Max	Max	22.0	25.5	7.0

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
No Data	

Melting Range

<i>°F</i>	<i>°C</i>
2500	1370

Density

<i>lb/in³</i>	<i>kg/m³</i>
No Data	

Magnetic Permeability

<i>H/m Annealed</i>
1.01

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
950

Thermal Treatment

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.460

Initial Forging

<i>°F</i>	<i>°C</i>
2250	1235

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
32-212°F	0-100°C
7.9	13.7

Annealing

<i>°F</i>	<i>°C</i>
2200	1205

Annealing

No Data

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
70-212°F	21-100°C
8.50×10^{-6}	15.3×10^{-6}

Hardening

Nonhardenable

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS N08366

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness, Typical HB, Max HR, Max</i>	
Plate, Sheet & Strip	B688						
Thickness:							
Under 0.187 in (4.8 mm)		75(515)	35(240)	30 ^a	—	—	B95
0.187 to 0.75 in (4.8 to 19 mm)		75(515)	35(240)	30 ^a	—	212	—
Over 0.75 in (19 mm)		75(515)	35(240)	30 ^a	—	212	—
Rod, Bar & Wire							
Annealed, Hot or cold finished	B691	75(515)	30(206)	30	—	—	—

^a Not applicable for thickness under 0.015 in (0.40 mm).

UNS N08367—AL-6XN®

AL-6XN is a low carbon, high purity, nitrogen-bearing super-austenitic stainless steel. It was designed for use in environments where chloride pitting or stress-corrosion cracking is a concern. It has higher strength than the conventional austenitic alloys. It is used in sea water and brackish water environments, and in numerous chemical and allied industrial environments.

The high strength and corrosion resistance of the alloy make it a better choice than the conventional duplex stainless steels, and a cost-effective alternative to more expensive nickel-base alloys in applications where excellent

Nitrogen-strengthened/Austenitic

formability, weldability, strength and corrosion resistance are essential.

Applications include chemical process tanks and pipelines; process systems for offshore oil and gas platforms; condensers, heat exchangers and piping containing seawater or crude oil; filter washers, vats and press rolls in pulp bleaching plants; power plant flue gas scrubber environments; tall oil distillation columns; desalination equipment and pumps; service water piping systems for nuclear power plants; transformer cases exposed to marine environments; pharmaceutical equipment (for product purity) and food processing equipment.

UNS N08367

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>	<i>Cu</i>
0.03	2.0	0.040	0.030	1.00	20.0	23.5	6.0	0.18	0.75
Max	Max	Max	Max	Max	22.0	25.5	7.0	0.25	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.3 × 10 ⁶	195,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.291	8,060

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
890

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.460

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
32-212°F	0-100°C
7.9	13.7

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
68-212°F	8.5×10^{-6}	20-100°C	15.3×10^{-6}
68-392°F	8.6×10^{-6}	20-200°C	15.5×10^{-6}
68-572°F	8.8×10^{-6}	20-300°C	15.7×10^{-6}
68-752°F	8.9×10^{-6}	20-400°C	16.0×10^{-6}
68-932°F	9.1×10^{-6}	21-500°C	16.4×10^{-6}
68-1112°F	9.3×10^{-6}	20-600°C	16.7×10^{-6}
68-1292°F	9.5×10^{-6}	20-700°C	17.1×10^{-6}
68-1472°F	9.8×10^{-6}	20-800°C	17.6×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2410-2550	1320-1400

Magnetic Permeability

<i>H/m Annealed</i>
1.0028

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1830-2300	1000-1260

Annealing

<i>°F</i>	<i>°C</i>
2025-2250	1107-1232

Annealing

Cool rapidly from these temperatures.

Hardening

Nonhardenable.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness, Typical HB, Max HR, Max</i>	
Plate, Sheet & Strip	B688						
Thickness:							
Under 0.187 in (4.8mm)		104(717)	46(317)	30 ^a	—	—	B100
0.187 to 0.75 in (4.8 to 19 mm)		100(690)	45(310)	30 ^a	—	240	—
Over 0.75 in (19 mm)		95(655)	45(310)	30 ^a		233	—
Rod, Bar & Wire							
Annealed, Hot or Cold Finished	B691	95(655)	45(310)	30			

^aNot applicable for thickness under 0.015 in (0.40 mm).

JS700 is a stabilized austenitic, highly-alloyed stainless steel. It has corrosion resistance superior to Type 317L. The high molybdenum level enhances corrosion resistance and resistance to stress corrosion cracking. The high chromium and nickel content contributes to the corrosion resistance and also provides high oxidation resistance. Columbium stabilization and a relatively low carbon content prevent corrosion in welds and heat affected zones.

JS700 has been used to withstand the extreme corrosion encountered in wet-process phosphoric acid plants, under conditions of the corrosive abrasive attack of sulfuric acid-sulfate rock slurries, in pulp and paper plants and in synthetic textile processing.

Applications include agitators, conveyors filters, mixers, pumps, screens, heat exchangers, stills vaporizers, digesters, tanks and vessels.

UNS N08700

Chemical Composition Limits Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	Cb	Cu
0.04	2.00	0.040	0.030	1.00	19.0	24.0	4.3	$8 \times C$	0.50
Max	Max	Max	Max	Max	23.0	26.0	5.0	0.40	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.4×10^6	196,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,060

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
800

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.505

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
8.5 at 68°F	14.6 at 20°C

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	0-100°C
9.15×10^{-6}	16.5×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
No Data	

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2000-2200	1090-1205

Annealing

<i>°F</i>	<i>°C</i>
1850-2100	1010-1149

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength <i>ksi(MPa), Min</i>	Yield Strength <i>ksi(MPa), Min</i>	Elongation <i>%, Min</i>	Reduction in Area <i>%, Min</i>	Hardness <i>HB, Max HR, Typical</i>	
Plate, Sheet & Strip							
Annealed	B599	80(550)	35(240)	30.0	—	—	B75-90
Bar							
Annealed	B672	80(550)	35(240)	30.0	50.0	—	—

UNS N08904—904L

Austenitic

904L is a high-alloy austenitic stainless steel with low carbon content. It is suitable for use in sulfuric acid solutions and wherever very strict demands are made on resistance to stress corrosion cracking.

Due to the combination of relatively high contents of chromium, nickel, molybdenum and copper, 904L has good resistance to pitting and crevice corrosion stress corrosion cracking, and

intergranular corrosion. The steel has good formability and weldability.

The material is used in various product forms in process equipment in the chemical industry. Applications include distillation columns; purification columns; pipes and tanks for sulfuric acid; scrubbers and fans in gas treatment systems; and containers for a wide variety of acids and for tall oil.

UNS N08904

Chemical Composition Limits Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	Cu
0.020	2.00	0.045	0.035	1.00	19.0	23.0	4.0	1.0
Max	Max	Max	Max	Max	23.0	28.0	5.0	2.0

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.288	8,000

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
850

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
7 at 68°F	13 at 20°C

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	20-100°C
8.3×10^{-6}	15×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2400-2530	1315-1390

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1740-2190	950-1200

Annealing

<i>°F</i>	<i>°C</i>
1975-2120	1080-1160

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength <i>ksi(MPa), Min</i>	Yield Strength <i>ksi(MPa), Min</i>	Elongation <i>%, Min</i>	Reduction in Area <i>%, Min</i>	Hardness <i>HB, Max</i>	<i>HR, Typical</i>
Plate, Sheet & Strip							
Annealed	B625	71(490)	31(220)	35	—	—	B70-90
Bar							
Annealed	B649	71(490)	31(220)	35	—	—	—
Pipe and Tube							
Annealed	B673, B674	71(490)	31(220)	35	—	—	—
Seamless Pipe and Tube							
Annealed	B677	71(490)	31(220)	35	—	—	—

UNS N08926—Alloy 25-6MO

Austenitic

25-6MO is a fully austenitic alloy containing 6% molybdenum which offers excellent corrosion resistance in a wide variety of aggressive, aqueous environments. It replaces Type 316 and 317 austenitic stainless steels where their capabilities are pushed to their performance limits. The alloy, therefore, falls into a "super austenitic stainless steel" category. It can also serve as a cost-effective alternative to the higher nickel alloys in some marine and chemical processing environments. It is especially resistant to non-oxidizing acids such as sulfuric and phosphoric.

The alloy has excellent resistance to environments containing chlorides or other halides. It is especially suited to handle high-chloride environments such as brackish water, sea water, caustic chlorides and pulp mill bleach systems. Applications include chemical and food processing, pulp and paper bleaching plants, marine and offshore platform equipment, salt plant evaporators, air pollution control systems, as well as condenser tubing, service water piping and feedwater heaters for the power industry.

UNS N08926

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>	<i>Cu</i>
0.020	2.00	0.030	0.010	0.50	19.0	24.0	6.0	0.15	0.5
Max	Max	Max	Max	Max	21.0	26.0	7.0	0.25	1.5

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
27.27×10^6	188,000

Modulus of Elasticity in Torsion

<i>psi</i>	<i>MPa</i>
10.25×10^6	70,700

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.290	8,030

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
800

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F	7.3
392°F	8.2
572°F	9.2
752°F	10.5
932°F	11.2
1112°F	12.7
1292°F	13.9
1472°F	14.3
1832°F	15.2
2192°F	16.5

Mean Coefficient of Thermal Expansion

	<i>in/in/°F</i>		<i>cm/cm/°C</i>
77-200°F	8.42×10^{-6}	25-93°C	15.16×10^{-6}
77-300°F	8.55×10^{-6}	25-149°C	15.39×10^{-6}
77-400°F	8.68×10^{-6}	25-204°C	15.62×10^{-6}
77-500°F	8.82×10^{-6}	25-260°C	15.88×10^{-6}
77-600°F	8.94×10^{-6}	25-316°C	16.09×10^{-6}
77-700°F	9.04×10^{-6}	25-371°C	16.27×10^{-6}
77-800°F	9.12×10^{-6}	25-427°C	16.42×10^{-6}
77-900°F	9.19×10^{-6}	25-482°C	16.54×10^{-6}
77-1000°F	9.22×10^{-6}	25-538°C	16.60×10^{-6}
77-1200°F	9.41×10^{-6}	25-649°C	16.94×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2410-2550	1320-1400

Magnetic Permeability

<i>H/m Annealed</i>
1.005

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
1800-2100	980-1150

Annealing

<i>°F</i>	<i>°C</i>
2150	1175

Annealing

Cooling after annealing should be a rapid air cool or water quench.

Hardening

Hardenable by cold work only.

UNS N08926

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	B625	94(650)	43(295)	35	—	—	—
Bar and Wire							
Annealed	B649	94(650)	43(295)	35	—	—	—
Pipe and Tube	B677	94(650)	43(295)	35	—	—	—

UNS S13800—Type XM-13; PH 13-8 Mo®

Precipitation hardening

Type XM-13 is a martensitic precipitation/age-hardening stainless steel capable of high strength and hardness along with good levels of resistance to both general corrosion and stress-corrosion cracking. Generally, this alloy

should be considered where high strength, toughness, corrosion resistance, and resistance to stress-corrosion cracking are required in a steel showing minimal directionality in properties.

UNS S13800
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Al</i>	<i>Mo</i>	<i>N</i>
0.05	0.20	0.010	0.008	0.10	<u>12.3</u>	<u>7.5</u>	<u>0.90</u>	<u>2.0</u>	0.010
Max	Max	Max	Max	Max	13.2	8.5	1.35	2.5	Max

Physical Properties in the H950^a Annealed
Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.4×10^6	203,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
1,020

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

	<i>Btu/ft·h/°F</i>		<i>W/m·K</i>
212°F	8.1	100°C	14.0
932°F	12.7	500°C	22.0

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	5.9×10^{-6}	0-100°C	10.6×10^{-6}
32-600°F	6.2×10^{-6}	0-315°C	11.2×10^{-6}
32-1000°F	6.6×10^{-6}	0-538°C	11.9×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2560-2625	1404-1440

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2150	1176

Solution Treatment

<i>°F</i>	<i>°C</i>
1700	926

Hardening

<i>°F</i>	<i>°C</i>
950-1150	510-620

^a Solution treatment plus 950°F (510°C), 4h, air cool. Must cool to 60°F (16°C) max after solution treatment.

UNS S13800
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Solution Treated ^b	A693	160(1,103) ^a	120(827) ^a	17 ^a	65 ^a	363	C 38
Condition H950 ^c	A693	220(1,517)	205(1,413)	8 ^d	—	—	C 45 ^e
Condition H1000 ^f	A693	200(1,379)	190(1,310)	8 ^d	—	—	C 43 ^e
Bar							
Solution Treated	A564	160(1,103) ^a	120(827) ^a	17 ^a	65 ^a	363	C 38
Condition H950 ^c	A564	220(1,517)	205(1,413)	10	45 ^g	430 ^e	C 45 ^e
Condition H1000 ^d	A564	205(1,413)	190(1,310)	10	45	400 ^e	C 43 ^e
Forgings							
Solution Treated	A705	—	—	—	—	363	C 38
Condition H950 ^c	A705	220(1517)	205(1,413)	10	45 ^g	430 ^e	C 45 ^e
Condition H1000 ^d	A705	205(1,413)	190(1,310)	10	45	400 ^e	C 43 ^e

^aTypical value.

^bFor material within a size range 0.0015 to 4 in (0.038 to 101.6 mm).

^cSolution treated 1700°F (927°C) cool below 60°F (21°C) and harden 950°F (510°C) 4 h and air cool.

^dMinimum elongation for material under 0.020 in (0.508 mm) thick is 6 percent and for material over 0.1874 in (4.76 mm) thick is 10 percent minimum, respectively.

^eMinimum.

^fSolution treated 1700°F (927°C) cool below 60°F (21°C) and harden 1000°F (538°C) 4 h and air cool.

^gFor transverse tests, the minimum reduction in area shall be 35 percent.

**UNS S15500—Type XM-12; 15-5PH®
15Cr-5Ni**

Precipitation hardening

Type XM-12 is a martensitic, precipitation hardening (maraging) stainless steel that combines high strength and hardness with corrosion resistance superior to the hardenable chromium stainless steels.

Its properties are similar to those of Type 630 (UNS S17400) except that it has improved forgeability and transverse properties.

The steel can be hardened by a single aging heat treatment. It is used primarily for aircraft components.

UNS S15500

**Chemical Composition Limits
Cast or Heat Analysis, Percent**

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Cu</i>	<i>Cb+Ta</i>
0.07	1.00	0.040	0.030	1.00	<u>14.0</u>	<u>3.5</u>	<u>2.5</u>	<u>0.15</u>
Max	Max	Max	Max	Max	15.5	5.5	4.5	0.45

Physical Properties in the H900^a Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
28.5×10^6	196,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
770

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.10	0.41

Thermal Conductivity

<i>Btu/ft·h/°F</i>		<i>W/m·K</i>	
212°F	10.3	100°C	17.8
932°F	13.1	500°C	22.7

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	6.0×10^{-6}	0-100°C	10.8×10^{-6}
32-600°F	6.3×10^{-6}	0-315°C	11.4×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2560-2625	1404-1440

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2150	1176

Solution Treatment

<i>°F</i>	<i>°C</i>
1900	1036

Cool to 90°F max after solution treatment.

Hardening

<i>°F</i>	<i>°C</i>
900-1150	482-620

^aSolution treatment plus 900°F (482°C), 1 h, air cool.

UNSS15500
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Solution Treated ^b	A693	160(1,103) ^a	145(1000) ^a	15 ^a	55 ^a	363	C 38
Condition H900 ^c	A693	190(1,310)	170(1,172)	5 ^c	— ^c	—	C 40-48 ^d
Condition H1150 ^f	A693	135(931)	105(724)	8 ^g	— ^g	—	C 28-38 ^d
Bar							
Solution Treated	A564	160(1,103) ^a	145(1000) ^a	15 ^a	55 ^a	363	C 38
Condition H900 ^c	A564	190(1,310)	170(1,172)	10	35	388 ^d	C 40 ^d
Condition H1150 ^f	A564	135(931)	105(724)	16	50	277 ^d	C 28 ^d
Forgings							
Solution Treated	A705	—	—	—	—	363	C 38
Condition H900 ^c	A705	190(1,310)	170(1,172)	10	35	388 ^d	C 40 ^d
Condition H1150 ^f	A705	135(931)	105(724)	16	50	277 ^d	C 28 ^d

^aTypical value.

^bFor material within a size range 0.0015 to 4 in (0.038 to 101.6 mm).

^cSolution treated 1700°F (927°C) cool as required and harden 900°F (482°C) 1 h and air cool. For bar product transverse values, refer to A564.

^dRange specified or minimum.

^eFor material 0.1875 to 0.625 in (4.76 to 15.87 mm) thick, the minimum elongation and reduction in area shall be 8 and 30 percent, respectively, and for material 0.626 to 4 in (15.90 to 101.6 mm) thick, 10 and 35 percent, respectively.

^fSolution treated 1900°F (1038°C) cool as required and harden 1150°F (621°C) 4 h and air cool. Also refer to A693 for other conditions.

^gFor material 0.1875 to 0.625 in (4.76 to 15.87 mm) thick, the minimum elongation and reduction in area shall be 10 and 40 percent, respectively, and for material 0.626 to 4 in (15.90 to 101.6 mm) thick, 16 and 50 percent, respectively.

UNS S15700—Type 632; PH 15-7 Mo®

Precipitation hardening

Type 632 is a semi-austenitic precipitation-hardening stainless steel that provides high strength and hardness, good corrosion resistance, and minimum distortion during heat treatment. It is easily formed in the annealed condition and develops an effective balance of properties by simple heat treatments.

For applications requiring exceptionally high strength, cold reduced steel (Condition CH 900) is particularly useful for applications permitting limited ductility and workability.

In the heat treated condition Type 632 pro-

vides excellent mechanical properties at temperatures up to 900°F (480°C). Its corrosion resistance is superior to that of the hardenable chromium stainless steels. In some environments the corrosion resistance approximates that of the chromium-nickel austenitic stainless steels.

Applications for the alloy include retaining rings, diaphragms, aircraft bulkheads, welded and brazed honeycomb paneling, and other aircraft components requiring high strength at elevated temperatures.

UNS S15700

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>Al</i>
0.09	1.00	0.040	0.030	1.00	14.0	6.5	2.0	0.75
Max	Max	Max	Max	Max	16.0	7.5	3.0	1.50

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0 × 10 ⁶	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.282	7,800

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
800

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
70-200°F	8.0 × 10 ⁻⁶	21-93°C	14.4 × 10 ⁻⁶
70-400°F	8.0 × 10 ⁻⁶	21-204°C	14.4 × 10 ⁻⁶
70-600°F	8.5 × 10 ⁻⁶	21-316°C	15.3 × 10 ⁻⁶
70-800°F	8.9 × 10 ⁻⁶	21-427°C	16.0 × 10 ⁻⁶
70-900°F	9.2 × 10 ⁻⁶	21-482°C	16.6 × 10 ⁻⁶
70-1000°F	9.4 × 10 ⁻⁶	21-538°C	16.9 × 10 ⁻⁶

Magnetic Permeability

<i>H/m Annealed</i>
Slightly magnetic

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
No data	

Annealing

<i>°F</i>	<i>°C</i>
1925-1975	1050-1080

Annealing

Air cool from temperature.

Hardening

Condition TH1050: Heat to 1400°F (760°C), cool to 50-60°F (10-15°C) within 1 h, hold for ½ h. Reheat to 1050°F (565°C), hold 90 min, air cool to room temperature.

Condition RH950: Heat to 1750°F (955°C), hold 10 min, air cool to room temperature, cool to -100°F (-73°C), hold 8 h, warm to room temperature, reheat to 950°F (510°C), hold 60 min, air cool to room temperature.

UNS S15700
MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength ksi(MPa), Min	Yield Strength ksi(MPa), Min	Elongation %, Min	Reduction in Area %, Min	Hardness HB, Max HR, Max	
Plate, Sheet & Strip							
Annealed	A693	150(1,103)Max	65(450)Max	25	—	—	B100
TH 1050	A693	190(1,310)	170(1,170)	2-5 ^a	20 ^a	—	C 40 Min
RH 950	A693	225(1,550)	200(1,380)	1-4 ^a	20 ^a	—	C 46 Min
Bar							
Annealed	A564	—	—	—	—	269	B100
TH 1050	A564	180(1,240)	160(1,100)	8	25	375 Min	—
RH 950	A564	200(1,380)	175(1,210)	7	25	415 Min	—

^aValues are a function of thickness.

UNS S17400—Type 630; 17-4 PH®

Precipitation hardening

Type 630 is a martensitic, precipitation hardening (maraging) stainless steel that combines high strength and hardness with corrosion resistance superior to that of the hardenable chromium stainless steels, together with improved

transverse properties. It can be hardened by a single aging treatment.

Applications for the alloy are found in the aerospace, chemical, petrochemical and food processing industries.

UNSS17400

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Cu</i>	<i>Cb + Ta</i>
0.07	1.00	0.040	0.030	1.00	15.0	3.0	3.0	0.15
Max	Max	Max	Max	Max	17.5	5.0	5.0	0.45

Physical Properties in the H900^a Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
28.5 × 10 ⁶	196,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
800

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F	100°C
932°F	500°C
10.6	18.4
13.1	22.7

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	0-100°C
32-600°F	0-315°C
6.0 × 10 ⁻⁶	10.8 × 10 ⁻⁶
6.4 × 10 ⁻⁶	11.6 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2560-2625	1404-1440

Magnetic Permeability

No Data

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2150	1176

Solution Treatment

<i>°F</i>	<i>°C</i>
1900	1036

Cool to 90°F (35°C) max within 1 h after solution treatment.

Hardening

<i>°F</i>	<i>°C</i>
900-1150	482-620

^aSolution treatment plus 900°F (482°C), 1 h, air cool.

UNSS17400
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Solution Treated ^b	A693	185(1,255)Max	160(1,105)Max	3	55 ^a	363	C 38
Condition 900 ^c	A693	190(1,310)	170(1,170)	5 ^e	— ^e	—	C 40-48 ^d
Condition 1150 ^f	A693	135(930)	105(725)	8 ^g	— ^g	—	C 28-38 ^d
Bar							
Solution Treated	A564	160(1,105) ^a	145(1,000) ^a	15 ^a	55 ^a	363	C 38
Condition 900 ^c	A564	190(1,310)	170(1,170)	10	40 ^h	388 ^d	C 40 ^d
Condition 1150 ^f	A564	135(930)	105(724)	16	50	277 ^d	C 28 ^d
Forgings							
Solution Treated	A705	—	—	—	—	363	C 38
Condition 900 ^c	A705	190(1,310)	170(1,170)	10	40 ^h	388 ^d	C 40 ^d
Condition 1150 ^f	A705	135(930)	105(725)	16	50	277 ^d	C 28 ^d

^aTypical value.

^bFor material within a size range 0.015 to 4 in (0.38 to 101.6 mm).

^cSolution treated 1700°F (927°C) cool as required and harden 900°F (482°C) 1 h and air cool. For bar product transverse values, refer to A564.

^dRange specified or minimum.

^eFor material 0.1875 to 0.625 in (4.76 to 15.87 mm) thick, the minimum elongation and reduction in area shall be 8 and 30 percent, respectively, and for material 0.626 to 4 in (15.90 to 101.6 mm) thick, 10 and 35 percent, respectively.

^fSolution treated 1700°F (927°C) cool as required and harden 1150°F (621°C) 4 h and air cool. Also refer to A693 for other conditions.

^gFor material 0.1875 in (4.76 mm) thick, the minimum elongation and reduction in area shall be 10 and 40 percent, respectively, and for material 0.626 to 4 in (15.90 to 101.6 mm) thick, 16 and 50 percent, respectively.

^hFor material over 3 in (76.2 mm) thickness, the minimum reduction in area shall be 35 percent.

UNS S17700—Type 631; 17-7 PH®

Precipitation hardening

Type 631 is a semi-austenitic, precipitation hardening (maraging) stainless steel that combines high strength and hardness with corrosion resistance superior to the hardenable chromium stainless steels, together with improved transverse

properties. The steel has excellent fatigue properties. It is easily formed in the annealed condition, but requires two or more subsequent operations for heat treatment. Applications for the steel include aerospace components and flat springs.

UNS S17700

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Al</i>
0.09	1.00	0.040	0.040	1.00	<u>16.0</u>	<u>6.5</u>	<u>0.75</u>
Max	Max	Max	Max	Max	18.0	7.5	1.50

Physical Properties in the CH900^a Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.5×10^6	203,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
830

Specific Heat

<i>Btu/lb · °F</i>	<i>kJ/kg · K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m · K</i>
212°F	9.5
932°F	12.6
100°C	16.4
500°C	21.8

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-200°F	8.6×10^{-6}
68-600°F	9.7×10^{-6}
20-93°C	15×10^{-6}
20-315°C	17.5×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2560-2625	1404-1440

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2150	1176

Solution Treatment

<i>°F</i>	<i>°C</i>
1900	1036

Hardening

<i>°F</i>	<i>°C</i>
900-1050	482-565

Transformation

(C) Cold rolled or cold drawn (T) 1400°F (760°C), air cool to 60°F (16°C) (R) 1750°F (953°C), plus -100°F (-73°C) plus 900°F (482°C) 1 h and air cool.

UNSS17700

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Wire		203-365					
Condition CH900	A313	(1,585-2,515) ^a	—	—	—	—	—
Sheet and Strip							
Solution Treated	A693	150(1,1035)Max	55-65(380-450) ^a Max	20 ^b	—	—	B92 ^b
Condition TH1050	A693	180(1,240)	150(1,035)	3-6 ^a	—	—	C 38 Min
Condition RH950	A693	210(1,450)	190(1,310)	1-4 ^a	—	—	C 44 Min
Condition CH900	A693	240(1,655)	230(1,580)	1	—	—	C 46 Min
Plate							
Solution Treated	A693	150(1,035)Max	55(380)Max	20	—	—	B92
Condition TH1050	A693	170(1,170)	140(965)	7	20	352 Min	C 38 Min
Condition RH950	A693	200(1,380)	180(1,240)	6	20	401 Min	C 43 Min

^aValues are a function of diameter or thickness.^bOver 0.10 to 4.0 in (0.25 to 102 mm).

**UNS S18200 — Type XM-34;
Project 70® Stainless 182-FM**

Free machining/Ferritic

Type XM-34 is a free-machining ferritic stainless steel designed to have corrosion resistance at least as good as the chromium-nickel, austenitic Type 303 stainless steel in many environments and machinability comparable to Type

416. It is superior to Type 303 in resisting stress-corrosion cracking in chlorides.

The steel has been used for automatic screw machine operations where long tool lives and high production rates have been obtained.

UNS S18200

**Chemical Composition Limits
Cast or Heat Analysis, Percent**

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Mo</i>
0.08	2.50	0.04	0.15	1.00	<u>17.5</u>	<u>1.50</u>
Max	Max	Max	Min	Max	19.5	2.50

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
29×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.278	7,700

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
600

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.460

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
No Data	

Mean Coefficient of Expansion

	<i>in/in/°F</i>		<i>cm/cm/°C</i>
73-400°F	5.8×10^{-6}	23-204°C	10.4×10^{-6}
73-800°F	6.4×10^{-6}	23-427°C	11.5×10^{-6}
73-1800°F	7.3×10^{-6}	23-982°C	13.1×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
~2730	1500

Magnetic Permeability

<i>H/m Annealed</i>
Ferromagnetic

Thermal Treatment

Initial Forging

	<i>°F</i>	<i>°C</i>
Preheat	1500-1600	816-871
Forge Temp.	1900-2000	1038-1093

Annealing

<i>°F</i>	<i>°C</i>
1400-1500	760-816

Annealing

Heat to above temperature and water quench.

Hardening

Cannot be thermally hardened. The hardness can be increased moderately by cold work, but the work hardening rate is low.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S18200
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A582	—	—	—	—	262	—
Wire							
Annealed	A581	85-125(585-860)	—	—	—	—	—

UNS S20100—Type 201

Austenitic

Type 201 is an austenitic chromium-nickel-manganese stainless steel which is comparable to Types 301 and 304 in many respects. The steel can provide some advantages in certain applications and it is more economical. Types 201 and 201L are the most widely used of the 200 series stainless steels.

Type 201 has high strength in the annealed condition, and it has excellent formability for severe forming applications such as washing machine tubs. It can be cold rolled to develop higher strengths and, because of this, it is used in a numerous structural application.

See also the Section on Typical Applications.

UNS S20100
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.15	<u>5.5</u>	0.060	0.030	1.00	<u>16.0</u>	<u>3.5</u>	0.25
Max	7.5	Max	Max	Max	18.0	5.5	Max

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
30.0×10^6	207,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.284	7,860

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
670

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
68-212°F	20-100°C
9.4	16.3

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	20-100°C
68-600°F	20-316°C
68-1000°F	20-538°C
68-1600°F	20-871°C
9.2×10^{-6}	16.6×10^{-6}
10.0×10^{-6}	18.0×10^{-6}
10.9×10^{-6}	19.6×10^{-6}
11.3×10^{-6}	20.3×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2650	1400-1455

Magnetic Permeability

<i>H/m Annealed</i>
1.02

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2100-2250	1150-1230

Annealing

<i>°F</i>	<i>°C</i>
1850-2000	1010-1095

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

UNS S20100
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet, & Strip	A666						
Annealed		95(655)	32(260)	40	—	217	B95
¼ Hard		125(860)	75(515)	25	—	—	C25 ^a
½ Hard		150(1035)	110(760)	18 ^b	—	—	C32 ^a
¾ Hard		175(1205)	135(930)	12 ^b	—	—	C37 ^a
Full Hard		185(1275)	140(965)	9 ^b	—	—	C41 ^a
Bar							
Annealed	A276	75(515)	40(275)	40	45	—	—
Forgings							
Annealed	A457	75(515)	30(205)	40	50	—	—
Plate, Sheet & Strip	A240/201-1	95(655)	38(260)	40.0	—	—	B95
	A240/201-2	95(655)	45(310)	40.0	—	—	B100

^aTypical value is for information only. The material is usually produced to meet tensile requirements.

^bValue given is for material 0.031 in (0.79 mm) and over in thickness. For limits on lighter thicknesses, refer to ASTM A666.

UNS S20103—Type 201L

Austenitic

Type 201L is low-carbon austenitic chromium-nickel-manganese stainless steel which is comparable to Type 304L in many respects. It can provide some advantages in certain applications and it is more economical.

Type 201L is the low carbon version of Type 201 and it maintains satisfactory intergranular

corrosion resistance in applications involving welding, particularly in heavier gage material. Type 201L can be cold rolled to very high strengths, making it suitable for many structural applications.

See also the Section on Typical Applications.

UNS S20103
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.03	<u>5.5</u>	0.045	0.030	0.75	<u>16.0</u>	<u>3.5</u>	0.25
Max	7.5	Max	Max	Max	18.0	5.5	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
30.0×10^6	207,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.284	7,860

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
670

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
68-212°F	20-100°C
9.4	16.3

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	20-100°C
9.2×10^{-6}	16.6×10^{-6}
68-600°F	20-316°C
10.0×10^{-6}	18.0×10^{-6}
68-1000°F	20-538°C
10.9×10^{-6}	19.6×10^{-6}
68-1600°F	20-871°C
11.3×10^{-6}	20.3×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2650	1400-1455

Magnetic Permeability

<i>H/m Annealed</i>
1.02

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2250	1150-1230

Annealing

<i>°F</i>	<i>°C</i>
1850-2000	1010-1095

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

UNS S20103
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip	A240	95(655)	38(260)	40.0	—	217	B95

UNS S20153—Type 201LN

Nitrogen-strengthened/Austenitic

Type 201LN is a nitrogen-strengthened austenitic chromium-nickel-manganese stainless steel which was developed for welded tanks and vessels to be used at temperatures as low as -320°F (-196°C). The alloy is also well suited for many

applications at ambient temperature, such as railroad freight cars, truck trailers, coal handling and other bulk transport equipment where there is a need for a good combination of corrosion resistance, strength and ease of fabrication.

UNS S20153

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>	<i>Cu</i>
0.03	6.4	0.045	0.15	0.75	16.0	4.0	0.10	1.00
Max	7.5	Max	Max	Max	17.5	5.0	0.25	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
30.0×10^6	207,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.284	7,860

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
670

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
68-212°F	20-100°C
9.4	16.3

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	20-100°C
9.2×10^{-6}	16.6×10^{-6}
68-600°F	20-316°C
10.0×10^{-6}	18.0×10^{-6}
68-1000°F	20-538°C
10.9×10^{-6}	19.6×10^{-6}
68-1600°F	20-871°C
11.3×10^{-6}	20.3×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2650	1400-1455

Magnetic Permeability

<i>H/m Annealed</i>
1.02

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2250	1150-1230

Annealing

<i>°F</i>	<i>°C</i>
1850-2000	1010-1095

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

UNS S20153

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi (MPa), Min</i>	<i>Yield Strength ksi (MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>	
						<i>HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip	A240	95(655)	45(310)	45.0	—	241	B100

UNS S20161—Gall-Tough®

Gall-Tough is a high-silicon, high-manganese, nitrogen-strengthened austenitic stainless steel which has superior self-mated galling resistance and metal-to-metal wear resistance. The alloy has higher strength and resists oxidation at higher temperatures than Type 304 stainless steel, and has comparable corrosion resistance in a given environment. Optimum galling resistance is obtained when both mating components are made of Gall-Tough stainless steel.

Nitrogen-strengthened/Austenitic

Gall-Tough stainless steel may be considered for applications in which parts are in relative motion under load without lubricants. Potential applications include chain link conveyor belts and other components in food and drug processing industries; bolts, nuts and other fasteners for electronic and nuclear applications; fittings for pumps and valves in the chemical process industry; surgical and analytical instrumentation; and bridge pins.

UNS S20161
Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	N
0.15	4.0	0.040	0.040	3.0	15.0	4.0	0.08
Max	6.0	Max	Max	4.0	18.0	6.0	0.20

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

psi	MPa
24.8 × 10 ⁶	171,000

Density

lb/in ³	kg/m ³
0.276	7,650

Electrical Resistivity

Microhm — mm at 68°F (20°C)
716

Specific Heat

Btu/lb °F	kJ/kg·K
126-212°F	52-102°C
0.123	0.515

Thermal Conductivity

Btu/ft·h·°F	W/m·K
°F	°C
122°F 7.02	50°C 12.22
212°F 7.80	100°C 13.49
392°F 8.85	200°C 15.33
572°F 9.84	300°C 17.03
752°F 10.74	400°C 18.60

Mean Coefficient of Expansion

in/in/°F	cm/cm/°C
77-212°F	9.60 × 10 ⁻⁶
77-392°F	9.74 × 10 ⁻⁶
77-572°F	9.93 × 10 ⁻⁶
77-752°F	10.13 × 10 ⁻⁶
77-932°F	10.29 × 10 ⁻⁶
77-1112°F	10.46 × 10 ⁻⁶
77-1292°F	10.63 × 10 ⁻⁶
	25-100°C
	17.28 × 10 ⁻⁶
	25-200°C
	17.54 × 10 ⁻⁶
	25-300°C
	17.87 × 10 ⁻⁶
	25-400°C
	18.24 × 10 ⁻⁶
	25-500°C
	18.53 × 10 ⁻⁶
	25-600°C
	18.83 × 10 ⁻⁶
	25-700°C
	19.14 × 10 ⁻⁶

Magnetic Permeability

Cold working results in a significant increase in permeability.

Thermal Treatment

Initial Forging

°F	°C
2100-2300	1149-1260

Annealing

°F	°C
1900-2000	1038-1093

Annealing

Anneal at temperature above and water quench.

Hardening

Hardenable by cold working only.

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength ksi(MPa), Min	Yield Strength ksi(MPa), Min	Elongation %, Min	Reduction in Area %, Min	Hardness HB, Max	HR, Max
Plate, Sheet & Strip							
Annealed	A240	125(860)	50(345)	40.0	—	255	C25
Bar							
Annealed	A276	125(860)	50(345)	40	40	255	—

UNS S20200—Type 202

Austenitic

Type 202 is an austenitic, chromium-nickel-manganese stainless steel with a higher alloy content than Type 201. The steel is an alternate for Type 302 in some applications.

See also the Section on Typical Applications.

UNS S20200
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.15	7.5	0.060	0.030	1.00	17.0	4.0	0.25
Max	10.0	Max	Max	Max	19.0	6.0	Max

Physical Properties in the Annealed Condition

Density	
<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Melting Range	
<i>°F</i>	<i>°C</i>
2550-2650	1399-1454

Electrical Resistivity	
<i>Microhm — mm at 68°F (20°C)</i>	
690	

Magnetic Permeability	
<i>H/m Annealed</i>	
1.02 Max	

Specific Heat	
<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Treatment

Thermal Conductivity	
<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
68-212°F	20-100°C
9.4	16.3

Initial Forging	
<i>°F</i>	<i>°C</i>
2100-2250	1149-1231

Annealing	
<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Mean Coefficient of Expansion

	<i>in/in/°F</i>		<i>cm/cm/°C</i>
32-600°F	10.2×10^{-6}	0-315°C	18.4×10^{-6}
32-800°F	10.5×10^{-6}	0-426°C	18.9×10^{-6}
32-900°F	10.6×10^{-6}	0-482°C	19.1×10^{-6}
32-1400°F	11.3×10^{-6}	0-760°C	20.5×10^{-6}
68-212°F	9.2×10^{-6}	20-100°C	16.6×10^{-6}

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold working only.

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A666	90(620)	38(260)	40	—	—	B90 ^a
¼ Hard	A666	125(860)	75(515)	12	—	—	C25 ^a
Bar							
Annealed	A276	75(515)	40(275)	40	45	—	—
Cold Finished	A276 ^b	115(795)	75(515)	15	—	—	—
Cold Finished	A276 ^c	125(860)	100(690)	12	—	—	—

^aTypical value is for information only. Material is usually produced to meet tensile requirements.

^bFor thicknesses ¾ in to 1 in (19.05 to 25.4 mm).

^cFor thicknesses up to ¾ in (19.05 mm).

UNS S20300—Type 203; Type XM-1; 203EZ®

Free machining/Austenitic

Type 203 is an austenitic, chromium-nickel-manganese stainless steel to which elements have been added to improve machining and non-seizing characteristics. It is the most readily machinable of all of the austenitic grades and it is suitable for use in automatic screw machines.

This steel should be considered as an alternative to Type 303 which has similar physical and mechanical properties. The steel is essentially nonmagnetic when annealed and can become slightly magnetic when cold worked.

UNS S20300
Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Cu
0.08	5.0	0.04	0.18	1.00	16.0	5.0	1.75
Max	6.5	Max	0.35	Max	18.0	6.5	2.25

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0 × 10 ⁶	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.284	7,860

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
740

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
68-212°F	20-212°C
9.4	16.3

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
68-212°F	9.4 × 10 ⁻⁶	20-100°C	17.0 × 10 ⁻⁶
68-932°F	10.9 × 10 ⁻⁶	20-500°C	19.6 × 10 ⁻⁶
68-1450°F	11.5 × 10 ⁻⁶	20-787°C	20.7 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2550	1400

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2150	1149-1177

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold working only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength ksi(MPa), Min	Yield Strength ksi(MPa), Min	Elongation %, Min	Reduction in Area %, Min	Hardness HB, Max	HR, Max
Bar							
Annealed	A582	85(586) ^a	30(241) ^a	45 ^a	55 ^a	262	—
Wire							
Annealed	A581	85-125(590-860)	—	—	—	—	—
Cold Worked	A581	115-145(790-1000)	—	—	—	—	—

^aTypical value.

UNS S20400—Nitronic 30®

Nitrogen-strengthened/Austenitic

Nitronic 30 is a nitrogen-strengthened austenitic stainless steel developed for applications requiring a good level of aqueous corrosion resistance combined with good toughness and economy. The steel has a yield strength almost double that of Type 304L stainless steel. The alloy work hardens rapidly while retaining good ductility.

Unlike other nitrogen-strengthened stainless

steels, Nitronic 30 is subject to magnetic transformation when cold worked.

Potential applications include hose clamps, truck and bus frames, water supply and control structures, sewage treatment plant structures, bulk solids handling equipment, magnetic ore separator screens, coal buckets and hopper cars.

UNS S20400

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.030	<u>7.0</u>	0.040	0.030	1.00	<u>15.0</u>	<u>1.50</u>	<u>0.15</u>
Max	9.0	Max	Max	Max	17.0	3.0	0.30

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.284	7,860

Magnetic Permeability

<i>H/m Annealed</i>
1.011

Mean Coefficient of Expansion

	<i>in/in/°F</i>		<i>cm/cm/°C</i>
79-200°F	9.35×10^{-6}	26-93°C	16.83×10^{-6}
79-400°F	9.81×10^{-6}	26-204°C	17.65×10^{-6}
79-600°F	10.18×10^{-6}	26-316°C	18.34×10^{-6}
79-800°F	10.50×10^{-6}	26-427°C	18.90×10^{-6}
79-1000°F	10.75×10^{-6}	26-538°C	19.35×10^{-6}
79-1200°F	11.00×10^{-6}	26-649°C	19.80×10^{-6}
79-1400°F	11.21×10^{-6}	26-760°C	20.18×10^{-6}
79-1600°F	11.42×10^{-6}	26-1600°C	20.56×10^{-6}

Thermal Treatment

Annealing

<i>°F</i>	<i>°C</i>
1950-2050	1065-1120

Hardening

Hardenable by cold working only.

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>Hardness HR, Max</i>
Plate, Sheet & Strip	A240	95(655)	43(330)	35	—	241	B100
Plate, Sheet, Strip, Flat Bar	A666						
Annealed		95(655)	48(330)	35	—	241	B100
1/4 Hard		140(965)	100(960)	20	—	—	—

UNS S20500—Type 205

Austenitic

Type 205 is an austenitic, chromium-nickel-manganese steel with a lower rate of work hardening than Type 202 and it has less change in magnetic permeability when cold worked.

The steel is used for spinning, for special drawing, and for cold heading operations. It is used for nonmagnetic and cryogenic applications.

UNS S20500
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
<u>0.12</u>	<u>14.0</u>	0.060	0.030	0.75	<u>16.5</u>	<u>1.00</u>	<u>0.32</u>
0.25	15.0	Max	Max	Max	18.0	1.75	0.40

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
28.6×10^6	197,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Mean Coefficient of Expansion

	<i>in/in/°F</i>		<i>cm/cm/°C</i>
68-392°F	9.4×10^{-6}	20-200°C	16.9×10^{-6}
68-851°F	10.4×10^{-6}	20-453°C	18.7×10^{-6}
68-1472°F	11.4×10^{-6}	20-798°C	20.5×10^{-6}
68-1700°F	11.7×10^{-6}	20-927°C	20.1×10^{-6}

Magnetic Permeability

<i>H/m Annealed</i>
1.005

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2250	1231

Annealing

<i>°F</i>	<i>°C</i>
1950	1063

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold working only.

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A666						
Annealed		115(790)	65(450)	40	—	255	B100
¼ Hard		125(860)	75(515)	45	—	—	—
½ Hard		150(1035)	110(760)	18 ^a	—	—	—
Full Hard		185(1275)	140(965)	4 ^a	—	—	—
Bar							
Annealed	A276	100(690)	60(415)	40	50	—	—

^aValue given is for material 0.031 in and over in thickness. For limits on lighter thicknesses refer to ASTM A666.

**UNS S20910 — Type XM-19; Nitronic 50®;
22Cr-13Ni-5Mn**
Nitrogen-strengthened/Austenitic

Type XM-19 is a nitrogen-strengthened, austenitic stainless steel that provides very good corrosion resistance in combination with high strength. The alloy has better corrosion resistance than Type 316 with approximately twice the yield strength. It can be welded, machined and cold worked using the same equipment and methods which are used for the conventional 300 series stainless steels. It remains nonmagnetic after severe cold work.

The alloy has an excellent combination of strength, ductility, toughness, corrosion resistance and fabricability. It has good toughness at cryogenic temperatures and relatively high strength at moderately high temperatures.

It has been used in applications such as valve shafts and taper pins, pumps and fittings for chemical and petrochemical equipment, fasteners, cables, chains, screens, wire cloth, marine hardware, boat shafting, heat exchanger parts, springs and photographic equipment.

UNS S20910

**Chemical Composition Limits
Cast or Heat Analysis, Percent**

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>	<i>V</i>	<i>Cb</i>
0.06	4.0	0.040	0.030	1.00	20.5	11.5	1.50	0.20	0.10	0.10
Max	6.0	Max	Max	Max	23.5	13.5	3.00	0.40	0.30	0.30

Physical Properties in the Annealed Condition
Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0 × 10 ⁶	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.285	7,880

Electric Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
820

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
300°F 9.0	149°C 15.6
900°F 11.7	482°C 20.3
1500°F 14.6	816°C 25.2

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
70-200°F 9.0 × 10 ⁻⁶	21-93°C 16.2 × 10 ⁻⁶
70-400°F 9.2 × 10 ⁻⁶	21-204°C 16.6 × 10 ⁻⁶
70-600°F 9.6 × 10 ⁻⁶	21-316°C 17.3 × 10 ⁻⁶
70-800°F 9.9 × 10 ⁻⁶	21-427°C 17.8 × 10 ⁻⁶
70-1000°F 10.2 × 10 ⁻⁶	21-538°C 18.4 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2550-2600	1400-1430

Magnetic Permeability

<i>H/m Annealed</i>
1.004

Thermal Treatment
Initial Forging

<i>°F</i>	<i>°C</i>
2100-2200	1149-1204

Annealing

<i>°F</i>	<i>°C</i>
1950-2050	1066-1121

Annealing

Heat to above temperature and cool rapidly.
Water quench large sections.

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S20910
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>	
						<i>HB, Max</i>	<i>HR, Max</i>
Sheet and Strip	A240	105(725)	60(415)	30	—	241	B100
Plate	A240	100(690)	55(380)	35	—	241	B100
Bar							
Annealed	A276	100(690)	55(380)	35	55	—	—
Wire							
Annealed	A580	100(690)	55(380)	35	55	—	—

UNS S21300—15-15LC®

15-15LC is an austenitic, nitrogen-strengthened stainless steel which should be considered for oil and gas industry applications such as non-magnetic drill collars and instrument housings. A low carbon content provides improved resistance to intergranular stress-corrosion cracking.

Nitrogen-strengthened/Austenitic

A post-machining ID compressive stress treatment for drill collars has been developed to further improve the resistance to intergranular stress corrosion cracking. High nitrogen content and warm working on a rotary forge result in high yield strength.

UNS S21300

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>	<i>Cu</i>
0.25	<u>15.0</u>	0.05	0.05	1.00	<u>16.0</u>	3.00	<u>0.50</u>	<u>0.20</u>	<u>0.50</u>
Max	18.0	Max	Max	Max	21.0	Max	3.00	0.80	2.0

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
27.7×10^6	191,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.280	7,760

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
733

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
79-241°F	26-116°C
0.118	0.491

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
73°F	8.0
122°F	8.2
212°F	8.7
392°F	9.6
572°F	10.4
752°F	11.1
23°C	13.8
50°C	14.3
100°C	15.1
200°C	16.6
300°C	18.0
400°C	19.2

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
70-212°F	8.85×10^{-6}
70-350°F	9.11×10^{-6}
70-392°F	9.34×10^{-6}
70-482°F	9.57×10^{-6}
70-572°F	9.75×10^{-6}
70-662°F	9.96×10^{-6}
70-752°F	10.16×10^{-6}
70-842°F	10.35×10^{-6}
70-932°F	10.52×10^{-6}
70-1022°F	10.67×10^{-6}
21-100°C	15.95×10^{-6}
21-150°C	16.41×10^{-6}
21-200°C	16.84×10^{-6}
21-250°C	17.26×10^{-6}
21-300°C	17.59×10^{-6}
21-350°C	17.98×10^{-6}
21-400°C	18.33×10^{-6}
21-450°C	18.68×10^{-6}
21-500°C	18.98×10^{-6}
21-550°C	19.25×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
~2590	1420

Magnetic Permeability

<i>H/m Annealed</i>
1.002

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2150-2200	1180-1200

Annealing

<i>°F</i>	<i>°C</i>
1900-2100	1040-1150

Annealing

Generally 15-15LC is used in as-forged, warm worked condition; however, if annealing is desired, heat to temperature above for 1 h/in of thickness and water quench.

Hardening

Hardenable by cold or warm work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S21300

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Typical HR, Typical</i>	
Annealed (1950°F, Water Quench)		92(633)	62(427)	50	60	210	—
Warm Worked		132(908)	110(758)	40	72	285	—
Warm Worked		129(887)	105(723)	40	74	269	—
Warm Worked		138(949)	118(813)	40	73	302	—

UNS S21600—Type 216; XM-17

Austenitic

Type 216 is a chromium-manganese-nickel-molybdenum austenitic stainless steel. The 200 series of austenitic stainless steels have mechanical properties and corrosion resistance similar to their corresponding 300 series chromium-nickel steels. Type 216 not only has corrosion resistance equivalent to Type 316 stainless, but in some instances, particularly those involving strong pitting media, Type 216 is superior. Type 216 offers higher strength at room temperature and elevated temperatures than Type 316.

The low magnetic permeability, even after severe cold working, further enhances the usefulness of this material.

In pitting media, such as 10% ferric chloride solutions and chloride-containing boiling acetic acid solutions, Type 216 is superior to Type 316 in resisting localized chemical attack. In severe oxidizing conditions, typified by 65% boiling nitric acid, corrosion rates of Type 216 are comparable to the chromium-nickel Types 304 and 316. Type 216 is slightly less resistant to attack in dilute sulfuric acid than Type 316.

UNS S21600
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>
0.08	7.5	0.045	0.03	0.75	17.5	5.0	2.00	0.25
Max	9.0	Max	Max	Max	22.0	7.0	3.00	0.50

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.287	7,944

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
698

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F	9.4
100°C	16.3

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	8.5×10^{-6}
20-100°C	15.3×10^{-6}
68-1800°F	11.2×10^{-6}
20-982°C	20.2×10^{-6}

Magnetic Permeability

<i>H/m Annealed</i>
1.003

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2150-2250	1175-1230

Annealing

<i>°F</i>	<i>°C</i>
1950-2100	1065-1150

Final Anneal

<i>°F</i>	<i>°C</i>
1950	1065

Annealing

Cool rapidly from the temperatures above.

Hardening

Hardenable only by cold working.

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate	A240	90(620)	50(345)	40.0	—	241	B100
Sheet and Strip	A240	100(690)	60(415)	40.0	—	241	B100
Bars & Shapes, Annealed	A479	90(620)	50(345)	40	50	212	—

UNS S21800—NITRONIC 60®

Nitrogen-strengthened/Austenitic

NITRONIC 60 is an austenitic stainless steel that provides better wear and galling resistance than cobalt-bearing and high nickel alloys at a significantly lower cost. Its uniform corrosion resistance is better than Type 304 in most media and its chloride resistance is superior to Type 316. The room temperature yield strength is nearly twice that of Types 304 and 316. The steel provides excellent high-temperature oxidation resistance and low-temperature impact resistance.

Outstanding galling resistance at both ambient and elevated temperatures makes NITRONIC 60 a suitable material for valve stems, seats and trim; fastening systems, including nuts and bolts; screening; chain-drive systems; pins, bushing and roller bearings; and pump components such as wear rings and lobes. It is the most effective wear- and galling-resistant alloy for bridge pins and other critical structural applications.

UNS S21800

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.10	<u>7.0</u>	0.060	0.030	<u>3.5</u>	<u>16.0</u>	<u>8.0</u>	<u>0.08</u>
Max	9.0	Max	Max	4.5	18.0	9.0	0.18

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
26.2×10^6	180,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,622

Electrical Resistivity

Microhm — mm at 68°F (20°C)
982

Mean Coefficient of Expansion

	<i>in/in/°F</i>		<i>cm/cm/°C</i>
75-200°F	8.8×10^{-6}	24-93°C	15.8×10^{-6}
75-400°F	9.2×10^{-6}	24-204°C	16.6×10^{-6}
75-600°F	9.6×10^{-6}	24-316°C	17.3×10^{-6}
75-800°F	9.8×10^{-6}	24-427°C	17.6×10^{-6}
75-1000°F	10.0×10^{-6}	24-538°C	18.0×10^{-6}
75-1200°F	10.3×10^{-6}	24-649°C	18.5×10^{-6}
75-1400°F	10.5×10^{-6}	24-760°C	18.8×10^{-6}
75-1600°F	10.7×10^{-6}	24-871°C	19.3×10^{-6}
75-1800°F	11.0×10^{-6}	24-982°C	19.8×10^{-6}

Melting Range	
<i>°F</i>	<i>°C</i>
2465-2536	1352-1391

Magnetic Permeability

H/m Annealed
1.002

Thermal Treatment

Forging

The following practice should be followed when forging sections 13 in (330 mm) and smaller: (1) charge in furnace below 1500°F (815°C); (2) raise to 2000°F (1090°C), equalize; (3) raise to 2150°F (1175°C), equalize and forge; (4) reheat as necessary.

Annealing

<i>°F</i>	<i>°C</i>
1950	1066

Hardening

Not hardenable by heat treatment.

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>	
						<i>HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip	A240	95(655)	50(345)	35.0	—	241	B100
Bars and Shapes, Annealed	A276	95(655)	50(345)	35	55	241	—
Wire, Annealed	A580	95(655)	50(345)	35	55	—	—

**UNS S21904 — Type XM-11; Nitronic 40®;
21Cr-6Ni-9Mn**

Nitrogen-strengthened/Austenitic

Type XM-11 is a high-manganese, nitrogen-strengthened, austenitic stainless steel that combines high strength in the annealed condition, excellent resistance to oxidation at high temperatures, good resistance to lead oxide and a high level of corrosion resistance at ambient temperatures.

The combination of high strength and toughness at temperatures as low as -423°F (-254°C) makes the steel ideal for cryogenic applications,

especially where low magnetic permeability is also a requirement.

The alloy can be fabricated and formed much the same as Types 304 and 316, and it is readily weldable. It remains nonmagnetic after severe cold working.

The alloy has been used for chemical processing and pollution control equipment, steam and autoclave applications and for aircraft engine components.

UNS S21904

**Chemical Composition Limits
Cast or Heat Analysis, Percent**

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.04	<u>8.0</u>	0.06	0.03	1.00	<u>19.0</u>	<u>5.5</u>	<u>0.15</u>
Max	10.0	Max	Max	Max	21.5	7.5	0.40

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.5×10^6	196,500

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.283	7,830

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
730

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

	<i>Btu/ft·h·°F</i>		<i>W/m·K</i>
200°F	8.0	93°C	14
400°F	9.3	204°C	16
600°F	10.5	316°C	18
800°F	11.7	427°C	20
1000°F	13.0	538°C	23
1200°F	14.3	649°C	25
1400°F	15.5	760°C	27
1600°F	16.7	871°C	29

Mean Coefficient of Expansion

	<i>in/in/°F</i>		<i>cm/cm/°C</i>
200°F	9.3×10^{-6}	93°C	16.7×10^{-6}
400°F	9.6×10^{-6}	204°C	17.3×10^{-6}
600°F	10.1×10^{-6}	316°C	18.2×10^{-6}
1000°F	10.6×10^{-6}	538°C	19.1×10^{-6}
1400°F	11.1×10^{-6}	760°C	20.0×10^{-6}
1600°F	11.2×10^{-6}	871°C	20.2×10^{-6}
1800°F	11.4×10^{-6}	982°C	20.5×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
~2600	1425

Magnetic Permeability

<i>H/m Annealed</i>
1.002

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2200	1149-1204

Annealing

<i>°F</i>	<i>°C</i>
1800-2150	982-1177

Annealing

Temperature must be selected according to the degree of softening required.

Hardening

Hot/cold working or cold working will harden material.

Not thermally hardenable.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNSS21904

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A276	90(620)	50(345)	45	60	—	—
Wire							
Cold finished annealed	A580	90(620)	50(345)	45	60	—	—

**UNS S24000 — NITRONIC 33®
XM-29; 18-3Mn**

Nitrogen-strengthened/Austenitic

NITRONIC 33 is a nitrogen-strengthened austenitic stainless steel that combines high yield strength with excellent toughness and ductility. Its magnetic permeability remains very low after severe cold working and also at very low temperatures, making it well-suited for cryogenic applications.

The material is used for cryogenic applica-

tions such as tanks, valves, forgings, tubing and piping. Riser pipe for underground electrical transmission lines is an application that uses the low magnetic permeability even after severe forming operations. It is also used for rotating equipment such as fans, containment rings and fabricated structures.

UNS S24000

**Chemical Composition Limits
Cast or Heat Analysis, Percent**

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.08	<u>11.5</u>	0.060	0.030	0.75	<u>17.0</u>	<u>2.25</u>	<u>0.20</u>
Max	14.5	Max	Max	Max	19.0	3.75	0.40

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
28.8×10^6	199,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.280	7,750

Electrical Resistivity

Microhm — mm at 68°F (20°C)

77°F (25°C)	740
212°F (100°C)	800
392°F (200°C)	870
572°F (300°C)	940
752°F (400°C)	1000
1112°F (600°C)	1110
1472°F (800°C)	1190

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F 9.2	100°C 15.8
392°F 10.0	200°C 17.3
572°F 10.9	300°C 18.9
752°F 11.7	400°C 20.4
932°F 12.7	500°C 21.9
1112°F 13.5	600°C 23.4
1292°F 14.3	700°C 24.8
1472°F 15.1	800°C 26.1

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
78-200°F 8.93×10^{-6}	25-93°C 16.07×10^{-6}
78-400°F 9.17×10^{-6}	25-204°C 16.51×10^{-6}
78-600°F 9.68×10^{-6}	25-316°C 17.42×10^{-6}
78-800°F 10.07×10^{-6}	25-427°C 18.13×10^{-6}
78-1000°F 10.43×10^{-6}	25-538°C 18.77×10^{-6}
78-1200°F 10.84×10^{-6}	25-649°C 19.51×10^{-6}
78-1400°F 11.15×10^{-6}	25-760°C 20.07×10^{-6}
78-1600°F 11.40×10^{-6}	25-871°C 20.52×10^{-6}
78-1800°F 11.69×10^{-6}	25-981°C 21.04×10^{-6}

Magnetic Permeability

H/m Annealed
1.0014

Thermal Treatment

Annealing

<i>°F</i>	<i>°C</i>
1900-2000	1040-1095

Annealing

Cool rapidly from the temperature above.

Hardening

Hardenable only by cold work.

UNS S24000

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>	
						<i>HB, Max</i>	<i>HR, Max</i>
Sheet and Strip	A240	100(690)	60(415)	40.0	—	241	B100
Plate	A240	100(690)	55(380)	40.0	—	241	B100
Bars and Shapes, Annealed	A276	100(690)	55(380)	30	50	—	—
Wire, Annealed	A580	100(690)	55(380)	30	50	—	—

**UNS S24100 — Type XM-28; Nitronic 32®;
18Cr-2Ni-12Mn**
Nitrogen-strengthened/Austenitic

Type XM-28 is a high-manganese, nitrogen-strengthened austenitic stainless steel that provides substantially higher strength than Type 304 and has general corrosion resistance between that of Types 430 and 304. The corrosion resistance approaches that of type 304 in some environments. The steel provides an excellent combination of toughness, ductility, strength, corrosion resistance and fabricability. The cost is lower than that of Type 304.

The steel can be welded, machined and cold worked using the same equipment and methods used for the conventional 300 Series austenitic stainless steels.

The alloy is nonmagnetic after cold working to high strength levels. It is an ideal material for simple cold-headed parts requiring high mechanical properties for applications such as pole line hardware and concrete reinforcing accessories. Other applications include skid wire for underground transmission lines, abrasion- and corrosion-resistant screens, high strength nonmagnetic springs, wire forms, racks and cages. The cold drawn steel has an excellent response to electropolishing and greater strength in weld joints than other austenitic stainless steels such as Type 304.

UNS S24100

**Chemical Composition Limits
Cast or Heat Analysis, Percent**

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.15	<u>11.0</u>	0.06	0.03	1.00	<u>16.5</u>	<u>0.50</u>	<u>0.20</u>
Max	14.0	Max	Max	Max	19.0	2.50	0.45

Physical Properties in the Annealed Condition
Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.280	7,750

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
700

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
No Data	

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
No Data	

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
70-1000°F	10.3×10^{-6}
	21-538°C
	18.5×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
~2615	1435

Magnetic Permeability

<i>H/m Annealed</i>
1.01

Thermal Treatment
Initial Forging

<i>°F</i>	<i>°C</i>
2100-2200	1149-1204

Annealing

<i>°F</i>	<i>°C</i>
1900-1950	1038-1066

Annealing

Cool rapidly or water quench from this temperature.

Hardening

Cannot be hardened by heat treatment. Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNSS24100

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A276	100(690)	55(380)	30	50	—	—
Wire							
Cold finished annealed	A580	100(690)	55(380)	30	50	—	—

UNS S28200 — 18-18 PLUS®

Austenitic

18-18 PLUS is a nickel-free, austenitic stainless steel with twice the yield strength of Type 304 and corrosion resistance between that of Types 304 and 316. The alloy has excellent ductility, toughness and good high temperature strength. The steel can be cold worked, welded and machined. Although the alloy contains no nickel, it is nonmagnetic in the annealed condition as well as after severe cold forming.

The steel is used in applications where the corrosion resistance of Type 304 is required, but where the strength, magnetic permeability or galling resistance of Type 304 is inadequate after cold working.

Typical applications include valve and pump components, shafting, fasteners, wire and Belleville springs and orthodontic applications.

UNS S28200

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Mo</i>	<i>N</i>	<i>Cu</i>
0.15	<u>17.0</u>	0.04	0.03	1.00	<u>17.0</u>	<u>0.75</u>	<u>0.40</u>	<u>0.75</u>
Max	19.0	Max	Max	Max	19.0	1.25	0.60	1.25

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension^a**

<i>psi</i>	<i>MPa</i>
30.0×10^6	207,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.285	7,880

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
846

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
No Data	

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-1200°F	0-649°C
10.2×10^{-6}	18.4×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
~2550	1400

Magnetic Permeability

<i>H/m Annealed</i>
1.001

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2150-2200	1180-1200

Annealing

<i>°F</i>	<i>°C</i>
1900-1200	1040-1204

Annealing

Heat to above temperature and quench in water.

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S28200
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A276	110(760)	60(410)	35	55	—	—
Wire							
Annealed	A580	110(760)	60(410)	35	55	—	—

UNS S30100 — Type 301

Austenitic

Type 301 is a lean austenitic, chromium-nickel stainless steel capable of unusually high uniform elongation with proper composition balance and is frequently used for severe cold forming applications.

The steel also attains high tensile strength

with reasonable ductility by moderate to severe cold working and it is often used in the cold rolled or cold drawn condition. Type 301 is essentially nonmagnetic as annealed, but becomes magnetic when cold worked.

See also the Section on Typical Applications.

UNS S30100
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.15	2.00	0.045	0.030	0.75	<u>16.0</u>	<u>6.0</u>	0.10
Max	Max	Max	Max	Max	18.0	8.0	Max

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension^a**

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Modulus of Elasticity in Torsion^a

<i>psi</i>	<i>MPa</i>
12.5×10^6	86,200

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm</i>	
68°F (20°C)	720
212°F (100°C)	780
392°F (200°C)	860
752°F (400°C)	1000
1112°F (600°C)	1110
1472°F (800°C)	1210
1652°F (900°C)	1260

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F	9.4
932°F	12.4
100°C	16.3
500°C	21.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	9.4×10^{-6}
32-600°F	9.5×10^{-6}
32-1000°F	10.1×10^{-6}
32-1200°F	10.4×10^{-6}
68-1600°F	11.0×10^{-6}
0-100°C	17.0×10^{-6}
0-315°C	17.2×10^{-6}
0-538°C	18.2×10^{-6}
0-649°C	18.8×10^{-6}
20-871°C	19.9×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2590	1399-1421

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S30100
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet, & Strip							
¼ Hard	A666	125(862)	75(517)	25	—	—	C25 ^a
½ Hard	A666	150(1,034)	110(758)	18 ^b	—	—	C32 ^a
¾ Hard	A666	175(1,207)	135(931)	12 ^b	—	—	C37 ^a
Full Hard	A666	185(1,275)	140(965)	9 ^b	—	—	C41 ^a
Welded Mechanical Tubing							
Annealed	A554	75(517)	30(207)	35	—	192	B90

^aTypical value is for information only. Material is usually produced to meet tensile requirements.

^bValue given is for material over 0.015 in (0.381 mm) thickness.

UNS S30200 — Type 302

Austenitic

Type 302 is one of the most widely used chromium-nickel austenitic stainless steels. It is extremely tough and ductile. Its corrosion resistance is somewhat superior to that of Type 301.

The alloy is nonmagnetic. It is not hardenable by heat treatment and it is generally used in the annealed condition.

See also the Section on Typical Applications.

UNS S30200

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.15	2.00	0.045	0.030	0.75	<u>17.0</u>	<u>8.0</u>	0.10
Max	Max	Max	Max	Max	19.0	10.0	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Modulus of Elasticity in Torsion^a

<i>psi</i>	<i>MPa</i>
12.5×10^6	86,200

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm</i>	
68°F (20°C)	720
212°F (100°C)	780
392°F (200°C)	860
752°F (400°C)	1000
1112°F (600°C)	1110
1472°F (800°C)	1210
1652°F (900°C)	1260

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F	9.4
932°F	12.4
100°C	16.3
500°C	21.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	9.6×10^{-6}
32-600°F	9.9×10^{-6}
32-1000°F	10.2×10^{-6}
32-1200°F	10.4×10^{-6}
68-1600°F	11.0×10^{-6}
0-100°C	17.2×10^{-6}
0-315°C	17.8×10^{-6}
0-538°C	18.4×10^{-6}
0-649°C	18.8×10^{-6}
20-341°C	19.8×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2590	1399-1421

Magnetic Permeability

H/m Annealed
1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S30200
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A240, A666	75(517)	30(207)	40	—	201	B92
1/8 Hard	A666	100(690)	55(380)	40	—	—	—
1/4 Hard	A666	125(862)	75(517)	12 ^a	—	—	—
1/2 Hard	A666	150(1034)	110(758)	10 ^a	—	—	—
Bar							
Annealed	A276, A479	75(517)	30(207)	40	50	—	—
Cold Finished	A276 ^b	90(621)	45(310)	30	40	—	—
Cold Finished	A276 ^c	75(517)	30(207)	30	40	—	—
Cold Finished Condition B (severely cold worked)	A276 ^d	125(862)	100(689)	12	35	—	—
Also refer to A193, A194 and A320 covering bolting material and nuts.							
Wire							
Annealed	A580	75(507)	30(207)	35 ^e	50 ^e	—	—
Cold Finished	A580	90(621)	45(310)	30 ^e	40 ^e	—	—
Cold Heading Quality	A493	85-105 ^f (586-724)	—	—	—	—	—
Also refer to A313 for Spring Wire, A368 for Wire Strand, A478 for Weaving Wire and A492 for Rope Wire.							
Forgings							
Annealed	A473	75(517)	30(207)	40	50	—	—
Mechanical Tubing							
Annealed	A511, A554	75(517)	30(207)	35	—	192	B90

^aValue given is for material over 0.030 in (0.762 mm) in thickness. For limits on lighter thickness material, refer to ASTM A666.

^bFor sizes up to ½ in (12.7 mm) inclusive.

^cFor sizes over ½ in (12.7 mm).

^dValues given are for sizes to ¾ in (19.05 mm) inclusive. For larger sizes, refer to ASTM A276.

^eFor material 5/32 in (3.97 mm) and under in size, the minimum elongation and reduction in area shall be 25 and 40 percent, respectively.

^fSpecified range for sizes 0.156 in (3.97 mm) and over in lightly drafted condition.

UNS S30215 — Type 302B

Austenitic

Type 302B is an austenitic chromium-nickel stainless steel with a silicon addition to enhance its resistance to scaling at elevated temperatures.

It is intended for parts which are exposed to high temperatures in service.

See also the Section on Typical Applications.

UNS S30215
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.15	2.00	0.045	0.030	<u>2.00</u>	<u>17.0</u>	<u>8.0</u>	0.10
Max	Max	Max	Max	3.00	19.0	10.0	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
720

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
No Data	

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	9.0×10^{-6}	0-100°C	16.2×10^{-6}
32-600°F	10.0×10^{-6}	0-315°C	18.0×10^{-6}
32-1000°F	10.8×10^{-6}	0-538°C	19.4×10^{-6}
32-1200°F	11.2×10^{-6}	0-649°C	20.4×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2500-2550	1371-1399

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2050-2250	1120-1231

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNSS30215
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip Annealed	A167	75(520)	30(210)	40	—	217	B95
Bar	A276						
Annealed		75(520)	30(210)	40	50	—	—
Cold finished, up to 0.5 in (12.7mm)		90(620)	45(310)	30	40	—	—
Over 0.5 in		75(520)	30(210)	30	40	—	—
Wire	A580						
Annealed:							
0.0156 in (3.96 mm) and under		75(520)	30(210)	25	40	—	—
Over 0.0156 in (3.96 mm)		75(520)	30(210)	35	50	—	—
Cold finished:							
0.0156 in (3.96 mm) and under		90(620)	45(310)	25	40	—	—
Over 0.0156 in (3.96 mm)		90(620)	45(310)	30	40	—	—
Forgings							
Annealed	A473	75(520)	30(210)	40	50	—	—

UNS S30300—Type 303
UNS S30323—Type 303Se

Free machining/Austenitic

Types 303 and 303Se are austenitic, chromium-nickel stainless steels which have elements added to improve their machining and non-seizing characteristics. They are the most readily machineable of all of the austenitic, chromium-nickel grades and are suitable for use in auto-

matic screw machines. Both types are widely used to minimize seizing or galling. The machineability of Type 303Se is slightly lower than that of Type 303, but Type 303Se has better hot and cold forming capability.

See also the Section on Typical Applications.

UNS S30300/S30323
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Se</i>
Type 303							
0.15	2.00	0.20	0.15	1.00	17.0	8.0	—
Max	Max	Max	Min	Max	19.0	10.0	
Type 303Se							
0.15	2.00	0.20	0.060	1.00	17.0	8.0	0.15
Max	Max	Max	Max	Max	19.0	10.0	Min

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0 × 10 ⁶	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
720

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F 9.4	100°C 16.3
932°F 12.4	500°C 21.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F 9.6 × 10 ⁻⁶	0-100°C 17.3 × 10 ⁻⁶
32-600°F 9.9 × 10 ⁻⁶	0-316°C 17.8 × 10 ⁻⁶
32-1000°F 10.2 × 10 ⁻⁶	0-538°C 18.4 × 10 ⁻⁶
32-1200°F 10.4 × 10 ⁻⁶	0-649°C 18.7 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2550-2590	1399-1421

Magnetic Permeability

H/m Annealed
 Less than 1.02

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2350	1149-1286

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S30300/S30323

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A582	—	—	—	—	262	—
Wire							
Annealed	A581	85-125 (586-862)	—	—	—	—	—
Cold worked	A581	115-145 (793-1000)					
Forgings							
Annealed	A473	75(517)	30(207)	40	50	—	—

Refer also to ASTM A320 covering bolting materials for low temperature service.

**UNS S30345—Type XM-2; 303 MA;
303Al Modified®**
Free machining/Austenitic

Type XM-2 is a free-machining austenitic stainless steel which owes its good machineability to the proper combination of aluminum and sulfur in its composition. It has better formabil-

ity than Type 303 and should be considered for cold forming operations where Type 303Se is now used, specifications permitting. Its corrosion resistance is similar to that of Type 303 but it has better pitting resistance than Type 303.

UNS S30345

**Chemical Composition Limits
Cast or Heat Analysis, Percent**

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>Al</i>
0.15	2.00	0.05	<u>0.11</u>	1.00	<u>17.0</u>	<u>8.0</u>	<u>0.40</u>	<u>0.60</u>
Max	Max	Max	0.16	Max	19.0	10.0	0.60	1.00

Physical Properties in the Annealed Condition
Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
27.6×10^6	190,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.283	7,830

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
768

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
No Data	

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
68-600°F	9.1×10^{-6}	20-316°C	16.4×10^{-6}
68-1000°F	10.3×10^{-6}	20-538°C	18.5×10^{-6}
68-1700°F	10.6×10^{-6}	20-649°C	19.1×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
~2625	1440

Magnetic Permeability

<i>H/m Annealed</i>
No Data

Thermal Treatment
Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1260

Annealing

<i>°F</i>	<i>°C</i>
1900-2000	1038-1093

Annealing

Anneal to above temperature and water quench.

Hardening

Cannot be hardened by heat treatment. Increase in strength and hardness via cold working.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S30345

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>	
						<i>HB, Max</i>	<i>HR, Max</i>
Bar							
Annealed	A582	—	—	—	—	262	—
Wire							
Annealed	A582	85-125 (590-860)	—	—	—	—	—

UNS S30400—Type 304
UNS S30409—Type 304H

Austenitic

Type 304 is the most widely used austenitic, chromium-nickel stainless steel. Its corrosion resistance is somewhat higher than that of Type 302. It is essentially nonmagnetic when annealed and can become slightly magnetic when cold worked. The alloy has excellent fabricability and weldability.

The alloy serves a wide range of applications. It resists rusting in architectural applications. It is resistant to food processing environments,

except for high-temperature conditions involving high acid and chloride contents, and it resists organic chemicals, dyestuffs and a wide variety of inorganic chemicals.

Type 304H is a modification of Type 304 in which the carbon content is controlled to a range of 0.04 to 0.10 to provide improved high temperature strength to parts exposed to temperatures above 800°F (425°C).

See also the Section on Typical Applications.

UNS S30400/S30409
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
Type 304							
0.08	2.00	0.045	0.030	0.75	<u>18.0</u>	<u>8.0</u>	0.10
Max	Max	Max	Max	Max	20.0	10.5	Max
Type 304H							
<u>0.04</u>	2.00	0.045	0.030	0.75	<u>18.0</u>	<u>8.0</u>	0.10
0.10	Max	Max	Max	Max	20.0	10.5	Max

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension^a**

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Modulus of Elasticity in Torsion^a

<i>psi</i>	<i>MPa</i>
12.5×10^6	86,200

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm</i>	
68°F (20°C)	720
212°F (100°C)	780
392°F (200°C)	860
752°F (400°C)	1000
1112°F (600°C)	1110
1472°F (800°C)	1210
1652°F (900°C)	1260

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F	9.4
932°F	12.4
100°C	16.3
500°C	21.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	9.6×10^{-6}
32-600°F	9.9×10^{-6}
32-1000°F	10.2×10^{-6}
32-1200°F	10.4×10^{-6}
32-1600°F	11.0×10^{-6}
0-100°C	17.2×10^{-6}
0-315°C	17.8×10^{-6}
0-538°C	18.4×10^{-6}
0-649°C	18.8×10^{-6}
20-871°C	19.9×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2650	1399-1454

Magnetic Permeability

H/m Annealed
 1.02 Max

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S30400/S30409
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A240, A666	75(517)	30(207)	40	—	201	B92
1/4 Hard	A666	125(862)	75(517)	12 ^a	—	—	—
1/2 Hard	A666	150(1034)	110(758)	7 ^a	—	—	—
Bar							
Annealed	A276, A479	75(517)	30(207)	40	50	—	—
Cold Finished ^b	A276	90(621)	45(310)	30	40	—	—
Cold Finished ^c	A276 (Condition A)	75(517)	30(207)	30	40	—	—
Cold Finished ^d	A276 (Condition B)	125(862)	100(689)	12 ^e	35	—	—
Also refer to A493 Cold Heading Quality Bar and A193, A194 and A320 covering bolting material and nuts.							
Wire							
Annealed	A580	75(517)	30(207)	35 ^f	50 ^e	—	—
Cold Finished	A580	90(621)	45(310)	35 ^f	45 ^e	—	—
Cold Heading Quality	A493	80-100 (552-689) ^g	—	—	—	—	—
Also refer to A313 for Spring Wire, A368 for Wire Strand, A478 for Weaving Wire and A492 for Rope Wire.							
Forgings							
Annealed	A473	75(517) ^h	30(207)	40	50	—	—
Pipe and Tubing							
Annealed	A213, A249, A271, A511, A554, A632, A688	75(517)	30(207)	35 ⁱ	—	192	B90 ^j
Annealed	A312, A376	75(517)	30(207)	35	—	—	—
Annealed	A409, A651	75(517)	30(207)	—	—	—	—
Annealed	A430	70(517)	30(207)	45 ^k	50 ^k	—	—
Also refer to A358.							

^aValue given is for material over 0.030 in (0.762 mm) in thickness. For limits on lighter thickness material, refer to A666.

^bFor sizes up to 1/2 in (12.7 mm) inclusive.

^cFor sizes over 1/2 in (12.7 mm).

^dValues given are for sizes to 3/4 in (19.05 mm) inclusive. For larger sizes, see ASTM A276.

^eMinimum elongation specified in A666 is 7 percent.

^fFor material 5/32 in (3.97 mm) and under in size, the minimum elongation and reduction in area shall be 25 and 40 percent, respectively.

^gSpecified range for sizes 0.156 in (3.97 mm) and over in lightly drafted condition.

^hFor material over 5 in (127 mm) in section, the tensile strength is 70 ksi (483 MPa) minimum.

ⁱSee specification for limits on specific pipe and tube sizes and wall thickness.

^jRequired by A511 and A554.

^kTransverse limits for elongation and reduction in area are 20 and 30 percent, respectively.

UNS S30403—Type 304L

Austenitic

Type 304L is a low carbon austenitic chromium-nickel stainless steel with general corrosion resistance similar to that of Type 304, but with superior resistance to intergranular corrosion following welding or stress relieving. It is sug-

gested for use in certain corrosive environments for parts which can not be annealed after fabrication by welding. Parts made of Type 304L are generally limited to service at temperatures up to 800°F (425°C).

See also the Section on Typical Applications.

UNS S30403

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.030	2.00	0.045	0.030	1.00	<u>18.0</u>	<u>8.0</u>	0.10
Max	Max	Max	Max	Max	20.0	12.0	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Modulus of Elasticity in Torsion^a

<i>psi</i>	<i>MPa</i>
12.5×10^6	86,200

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

Microhm — mm

68°F (20°C)	720
212°F (100°C)	780
392°F (200°C)	860
752°F (400°C)	1000
1112°F (600°C)	1110
1472°F (800°C)	1210
1652°F (900°C)	1260

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h·°F</i>	<i>W/m·K</i>
212°F	9.4
100°C	16.3
932°F	12.4
500°C	21.5

Mean Coefficient of Expansion

	<i>in/in/°F</i>		<i>cm/cm/°C</i>
32-212°F	9.4×10^{-6}	0-100°C	17.0×10^{-6}
32-600°F	9.5×10^{-6}	0-315°C	17.2×10^{-6}
32-1000°F	10.1×10^{-6}	0-538°C	18.2×10^{-6}
32-1200°F	10.4×10^{-6}	0-649°C	18.8×10^{-6}
68-1600°F	11.0×10^{-6}	20-871°C	19.8×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2650	1399-1455

Magnetic Permeability

H/m Annealed

1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S30403

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A240	70(483)	25(172)	40	—	183	B88
Bar							
Annealed	A276	70(483)	25(172)	40	50	—	—
Annealed	A479	70(483)	25(172)	30	40	—	—
Wire							
Annealed	A580	70(483)	25(172)	35 ^a	50 ^a	—	—
Cold Finished	A580	90(621)	45(310)	30 ^a	40 ^a	—	—
Also refer to A478 Weaving Wire.							
Pipe Tubing							
Annealed	A213, A249, A511, A554, A632, A688	70(483)	25(172)	35	—	192	B90
	A312	70(483)	25(172)	35	—	—	—
	A409	70(483)	25(172)	—	—	—	—
Also refer to A358.							
Forgings							
Annealed	A473	65(448)	25(172)	40	50	—	—

^aFor material 5/32 in (3.97 mm) and under in size, the elongation and reduction in area shall be 25 and 40 percent, respectively.

Alloy 153 MA is an austenitic stainless steel intended primarily for use at high temperatures where corrosion only from hot gases occurs. It has very good creep strength, good scaling resistance and is especially resistant to embrittlement. The addition of rare earth metals to a conventional 18-8 analysis provides very good oxidation resistance, and the addition of nitrogen increases the creep strength. The steel is designed for use in the temperature range 1110 to 1740°F (600 to 950°C).

Typical applications include internal shell in bell-type furnaces and electrically-heated muffle furnaces, combustion chambers for destruction of industrial gases, as well as off-gas line and recuperators, where temperatures are moderate, i.e., up to about 1740°F (950°C), anchoring grids for refractory ceramics, conveyor belts for continuous furnaces, cyclones and fan impellers for hot gases and calcination furnaces.

UNS S30415

Chemical Composition Limits Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	N	Ce
0.04	0.80	0.045	0.030	1.00	18.0	8.0	0.12	0.03
0.06	Max	Max	Max	2.00	19.0	10.0	0.18	0.08

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.282	7,800

Electrical Resistivity

Microhm — mm

68°F (20°C)	850
315°F (600°C)	1370
425°F (800°C)	1430
540°F (1000°C)	1450

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
68°F 8.7	20°C 15.0
315°F 13.0	600°C 22.5
425°F 14.7	800°C 25.4
540°F 16.2	1000°C 28.0

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	9.2×10^{-6}
68-315°F	10.3×10^{-6}
68-425°F	10.6×10^{-6}
68-540°F	11.1×10^{-6}
	20-100°C
	20-600°C
	20-800°C
	20-1000°C
	16.5×10^{-6}
	18.5×10^{-6}
	19.0×10^{-6}
	20.0×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2640	1370-1450

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1650-2100	900-1150

Annealing

<i>°F</i>	<i>°C</i>
1870-2050.1	1000-1120

Stress Relief Annealing

<i>°F</i>	<i>°C</i>
1650	900

Cool rapidly from the annealing temperature.

Hardening

Hardenable by cold work only.

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength ksi(MPa), Min	Yield Strength ksi(MPa), Min	Elongation %, Min	Reduction in Area %, Min	Hardness HB, Max HR, Max
Plate, Sheet & Strip	A240	87(600)	42(290)	40.0	—	217 B95

UNS S30430—Type 304Cu; 18-9LW

Austenitic

Type 304Cu is an austenitic, chromium-nickel-copper stainless steel which exhibits a lower

rate of work hardening rate than Type 304. It is used for severe cold heading and forming operations.

UNS S30430
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Cu</i>
0.03	2.00	0.045	0.030	1.00	17.0	8.0	3.0
Max	Max	Max	Max	Max	19.0	10.0	4.0

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0 × 10 ⁶	193,000

Melting Range

<i>°F</i>	<i>°C</i>
2550-2650	1399-1454

Modulus of Elasticity in Torsion^a

<i>psi</i>	<i>MPa</i>
12.5 × 10 ⁶	86,200

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
720

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
212°F 9.4	100°C 16.3
932°F 12.4	500°C 21.5

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

Mean Coefficient of Expansion

	<i>in/in/°F</i>		<i>cm/cm/°C</i>
32-212°F	9.6 × 10 ⁻⁶	0-100°C	17.2 × 10 ⁻⁶
32-600°F	9.9 × 10 ⁻⁶	0-315°C	17.8 × 10 ⁻⁶
32-1200°F	10.4 × 10 ⁻⁶	0-649°C	18.8 × 10 ⁻⁶

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S30430
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Wire	A493						
Annealed		88(605)	—	—	—	—	—
Lightly drafted		96(660)	—	—	—	—	—

UNS S30451—Type 304N

Nitrogen-strengthened/Austenitic

Type 304N is a nitrogen-strengthened austenitic stainless steel. It is stronger than Type 304 but there is little effect on ductility and corrosion resistance. The alloy is essentially nonmag-

netic when annealed and it is more resistant to increased magnetic permeability on cold working than Type 304.

UNS S30451

Chemical Composition Limits Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	N
0.08	2.00	0.045	0.030	0.75	18.0	8.0	0.10
Max	Max	Max	Max	Max	20.0	10.5	0.16

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

psi	MPa
28.5 × 10 ⁶	196,000

Density

lb/in ³	kg/m ³
0.29	8,027

Electrical Resistivity

Microhm — mm at 68°F (20°C)
720

Specific Heat

Btu/lb °F	kJ/kg·K
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

Btu/ft·h/°F	W/m·K
212°F 9.4	100°C 16.3
932°F 12.4	500°C 21.5

Mean Coefficient of Expansion

in/in/°F	cm/cm/°C
32-1200°F	10.5 × 10 ⁻⁶
	0-649°C
	18.9 × 10 ⁻⁶

Melting Range

°F	°C
2550-2650	1398-1454

Thermal Treatment

Initial Forging

°F	°C
2100-2300	1149-1259

Annealing

°F	°C
1850-2050	1080-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S30451

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength ksi(MPa), Min	Yield Strength ksi(MPa), Min	Elongation %, Min	Reduction in Area %, Min	Hardness HB, Max	HR, Max
Plate, Sheet & Strip							
Annealed	A240	80(552)	35(241)	30	—	201	B92
Bar							
Annealed	A276, AA479	80(552)	35(241)	30	—	—	—
Pipe & Tubing							
Annealed	A213, A249	80(552)	35(241)	35	—	192	B90
	A312, A376	80(552)	35(241)	35	—	—	—
Annealed	A358	80(552)	35(241)	30	—	—	B88
Annealed	A430	75(517)	35(241)	45 ^a	50 ^a	—	—

^aValues given are for longitudinal tests. For transverse tests, elongation and reduction of area shall be 20 and 30 percent, respectively.

UNS S30453—Type 304LN

Type 304LN is an austenitic chromium-nickel stainless with low carbon and added nitrogen. Its physical properties and thermal treatments are similar to, but not necessarily identical to,

Nitrogen-strengthened/Austenitic

those of Type 304. The alloy is used in the welded condition where its strength exceeds that of Type 304L. Applications include pressurized water fire extinguishers, and nuclear power generation equipment.

UNS S30453

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.030	2.00	0.045	0.030	0.75	<u>18.0</u>	<u>8.0</u>	<u>0.10</u>
Max	Max	Max	Max	Max	20.0	12.0	0.16

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Modulus of Elasticity in Torsion^a

<i>psi</i>	<i>MPa</i>
12.5×10^6	86,200

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

Microhm — mm at

68°F (20°C)	720
212°F (100°C)	780
392°F (200°C)	860
752°F (400°C)	1000
1112°F (600°C)	1110
1472°F (800°C)	1210
1652°F (900°C)	1260

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F	9.4
100°C	16.3
932°F	12.4
500°C	21.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	9.6×10^{-6}
32-600°F	9.9×10^{-6}
32-1000°F	10.2×10^{-6}
32-1200°F	10.4×10^{-6}
68-1600°F	11.0×10^{-6}
0-100°C	17.2×10^{-6}
0-315°C	17.8×10^{-6}
0-538°C	18.4×10^{-6}
0-649°C	18.8×10^{-6}
20-871°C	19.9×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2650	1399-1454

Magnetic Permeability

H/m Annealed

1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Hardening

Hardenable by cold work only.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S30453

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A240	75(517)	30(207)	40	—	—	B92
Bar							
Annealed	A479	75(517)	30(207)	30	40	—	—
Pipe and Tubing							
Annealed	A312 A376	75(517)	30(207)	35	—	—	—

UNS S30500—Type 305

Austenitic

Type 305 is an austenitic, chromium-nickel stainless steel with a lower rate of work hardening than Types 302 or 304 because of its high nickel content. It is used extensively for cold

heading, severe deep drawing and spinning operations. The alloy maintains a low magnetic permeability after deep drawing.

See also the Section on Typical Applications.

UNS S30500
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>
0.12	2.00	0.045	0.030	0.75	<u>17.0</u>	<u>10.5</u>
Max	Max	Max	Max	Max	19.0	13.0

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Modulus of Elasticity in Torsion^a

<i>psi</i>	<i>MPa</i>
12.5×10^6	86,200

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

Microhm — mm at

68°F (20°C)	720
212°F (100°C)	780
392°F (200°C)	860
752°F (400°C)	1000
1112°F (600°C)	1110
1472°F (800°C)	1210
1652°F (900°C)	1260

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F 9.4	100°C 16.3
932°F 12.4	500°C 21.5

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	9.6×10^{-6}	0-100°C	17.2×10^{-6}
32-600°F	9.9×10^{-6}	0-315°C	17.8×10^{-6}
32-1000°F	10.2×10^{-6}	0-538°C	18.4×10^{-6}
32-1200°F	10.4×10^{-6}	0-649°C	18.8×10^{-6}
68-1600°F	11.0×10^{-6}	20-871°C	19.8×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2650	1399-1455

Magnetic Permeability

H/m Annealed

1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Hardening

Hardenable by cold work only.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S30500
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A240	70(485)	25(170)	40	—	183	B88
Bar							
Annealed	A276	75(517)	30(207)	40	50	—	—
Cold Finished ^a	A276	90(621)	45(310)	30	40	—	—
Cold Finished ^b	A276	75(517)	30(207)	30	40	—	—

Also refer to A493 Cold Heading Quality Bar.

Wire

Annealed	A580	75(517)	30(207)	35 ^c	50 ^c	—	—
Cold Finished	A580	90(621)	45(310)	30 ^c	40 ^c	—	—
Cold Heading Quality	A493	85(585) Max	—	—	—	—	—
Annealed Lightly drafted	A493	95(655) Max	—	—	—	—	—

Also refer to A313 for Spring Wire, A368 for Wire Strand, A478 for Weaving Wire and A492 for Rope Wire.

Forgings

Annealed	A473	75(517)	30(207)	40	50	—	—
Tubing							
Annealed	A249, A511, A554	75(517)	30(207)	35	—	—	—

^aFor material sizes up to 1/2 in (12.7 mm) inclusive.

^bFor material sizes over 1/2 in (12.7 mm).

^cFor material 5/32 in (3.97 mm) and under in size, the minimum elongation and reduction in area shall be 25 and 40 percent, respectively.

UNS S30600—Cronifer® 1815 LCSi Alloy 1815

Austenitic

S30600 is a silicon-containing low carbon austenitic chromium-nickel stainless steel which is used in the chemical industry within the temperature range -60 to 660°F (-50 to 350°C). The alloy has excellent resistance to oxidizing media such as highly-concentrated boiling nitric acid. It has good corrosion resistance in nitric acid solutions containing oxidizing agents and good resistance to concentrated hot sulfuric acid. It is resistant to intercrystalline corrosion.

Typical applications include heat exchangers, tubing, stirring equipment, pumps and vessels for the production, storage and transportation of highly concentrated ($\geq 95\%$) nitric acid; solution vessels for processing nuclear waste; tubing and heat exchangers for processes involving highly concentrated ($\geq 98.5\%$) sulfuric acid.

UNS S30600

**Chemical Composition Limits
Cast or Heat Analysis, Percent**

C	Mn	P	S	Si	Cr	Ni	Mo	Cu
0.018	2.00	0.020	0.020	<u>3.7</u>	<u>17.0</u>	<u>14.0</u>	0.20	0.50
Max	Max	Max	Max	4.3	18.5	15.5	Max	Max

Physical Properties in the Annealed Condition
Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.4×10^6	203,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,800

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
750

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
75°F	24°C
8.4	14.6

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-200°F	20-93°C
9.2 × 10 ⁻⁶	16.6 × 10 ⁻⁶
68-392°F	20-200°C
9.4 × 10 ⁻⁶	17.0 × 10 ⁻⁶
68-572°F	20-300°C
9.7 × 10 ⁻⁶	17.5 × 10 ⁻⁶
68-752°F	20-400°C
10.1 × 10 ⁻⁶	18.1 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
~2640	~1450

Magnetic Permeability

<i>H/m Annealed</i>
< 1.01

Thermal Treatment
Initial Forging

<i>°F</i>	<i>°C</i>
1650-2200	900-1200

Solution Treatment

<i>°F</i>	<i>°C</i>
2010-2140	1100-1170

Diffusion Annealing

<i>°F</i>	<i>°C</i>
2280	1250

Fast water quenching is essential for maximum corrosion resistance. Air cooling is acceptable for thicknesses less than 0.06 in (1.5 mm) only.

Hardening

Not hardenable by heat treatment.

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip	A240	78(540)	35(240)	40.0	—	—	—

RA85H is a high silicon austenitic alloy which has very good resistance to hot corrosion by a range of aggressive environments—including carbon, sulfur and molten chloride salts. With twice the creep strength of Type 310S, this alloy is becoming one of the preferred materials for both coal conversion and waste incineration systems.

Initially developed for use in heat treat fixtures, RA85H offers superior strength and ther-

mal fatigue resistance in bar frame baskets for carburizing and carbonitriding service.

Applications include waste incineration hot components; fluidized bed coal combustors—vortex finders, cyclones, fuel guns, tuyeres and tube hangers; stack dampers; coal gasification equipment; rotary kilns; heat treating fixtures for carburizing or molten salt service; brazing and sintering muffles and retorts; furnace fans and shafts; and hot dip galvanizing fixtures.

UNS S30615
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Al</i>
<u>0.16</u>	2.00	0.030	0.030	<u>3.2</u>	<u>17.0</u>	<u>13.5</u>	<u>0.8</u>
0.24	Max	Max	Max	4.0	19.5	16.0	1.5

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
28.5×10^6	196,700

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.274	7,590

Electrical Resistivity

<i>Microhm — mm</i>	
75°F (24°C)	1020
200°F (93°C)	1050
400°F (204°C)	1090
600°F (316°C)	1130
1000°F (538°C)	1180
1500°F (816°C)	1230
2000°F (1093°C)	1280

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.10	0.42

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>	
75°F	7.0	24°C
200°F	7.9	93°C
800°F	12.4	427°C
1200°F	14.4	649°C
1400°F	15.9	760°C
1600°F	17.3	871°C

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
75-200°F	9.2×10^{-6}
75-400°F	9.4×10^{-6}
75-600°F	9.5×10^{-6}
75-800°F	9.7×10^{-6}
75-1000°F	9.9×10^{-6}
75-1200°F	10.1×10^{-6}
75-1400°F	10.3×10^{-6}
75-1600°F	10.4×10^{-6}
75-1800°F	10.7×10^{-6}
24-93°C	16.6×10^{-6}
24-204°C	16.9×10^{-6}
24-316°C	17.1×10^{-6}
24-427°C	17.5×10^{-6}
24-538°C	17.8×10^{-6}
24-649°C	18.2×10^{-6}
24-760°C	18.5×10^{-6}
24-871°C	18.7×10^{-6}
24-982°C	19.3×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2400-2520	1315-1380

Magnetic Permeability

H/m Annealed

Essentially nonmagnetic

Thermal Treatment

Full Annealing

<i>°F</i>	<i>°C</i>
2050	1120

Process Annealing

<i>°F</i>	<i>°C</i>
1850	1010

Furnace cool until black, then air cool—do not quench.

UNS S30615

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A240	90(620)	40(275)	35.0	—	217	B95

UNS S30800—Type 308

Austenitic

Type 308 is an austenitic, chromium-nickel stainless steel with corrosion and heat resistance superior to that of Type 304. It is used primarily for welding wire, with composition

balanced to produce some ferrite in the weld deposit for the control of microfissuring.

See also the Section on Typical Applications.

UNS S30800

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>
0.08	2.00	0.045	0.030	0.75	<u>19.0</u>	<u>10.0</u>
Max	Max	Max	Max	Max	21.0	12.0

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at</i>
68°F (20°C) 720
1200°F (649°C) 1160

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F 8.8	100°C 15.2
932°F 12.5	500°C 21.6

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	9.6×10^{-6}	0-100° C	17.3×10^{-6}
32-600°F	9.9×10^{-6}	0-315° C	17.8×10^{-6}
32-1000°F	10.2×10^{-6}	0-538° C	18.4×10^{-6}
32-1200°F	10.4×10^{-6}	0-649° C	18.8×10^{-6}
68-1832°F	10.9×10^{-6}	20-1000° C	10.4×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2590	1399-1421

Magnetic Permeability

H/m Annealed

1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

UNS S30800

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A167	75(517)	30(207)	40	—	183	B88
Bar							
Annealed	A276	75(517)	30(207)	40	50	—	—
Cold Finished ^a	A276	90(621)	45(310)	30	40	—	—
Cold Finished ^b	A276	75(517)	30(207)	30	40	—	—
Wire							
Annealed	A580	75(517)	30(207)	35 ^c	50 ^c	—	—
Cold Finished	A580	90(621)	45(310)	30 ^c	40 ^c	—	—
Forgings							
Annealed	A473	75(517)	30(207)	40	50	—	—

^aFor material up to 1/2 in (12.7 mm) in size.^bFor material over 1/2 in (12.7 mm) in size.^cFor material 5/32 in (3.97 mm) and under in size, the minimum elongation and reduction in area shall be 25 and 40 percent, respectively.

253 MA is a fully austenitic stainless steel containing small additions of rare earth metals which provide oxidation resistance and good creep strength. Despite the relatively low levels of chromium and nickel, this is a high-temperature steel which can, in many cases, replace more highly alloyed steels and nickel-base alloys.

The steel has a very high scaling temperature in air, 2100°F (1150°C), and a very adherent oxide makes it resistant to scaling when exposed to large, rapid temperature fluctuations. The protective oxide does not form, however, in a reducing atmosphere.

The steel has good resistance to deformation at high temperatures even in connection with rapid temperature fluctuations. The mechanical properties are very good also at lower temperatures where creep is not a factor. The material is easily formed and possesses good weldability despite its high strength.

Typical applications are as follows:

Sintering plants—grids, wind boxes and fans.

Blast furnace plants—charging pipes for pulverized coal, circulation fans, piping, expansion bellows and recuperators of blast furnace gas.

Steel melting, smelters and continuous casting plants—extraction hoods, flue gas ducts, dampers, doors, bridges, preheaters for scrap and ladles.

Heat treatment furnaces and accessories—muffles, retorts, fans, heat exchangers, furnace hearths, conveyors, radiant tubes, electric heater elements, anchor bolts and fasteners for refractory materials, fixtures for brazing work, trays and brackets and thermocouple sheathing.

Mineral preparation and cement production—feeding and discharging systems in preheaters, rotary kilns and coolers; pipes, burner shields, burners, grate plates, flap valves, ring segments and refractory anchors.

UNS S30815

Chemical Composition Limits Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	N	Ce
0.05	0.80	0.040	0.030	1.10	20.0	10.0	0.14	0.03
0.10	Max	Max	Max	2.00	22.0	12.0	0.20	0.08

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

psi	MPa
29.0 × 10 ⁶	200,000

Density

lb/in ³	kg/m ³
0.28	7,800

Electrical Resistivity

Microhm — mm

68°F (20°C)	850
1110°F (600°C)	1370
1470°F (800°C)	1430
1830°F (1000°C)	1450

Specific Heat

Btu/lb °F	kJ/kg·K
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

Btu/ft·h/°F	W/m·K
68°F	8.7
1110°F	13.0
1470°F	14.7
1830°F	16.8
20°C	15.0
600°C	22.5
800°C	25.5
1000°C	29.0

Mean Coefficient of Expansion

in/in/°F	cm/cm/°C
68-212°F	9.4 × 10 ⁻⁶
68-1110°F	10.3 × 10 ⁻⁶
68-1470°F	10.6 × 10 ⁻⁶
68-1830°F	10.8 × 10 ⁻⁶
20-100°C	17.0 × 10 ⁻⁶
20-600°C	18.5 × 10 ⁻⁶
20-800°C	19.0 × 10 ⁻⁶
20-1000°C	19.5 × 10 ⁻⁶

Melting Range

°F	°C
2460-2605	1350-1430

Thermal Treatment

Initial Forging

°F	°C
1600-2100	900-1150

Annealing

°F	°C
1870-2050	1020-1120

Stress Relief Annealing

°F	°C
1650	900

Hold at temperature for 1/2 h minimum.

UNS S30815

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A240	87(600)	45(310)	40.0	—	217	B95
Bars and Shapes							
Annealed	A276	87(600)	45(310)	40	50	—	—

UNS S30900—Type 309
UNS S30908—Type 309S

Austenitic

Types 309 and 309S are austenitic, chromium-nickel stainless steels with heat resisting qualities. They are widely used for welding wire ap-

plications, including those used for joining dissimilar metals.

See also the Section on Typical Applications.

UNS S30900/S30908
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>
Type 309						
0.20	2.00	0.045	0.030	1.00	<u>22.0</u>	<u>12.0</u>
Max	Max	Max	Max	Max	24.0	15.0
Type 309S						
0.08	2.00	0.045	0.030	1.00	<u>22.0</u>	<u>12.0</u>
Max	Max	Max	Max	Max	24.0	15.0

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension^a**

<i>psi</i>	<i>MPa</i>
29.0 × 10 ⁶	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at</i>
68°F (20°C) 780
1200°F (649°C) 1140

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F 0.12	0-100°C 0.50

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
212°F 9.0	100°C 15.6
932°F 10.8	500°C 18.7

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F 8.3 × 10 ⁻⁶	0-100° C 15.0 × 10 ⁻⁶
32-600°F 9.3 × 10 ⁻⁶	0-315° C 16.6 × 10 ⁻⁶
32-1000°F 9.6 × 10 ⁻⁶	0-538° C 17.2 × 10 ⁻⁶
32-1200°F 10.0 × 10 ⁻⁶	0-649° C 18.0 × 10 ⁻⁶
32-1800°F 11.5 × 10 ⁻⁶	0-982° C 20.6 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2550-2650	1399-1454

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2050-2250	1120-1231

Annealing

<i>°F</i>	<i>°C</i>
1900-2050	1036-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S30900/S30908

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A167, A240	75(517)	30(207)	40	—	217	B95
Bar							
Annealed	A276, A479	75(517)	30(207)	40	50	—	—
Cold Finished ^a	A276	90(621)	45(310)	30	40	—	—
Cold Finished ^b	A276	75(517)	30(207)	30	40	—	—
Wire							
Annealed	A580	75(517)	30(207)	35 ^c	50 ^c	—	—
Cold Finished	A580	90(621)	45(310)	30 ^c	40 ^c	—	—
Also refer to A313 for Spring Wire.							
Forgings							
Annealed	A473	75(517)	30(207)	40	50	—	—
Pipe and Tubing							
Annealed	A249, A511, A554	75(517)	30(207)	35	—	192	B90
	A312	75(517)	30(207)	35	—	—	—
	A409	75(517)	30(207)	—	—	—	—
Annealed	A358	75(517)	30(207)	40	—	—	B95

^aFor material up to 1/2 in (12.7 mm) in size.^bFor material over 1/2 in (12.7 mm) in size.^cFor material 5/32 in (3.97 mm) and under in size, the minimum elongation and reduction in area shall be 25 and 40 percent, respectively.

S31000—Type 310
S31008—Type 310S

Austenitic

Types 310 and 310S are austenitic, chromium-nickel stainless steels with heat resisting properties, and greater hot strength than Types 309

and 309S. They are essentially nonmagnetic when annealed or cold worked.

See also the Section on Typical Applications.

UNS S31000/S31008
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>
Type 310						
0.25	2.00	0.045	0.030	1.50	<u>24.0</u>	<u>19.0</u>
Max	Max	Max	Max	Max	26.0	22.0
Type 310S						
0.08	2.00	0.045	0.030	1.50	<u>24.0</u>	<u>19.0</u>
Max	Max	Max	Max	Max	26.0	22.0

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
720

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F	8.2
100°C	14.2
932°F	10.8
500°C	18.7

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	8.8×10^{-6}
0-100°C	15.9×10^{-6}
32-600°F	9.0×10^{-6}
0-315°C	16.2×10^{-6}
32-1000°F	9.4×10^{-6}
0-538°C	17.0×10^{-6}
32-1200°F	9.7×10^{-6}
0-649°C	17.5×10^{-6}
32-1800°F	10.6×10^{-6}
0-982°C	19.1×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2650	1399-1454

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2000-2250	1193-1232

Annealing

<i>°F</i>	<i>°C</i>
1900-2100	1036-1149

Hardening

Hardenable by cold work only.

UNS S31000/S31008
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A167, A240	75(517)	30(207)	40	—	217	B95
Bar							
Annealed	A276, A479	75(517)	30(207)	40	50	—	—
Cold Finished ^a	A276	90(621)	45(310)	30	40	—	—
Cold Finished ^b	A276	75(517)	30(207)	30	40	—	—
Wire							
Annealed	A580	75(517)	30(207)	35 ^c	50 ^c	—	—
Cold Finished	A580	90(621)	45(310)	35 ^c	45 ^c	—	—
Forgings							
Annealed	A473	75(517)	30(207)	40	50	—	—
Pipe and Tubing							
Annealed	A213, A249, A511, A554, A632	75(517)	30(207)	35	—	192	B90
	A312	75(517)	30(207)	35	—	—	—
	A409	75(517)	30(207)	—	—	—	—
Annealed	A358	75(517)	30(207)	40	—	—	B95

^aFor material up to 1/2 in (12.7 mm) inclusive in size.

^bFor material over 1/2 in (12.7 mm) in size.

^cFor material 5/32 in (3.97 mm) and under in size, the minimum elongation and reduction in area shall be 25 and 40 percent, respectively.

254 SMO is an austenitic stainless steel designed for maximum resistance to pitting and crevice corrosion. With high levels of chromium, molybdenum and nitrogen, the steel is especially suited for high chloride environments such as brackish water, seawater, pulp mill bleach plants and other high chloride process streams. 254 SMO offers chloride resistance superior to that of alloys 904L, 20, 825 and G. The steel is often used as a replacement in critical components of larger constructions where Type 316L or 317L has failed by pitting, crevice attack, or chloride stress corrosion cracking.

In new construction, this steel has been found in many cases to be a technically adequate and much less costly substitute for nickel-base alloys and titanium.

The steel is 50% stronger than the 300-series austenitic stainless steels. It has excellent impact toughness, good workability and weldability.

Applications include seawater handling equipment, pulp mill bleach systems, tall oil distillation columns and equipment, chemical processing equipment, food processing equipment, desalination equipment, flue gas desulfurization scrubbers and oil and gas production equipment.

UNS S31254

Chemical Composition Limits Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>	<i>Cu</i>
0.020	1.00	0.030	0.010	0.80	<u>19.5</u>	<u>17.5</u>	<u>6.0</u>	<u>0.18</u>	<u>0.50</u>
Max	Max	Max	Max	Max	20.5	18.5	6.5	0.22	1.00

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.287	7,944

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
850

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
68°F 8.1	20°C 14.0

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
70-212°F 9.4×10^{-6}	21-100°C 16.9×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2420-2550	1327-1400

Magnetic Permeability

<i>H/m Annealed</i>
1.003

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1800-2100	980-1150

Annealing

<i>°F</i>	<i>°C</i>
2100-2200	1150-1200

Water quench after annealing.

Hardening

Not hardenable by heat treatment.

UNSS31254

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A240	94(650)	44(300)	35.0	—	233	B96
Bars and Shapes							
Annealed	A276	95(655)	44(300)	35	50	—	—
Forgings	A473	95(655)	44(300)	35	50	—	—

UNS S31260—DP3; UR47N

Duplex

DP3 is a duplex stainless steel containing about equal amounts of ferrite and austenite. The alloy has high resistance to pitting and crevice corrosion in high-temperature water. It has better resistance to stress-corrosion cracking in chloride solutions than conventional austenitic stainless steels such as Type 316.

The weldability of the steel is good and DP3

welds also have superior resistance to high-temperature sea water. The toughness is equal to that of Type 316L and better than that of the ferritic stainless steels. The material is widely used for heat exchanger tubes and is one of the most economical steels having good corrosion resistance to sea water.

UNS S31260

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>	<i>Cu</i>	<i>W</i>
0.030	1.00	0.030	0.030	0.75	<u>24.0</u>	<u>5.5</u>	<u>2.5</u>	<u>0.10</u>	<u>0.20</u>	<u>0.10</u>
Max	Max	Max	Max	Max	26.0	7.5	3.5	0.30	0.80	0.50

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.282	7,800

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.120	0.503

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
77°F	25°C
212°F	100°C
392°F	200°C
7.8	13.4
8.7	15.1
9.7	16.7

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-122°F	20-50°C
68-212°F	20-100°C
68-392°F	20-200°C
68-572°F	20-300°C
68-752°F	20-400°C
4.95×10^{-6}	8.91×10^{-6}
6.50×10^{-6}	11.7×10^{-6}
7.22×10^{-6}	13.0×10^{-6}
7.50×10^{-6}	13.5×10^{-6}
7.72×10^{-6}	13.9×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
~2580	1415

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2010-2280	1100-1250

Annealing

<i>°F</i>	<i>°C</i>
1920-2100	1050-1150

Hardening

Not hardenable by heat treatment.

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip	A240	100(690)	70(485)	20.0	—	290	—
Pipe	A790	100(690)	65(450)	25	—	—	—

UNS S31600—Type 316
UNS S31609—Type 316H

Austenitic

Type 316 is an austenitic, chromium-nickel-molybdenum stainless steel with corrosion resistance superior to most other chromium-nickel stainless steels in many types of chemical corrodents, as well as marine atmospheres. It also has higher tensile and creep strengths at elevated temperatures than the conventional 18% chromium-8% nickel alloys.

Type 316H is a modification of Type 316 where the carbon is controlled to a range of 0.04 to 0.10 to provide improved high temperature strength. Typical applications include parts exposed to temperatures above 800°F (425°C), such as powerplant superheater tubing.

See also the Section on Typical Applications.

UNS S31600/S31609

Chemical Composition Limits
Cast or Heat Analysis, Percent

	<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>
Type 316									
	0.08	2.00	0.045	0.030	0.75	<u>16.0</u>	<u>10.0</u>	<u>2.00</u>	0.10
	Max	Max	Max	Max	Max	18.0	14.0	3.00	Max
Type 316H									
	<u>0.04</u>	2.00	0.045	0.030	0.75	<u>16.0</u>	<u>10.0</u>	<u>2.00</u>	0.10
	0.10	Max	Max	Max	Max	18.0	14.0	3.00	Max

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension^a**

<i>psi</i>	<i>MPa</i>
28.0 × 10 ⁶	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
740

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
212°F	9.4
100°C	16.3
932°F	12.4
500°C	21.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	8.9 × 10 ⁻⁶
0-100°C	15.9 × 10 ⁻⁶
32-600°F	9.0 × 10 ⁻⁶
0-315°C	16.2 × 10 ⁻⁶
32-1000°F	9.7 × 10 ⁻⁶
0-538°C	17.5 × 10 ⁻⁶
32-1200°F	10.3 × 10 ⁻⁶
0-649°C	18.6 × 10 ⁻⁶
32-1500°F	11.1 × 10 ⁻⁶
0-815°C	20.0 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2500-2550	1371-1399

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNSS31600/S31609
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A240, A666	75(517)	30(207)	40	—	217	B95
1/4 Hard	A666	125(862)	75(517)	10	—	—	—
1/2 Hard	A666	150(1034)	110(758)	7 ^a	—	—	—
Bar							
Annealed	A276, A479, A666	75(517)	30(207)	40	50	—	—
Cold Finished ^b	A276	90(621)	45(310)	30	40	—	—
Cold Finished ^c	A276	75(517)	30(207)	30	40	—	—
Cold Finished ^d	A276	125(862)	100(689)	12 ^e	35	—	—
	(Condition B)						

Also refer to A493 Cold Heading Quality Bar and A193, A194 and A320 covering bolting material and nuts.

Wire							
Annealed	A580	75(517)	30(207)	35 ^f	50 ^f	—	—
Cold Finished	A580(Condition B)	125(862)	100(689)	12	35	—	—
Cold Finished	A580	90(621)	45(310)	30 ^f	40 ^f	—	—
Cold Heading Quality	A493						
Annealed		90(620) Max	—	—	—	—	—
Lightly drafted		95(655) Max	—	—	—	—	—

Also refer to A313 for Spring Wire, A368 for Wire Strand, A478 for Weaving Wire and A492 for Rope Wire.

Forgings							
Annealed	A473	75(517) ^g	30(207)	40	50	—	—
Pipe and Tubing							
Annealed	A213, A511, A554						
	A632, A688	75(517)	30(207)	35 ^h	—	192	B90 ⁱ
	A312, A376	75(517)	30(207)	35	—	—	—
	A409	75(517)	30(207)	—	—	—	—
Annealed	A430	70(517)	30(207)	45 ^j	50 ^j	—	—

Also refer to A358A.

^aValue given is for material over 0.030 in (0.76 mm) in thickness. Refer to A666 for limits on lighter thickness material.

^bFor material up to 1/2 in (12.7 mm) inclusive in size.

^cFor material over 1/2 in (12.7 mm) in size.

^dValue shown is for sizes up to 3/4 in (19.05 mm) inclusive. For larger sizes, see ASTM A276.

^eMinimum elongation specified in A666 is 7 percent.

^fFor material 5/32 in (3.97 mm) and under in size, the minimum elongation and reduction in area shall be 25 and 40 percent, respectively.

^gFor material over 5 in (127 mm) in section, the tensile strength is 70 ksi (483 MPa) minimum.

^hSee specification for limits on specific pipe and tube sizes and wall thickness.

ⁱRequired by A511 and A554.

^jTransverse limits for elongation and reduction in area are 20 and 30 percent, respectively.

UNS S31603—Type 316L

Austenitic

Type 316L is a low carbon austenitic, chromium-nickel-molybdenum stainless steel with general corrosion resistance similar to Type 316, but with superior resistance to intergranular corrosion following welding or stress relieving. It is suggested for use in certain corrosive envi-

ronments for parts that are fabricated by welding that cannot be subsequently annealed. Parts made from Type 316L are generally limited to service temperatures up to 800°F (425°C).

See also the Section on Typical Applications.

UNS S31603

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>
0.030	2.00	0.045	0.030	0.75	16.0	10.0	2.00	0.10
Max	Max	Max	Max	Max	18.0	14.0	3.00	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0 × 10 ⁶	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
740

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F	9.4
932°F	12.4
100°C	16.3
500°C	21.5

Mean Coefficient of Expansion

	<i>in/in/°F</i>		<i>cm/cm/°C</i>
32-212°F	8.9 × 10 ⁻⁶	0-100°C	15.9 × 10 ⁻⁶
32-600°F	9.0 × 10 ⁻⁶	0-315°C	16.2 × 10 ⁻⁶
32-1000°F	9.7 × 10 ⁻⁶	0-538°C	17.5 × 10 ⁻⁶
32-1200°F	10.3 × 10 ⁻⁶	0-649°C	18.5 × 10 ⁻⁶
32-1500°F	11.1 × 10 ⁻⁶	0-815°C	20.0 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2500-2550	1371-1399

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNSS31603

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A240	70(483)	25(172)	40	—	217	B95
Bar							
Hot Finished	A276	75(517)	30(207)	40	50	—	—
Annealed	A479	70(483)	25(172)	30	40	—	—
Wire							
Annealed	A580	70(483)	25(172)	35 ^a	50 ^a	—	—
Cold Finished	A580	90(621)	45(310)	30 ^a	40 ^a	—	—
Also refer to A478 for Weaving Wire.							
Forgings							
Annealed	A473	65(448)	25(172)	40	50	—	—
Pipe and Tubing							
Annealed	A213, A249, A511	70(483)	25(172)	35	—	192	B90
	A554, A688	70(483)	25(172)	35	—	—	—
	A312, A632 A409	70(483)	25(172)	—	—	—	—
Also refer to A358.							

^aFor material 5/32 in (3.97 mm) and under in size, the minimum elongation and reduction in area shall be 25 and 40 percent, respectively.

UNS S31620—Type 316F

Free machining/Austenitic

Type 316F is an austenitic, chromium-nickel-molybdenum stainless steel similar to Type 316, to which elements have been added to improve

the machining and nonseizing characteristics. It is suitable for use in automatic screw machines.

UNS S31620

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>
0.08	2.00	0.02	0.10	1.00	<u>16.00</u>	<u>10.00</u>	<u>1.75</u>
Max	Max	Max	Min	Max	18.00	14.00	2.50

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
740

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.116	0.486

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F	8.3
100°C	14.4

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	9.2×10^{-6}
32-600°F	9.7×10^{-6}
32-1000°F	10.1×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2500-2550	1371-1398

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Not hardenable by heat treatment.

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Typical</i>
Bar							
Annealed	^b	85(586)	35(241)	40 ^a	55 ^a	—	C20-28
Wire							
Annealed	^b	125(862)	—	—	—	—	—
Forgings							
Annealed	^b	—	—	—	—	187	—

^aTypical properties.

^bAMS 5649B.

UNS S31651—Type 316N

Nitrogen-strengthened/Austenitic

Type 316N is a nitrogen-strengthened austenitic, chromium-nickel-molybdenum stainless steel. The added nitrogen increases strength

with little effect on ductility and corrosion resistance.

UNS S31651

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>
0.08	2.00	0.045	0.030	0.75	16.0	10.0	2.00	0.10
Max	Max	Max	Max	Max	18.0	14.0	3.00	0.16

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.5×10^6	196,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
740

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-1200°F	0-649°C
10.3×10^{-6}	18.6×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2500-2550	1371-1398

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1141-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S31651

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip							
Annealed	A240	80(552)	35(241)	35	—	217	B95
Bar							
Annealed	A276, A479	80(552)	35(241)	30	—	—	—
Cold Finished	A276 (Condition B)	125(862) ^a	100(689) ^a	12 ^a	35	—	—
Pipe and Tubing							
Annealed	A213, A249	80(552)	35(241)	35	—	192	B90
	A312, A376	80(552)	35(241)	35	—	—	—
Annealed	A358	80(552)	35(241)	30	—	—	B95

^aFor sizes up to 3/4 in (19.05 mm) in section. For larger sizes, see ASTM A276.

UNS S31653—Type 316LN

Nitrogen-strengthened/Austenitic

Type 316LN is a low carbon, nitrogen-strengthened, austenitic, chromium-nickel-molybdenum stainless steel. Its physical properties and thermal treatments are similar to, but not neces-

sarily identical to, those of Type 316. Its mechanical strength exceeds that of Type 316L and it is used in welded fabrication.

UNS S31653

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>
0.030	2.00	0.045	0.030	0.75	16.0	10.0	2.0	0.10
Max	Max	Max	Max	Max	18.0	14.0	3.0	0.16

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0 × 10 ⁶	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
740

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
212°F 9.4	100°C 16.3
932°F 12.4	500°C 21.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F 8.9 × 10 ⁻⁶	0-100°C 15.9 × 10 ⁻⁶
32-600°F 9.0 × 10 ⁻⁶	0-315°C 16.2 × 10 ⁻⁶
32-1000°F 9.7 × 10 ⁻⁶	0-538°C 17.5 × 10 ⁻⁶
32-1200°F 10.3 × 10 ⁻⁶	0-649°C 18.6 × 10 ⁻⁶
32-1500°F 11.1 × 10 ⁻⁶	0-815°C 20.0 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2500-2550	1371-1399

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S31653

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip							
Annealed	A240	75(517)	30(207)	40	—	217	B95
Pipe and Tubing							
Annealed	A312, A376	75(517)	30(207)	35	—	—	—

UNS S31700—Type 317

Austenitic

Type 317 is an austenitic, chromium-nickel-molybdenum stainless steel. It has excellent corrosion resistance which is superior to that

of Type 316 in some applications.

See also the Section on Typical Applications.

UNSS31700

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>
0.08	2.00	0.045	0.030	0.75	<u>18.0</u>	<u>11.0</u>	<u>3.00</u>	0.10
Max	Max	Max	Max	Max	20.0	15.0	4.00	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
740

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F 9.4	100°C 16.3
932°F 12.4	500°C 21.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F 8.9×10^{-6}	0-100°C 16.0×10^{-6}
32-600°F 9.0×10^{-6}	0-315°C 16.2×10^{-6}
32-1000°F 9.7×10^{-6}	0-538°C 17.5×10^{-6}
32-1200°F 10.3×10^{-6}	0-649°C 18.6×10^{-6}
32-1500°F 11.1×10^{-6}	0-815°C 20.0×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2500-2550	1371-1399

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1850-2050	1008-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNSS31700

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A240	75(517)	30(207)	35	—	217	B95
Bar							
Annealed	A276	75(517)	30(207)	40	50	—	—
Wire							
Annealed	A580	75(517)	30(207)	35 ^a	50 ^a	—	—
Cold Finished	A580	90(621)	45(310)	30 ^a	40 ^a	—	—
Forgings							
Annealed	A473	75(517)	30(207)	40	50	—	—
Pipe and Tubing							
Annealed	A249	75(517)	30(207)	35	—	—	B90
	A409	75(517)	30(207)	—	—	—	—
	A312, A632	75(517)	30(207)	35	—	—	—
	A511, A554	75(517)	30(207)	35	—	192	B90

^aFor material 5/32 in (3.97 mm) and under in size, the minimum elongation and reduction in area shall be 25 and 40 percent, respectively.

UNS S31703—Type 317L
 UNS S31725—317LM; 317LX™
 UNS S31726—317LMN; 317LXN™;
 UNS S31753—Type 317LN

Austenitic

These are low carbon, chromium-nickel-molybdenum austenitic stainless steels with much greater resistance to chemical attack than conventional austenitic stainless steels such as Type 304. In addition, these alloys offer higher creep, stress-to-rupture and tensile strengths at elevated temperatures than conventional stainless steels. These alloys provide significant improvements over Type 317 stainless steel. They are not recommended for long exposure in the range 800 to 1500°F (425 to 815°C).

All are low carbon grades which provide resistance to sensitization during welding and other thermal processes. The combination of molybdenum and nitrogen is particularly effective in enhancing resistance to pitting and crevice corrosion, especially in process streams containing acids, chlorides and sulfur compounds at elevated temperatures. Nitrogen also serves to increase the strength of these alloys. The alloys are intended for severe service conditions such as flue gas desulfurization systems.

UNS S31703 et al
Chemical Composition Limits
Cast or Heat Analysis, Percent

	<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>
UNS S31703—317L	0.030 Max	2.00 Max	0.045 Max	0.030 Max	0.75 Max	<u>18.0</u> 20.0	<u>11.0</u> 15.0	<u>3.0</u> 4.0	0.10 Max
UNS S31725—317LM	0.030 Max	2.00 Max	0.045 Max	0.030 Max	0.75 Max	<u>18.0</u> 20.0	<u>13.5</u> 17.5	<u>4.0</u> 5.0	0.20 Max
UNS S31726—317LMN	0.030 Max	2.00 Max	0.045 Max	0.030 Max	0.75 Max	<u>17.0</u> 20.0	<u>13.5</u> 17.5	<u>4.0</u> 5.0	<u>0.10</u> 0.20
UNS S31753—317LN	0.030 Max	2.00 Max	0.045 Max	0.030 Max	0.75 Max	<u>18.0</u> 20.0	<u>11.0</u> 15.0	<u>3.0</u> 4.0	<u>0.10</u> 0.22

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension^a**

<i>psi</i>	<i>MPa</i>
29.0 × 10 ⁶	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
790

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.116	0.486

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
68-212°F	8.3
20-100°C	14.4

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	9.2 × 10 ⁻⁶	0-100°C	16.5 × 10 ⁻⁶
32-1000°F	10.1 × 10 ⁻⁶	0-538°C	18.1 × 10 ⁻⁶
32-1200°F	10.3 × 10 ⁻⁶	0-649°C	18.6 × 10 ⁻⁶
68-1832°F	10.8 × 10 ⁻⁶	20-1000°C	19.4 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2410-2550	1320-1400

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2100-2200	1150-1205

Annealing

<i>°F</i>	<i>°C</i>
1975-2150	1080-1175

Annealing

Cool rapidly from these temperatures.

Hardening

Not hardenable by thermal treatment.

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

**MECHANICAL PROPERTIES
S31703-317L**

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A240	75(517)	30(207)	40	—	217	B95
Welded Tubes	A249	75(517)	30(207)	35	—	—	B90
Bar	—	85(586) ^a	35(241) ^a	45 ^a	—	—	—

^aTypical value.

**MECHANICAL PROPERTIES
S31725-317LM**

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A240	75(515)	30(205)	40.0	—	217	B95
Bar (S31725)	A276, A479	75(515)	30(205)	40	—	—	—
Tubing	A249	75(515)	30(205)	35	—	—	B90

**MECHANICAL PROPERTIES
S31726-317LMN**

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A240	80(550)	30(240)	40.0	—	223	B96
Bar, annealed	A276	80(550)	35(240)	40	—	—	—
Tubing	A249	80(550)	35(240)	35	—	—	B90

**MECHANICAL PROPERTIES
S31753-317LN**

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A167	80(550)	35(240)	40.0	—	217	B95

UNS S31803— Alloy 2205; A903; AF22;
DP8; Falc 223; Fe-22Cr-5.5Ni-3Mo-0.15N;
Hyresist 22/5; NKCr22; Remanit 4462;
SM22Cr; UR45N; VS22

Duplex

S31803 is a duplex (austenitic-ferritic) stainless steel designed for superior resistance to pitting and crevice corrosion, for resistance to stress corrosion cracking, and for high strength. The steel is well-suited for high chloride environments such as brackish water, chemical processing and applications in the oil and gas industry. The pitting and crevice corrosion resistance are equal to or superior to that of Type 317L. The strength is about twice that of the common austenitic steels.

Although not immune to stress corrosion, the steel is a practical engineering solution to the problem of stress corrosion in sodium

chloride environments.

It has excellent resistance also to sulfide stress corrosion. The steel should not be used above about 650°F (340°C).

Applications include heat exchangers, chemical tankers, brown stock washers, chemical reactor vessels, flue gas filters, acetic acid distillation, oil and gas industry equipment.

Note—S32205 was introduced in 1996, as a modification of S31803, with restricted chemistry in order to obtain superior metallurgical properties as determined by experience.

UNS S31803

Chemical Composition Limits Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>
0.030	2.00	0.030	0.020	1.00	21.0	4.5	2.5	0.08
Max	Max	Max	Max	Max	23.0	6.5	3.5	0.20

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
29.0 × 10 ⁶	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.282	7,805

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
850

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.45

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
68°F	11.6
20°C	20

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	7.2 × 10 ⁻⁶
20-100°C	13.0 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2525-2630	1385-1435

Magnetic Permeability

<i>H/m Annealed</i>
Magnetic

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1750-2100	950-1150

Annealing

<i>°F</i>	<i>°C</i>
1750-1960	950-1070

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work. Heat treatments may increase hardness, but with a loss of ductility and corrosion resistance.

Scaling Temperature in Air

<i>°F</i>	<i>°C</i>
1830	1000

^a As cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNSS31803

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A240	90(620)	65(450)	25	—	293	C31
Bar							
Annealed	A276	90(620)	65(450)	25	—	290	—
Tubing							
Annealed	A789	90(620)	65(450)	25	—	290	—
Pipe							
Annealed	A790	90(620)	65(450)	25	—	290	—

UNS S32100—Type 321
UNS S32109—Type 321H

Stabilized/Austenitic

Type 321 is an austenitic, chromium-nickel stainless steel containing titanium to stabilize the carbon. This steel is suggested for use in certain corrosive environments for parts which are fabricated by welding and cannot be subsequently annealed. It is also suggested for parts to be used at temperatures between 800 and 1650°F (425 and 900°C) which will subsequently

be exposed to certain corrosive environments. This alloy is not recommended for use in decorative applications.

Type 321H is a modification of Type 321 wherein the carbon content is controlled to a range of 0.04 to 0.10 to provide improved high temperature strength.

See also the Section on Typical Applications.

UNS S32100/S32109

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Ti</i>	<i>N</i>
Type 321								
0.08	2.00	0.045	0.030	0.75	<u>17.0</u>	<u>9.0</u>	<u>5(C+N)</u>	0.10
Max	Max	Max	Max	Max	19.0	12.0	0.70	Max
Type 321H								
<u>0.04</u>	2.00	0.045	0.030	0.75	<u>17.0</u>	<u>9.0</u>	<u>4(C+N)</u>	—
0.10	Max	Max	Max	Max	19.0	12.0	0.70	

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm</i>	
68°F (20°C)	720
212°F (100°C)	780
392°F (200°C)	860
752°F (400°C)	1000
1112°F (600°C)	1110
1472°F (800°C)	1210
1652°F (900°C)	1260

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
212°F	9.3
100°C	16.1
932°F	12.8
500°C	22.2

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	9.3×10^{-6}
32-600°F	9.5×10^{-6}
32-1000°F	10.3×10^{-6}
32-1200°F	10.7×10^{-6}
32-1500°F	11.2×10^{-6}
68-1700°F	11.4×10^{-6}
	0-100°C
	0-315°C
	0-538°C
	0-649°C
	0-815°C
	20-926°C
	16.6×10^{-6}
	17.2×10^{-6}
	18.6×10^{-6}
	19.3×10^{-6}
	20.2×10^{-6}
	20.6×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2600	1399-1427

Magnetic Permeability

<i>H/m Annealed</i>
1.02 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1259

Annealing

<i>°F</i>	<i>°C</i>
1750-2050	953-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

UNSS32100/S32109

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A240	75(517)	30(207)	40	—	217	B95
Bar							
Annealed	A276, A479	75(517)	30(207)	40	50	—	—
Cold Finished ^a	A276	90(621)	45(310)	30	40	—	—
Cold Finished ^b	A276	75(517)	30(207)	30	40	—	—
Also refer to A493 for Cold Heading Quality Bar and A193, A194 and A320 covering bolting material and nuts.							
Wire							
Annealed	A580	75(517)	30(207)	35 ^c	50 ^c	—	—
Cold Finished	A580	90(621)	45(310)	30 ^c	40 ^c	—	—
Forgings							
Annealed	A473	75(517)	30(207)	40	50	—	—
Pipe and Tubing							
Annealed	A213, A249, A271						
	A511, A554	75(517)	30(207)	35	—	192	B90
	A312, A376	75(517)	30(207)	35	—	—	—
	A409	75(517)	30(207)	—	—	—	—
	A430	70(483)	30(207)	45 ^d	50 ^d	—	—
Also refer to A358.							

^aFor material up to 1/2 in (12.7 mm) inclusive in size.^bFor material over 1/2 in (12.7 mm) in size.^cFor material 5/32 in (3.97 mm) and under in size, the minimum elongation and reduction in area shall be 25 and 40 percent, respectively.^dTransverse limits for elongation and reduction in area are 20 and 30 percent, respectively.

S32205 is a duplex stainless steel which has excellent resistance to pitting, crevice corrosion and chloride stress corrosion, and it has high strength. This grade is a modification of S31803 wherein the nitrogen content is maintained at a higher level to enhance its corrosion resistance, strength and metallurgical stability. The steel also has superior properties after welding. The steel is not recommended for use above 600°F (1110°C) because of the risk of reduced corrosion resistance and toughness.

Applications include pressure vessels, tanks, piping and heat exchangers in the chemical industry; piping and heat exchangers for the handling of gas and oil; effluent scrubbing systems; pulp and paper industry digesters, bleaching equipment and stock handling systems; rotors fans, shafts and press rolls requiring strength and corrosion resistance; cargo tanks for ships and trucks; and food processing equipment.

UNS S32205

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>
0.030	2.00	0.030	0.020	1.00	22.0	4.5	3.0	0.14
Max	Max	Max	Max	Max	23.0	6.5	3.5	0.20

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
27.6×10^6	190,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

Microhm — mm

68°F (20°C)	850
212°F (100°C)	900
392°F (200°C)	950
572°F (300°C)	1000

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.112	0.469

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
68°F	8.2
212°F	8.8
392°F	10.0
572°F	10.6

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	7.5×10^{-6}
68-392°F	7.8×10^{-6}
68-572°F	8.1×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2525-2630	1385-1445

Magnetic Permeability

Magnetic

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1750-2100	950-1150

Full Annealing

<i>°F</i>	<i>°C</i>
1900 Min	1040 Min

Water quench.

Hardening

Not hardenable by heat treatment.

UNS S32205

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip	A240	90(620)	65(450)	25.0	—	293	C31

**UNS S32304—SAF 2304™; DP 11;
Fe-23Cr-4Ni-0.1N; UR35N**

Duplex

2304 is a duplex stainless steel (austenitic-ferritic) with a low carbon content. The steel was designed for demanding applications where high strength and resistance to stress corrosion cracking and pitting are required. The duplex structure combines the most desirable characteristics of both ferritic and austenitic steels.

The steel has high strength—approximately twice the yield strength of standard austenitic steels. It has good toughness and it is easy to fabricate. The steel is not recommended for applications which require long exposures to temperatures exceeding 570°F (300°C) because of the increased risk of reduction in toughness.

Applications include:

Coal Handling Equipment

Food and Beverage Industry—wet and dry mixers, pots; screw conveyors, pressure vessels, and hot water tanks.

Pulp and Paper Industry—screw and chip chutes; fans and blowers (bleach plant); blow lines, tanks and plates; causticizers, pulp lines and digestors; heat exchangers.

Waste Water Treatment Systems

Offshore Platforms—fire and blast walls.

Potash Industry—chutes, bins, fans blowers.

Reinforcement bars and hand railings.

UNS S32304

**Chemical Composition Limits
Cast or Heat Analysis, Percent**

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>
0.030	2.50	0.040	0.030	1.00	<u>21.5</u>	<u>3.0</u>	<u>0.05</u>
Max	Max	Max	Max	Max	24.5	5.5	0.60

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,800

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
850

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
68°F 9.2	20°C 15.9
212°F 9.8	100°C 17
392°F 10.4	200°C 18
572°F 11.0	300°C 19
752°F 12.1	400°C 21

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
68-212°F	7.2×10^{-6}	20-100°C	13.0×10^{-6}
68-752°F	8.1×10^{-6}	20-400°C	14.5×10^{-6}

Magnetic Permeability

<i>H/m Annealed</i>
Magnetizable

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1750-2000	950-1100

Solution Annealing

<i>°F</i>	<i>°C</i>
1870-2010	1020-1100

Rapid air or water quench.

Hardening

Not hardenable by heat treatment.

UNS S32304

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip	A240	87(600)	58(400)	25.0	—	290	C32
Tubing	A789	87(600)	58(400)	25	—	290	—

**UNS S32550—Ferallium 255®;
Uranus® 52N⁺**
Duplex

S32550 is an austenitic-ferritic duplex stainless steel having enhanced mechanical properties, corrosion resistance to reducing acids and resistance to stress corrosion cracking. The molybdenum and nitrogen additions have been optimized in order to obtain the best corrosion resistance, even for heavy plates. Copper additions increase the corrosion resistance properties, particularly in sulfuric acid media.

Applications include sea water systems and applications (diving spheres); oil and gas industry including sour gas applications; petrochemical industry including PVC strippers; pulp and paper industry (digesters, bleaching towers); chemical industry, including organic acid applications; sulfuric acid plants; phosphoric acid plants; multipurpose containers and pollution control equipment (scrubbers).

UNS S32550

**Chemical Composition Limits
Cast or Heat Analysis, Percent**

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>	<i>Cu</i>
0.040	1.5	0.040	0.030	1.0	24.0	4.5	2.9	0.10	1.5
Max	Max	Max	Max	Max	27.0	6.5	3.9	0.25	2.5

Physical Properties in the Annealed Condition
Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
29.7 × 10 ⁶	205,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.282	7,810

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
850

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
68°F 0.11	20°C 0.45

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
68°F 9.8	20°C 17

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
68-392°F	7.5 × 10 ⁻⁶	20-200°C	13.5 × 10 ⁻⁶
68-572°F	7.8 × 10 ⁻⁶	20-300°C	14.0 × 10 ⁻⁶
68-932°F	8.1 × 10 ⁻⁶	20-500°C	14.5 × 10 ⁻⁶

Melting Range

No Data

Magnetic Permeability

H/m Annealed
Magnetic

Thermal Treatment
Initial Forging

<i>°F</i>	<i>°C</i>
1830-2100	1000-1150

Annealing

<i>°F</i>	<i>°C</i>
1975-2020	1080-1120

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by aging, but with loss of ductility and corrosion resistance.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S32550

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip							
Annealed	A240	110(760)	80(550)	15.0	—	302	C32
Bar							
Annealed	A479	110(760)	80(550)	15.0	—	297	—
Tube and Pipe							
Annealed	A789, A790	110(760)	80(550)	15.0	—	297	—

UNS S32615—Sandvik SX™

Austenitic

Sandvik SX is an austenitic stainless steel which was developed for use in concentrated sulfuric acid. It has excellent corrosion resistance to concentrated sulfuric acid in both static and dynamic conditions.

The steel is suitable for use in applications including acid coolers, acid pumping systems, absorption and drying towers, acid distributors, pump tanks, demisters and pumps.

UNS S32615

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>Cu</i>
0.07	2.00	0.045	0.030	4.8	16.5	19.0	0.3	1.5
Max	Max	Max	Max	6.0	19.5	22.0	1.5	2.5

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,800

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
68°F 6.4	20°C 11
212°F 7.5	100°C 13
392°F 8.1	200°C 14

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F 8.3×10^{-6}	20-100° C 15.0×10^{-6}
68-392°F 8.6×10^{-6}	20-200° C 15.5×10^{-6}
68-572°F 8.9×10^{-6}	20-300° C 16.0×10^{-6}

UNS S32615

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip	A240	80(550)	32(220)	25	—	—	—
Pipe	A312	80(550)	32(220)	25	—	—	—

654 SMO is an austenitic stainless steel which has excellent resistance to pitting and crevice corrosion. It also has high resistance to general corrosion in acids, especially those containing halide ions. The steel has very high strength when compared with the conventional austenitic grades.

654 SMO is a further development of 254 SMO and can be used in the same applications but at higher chloride levels, higher temperatures, lower pH values and in more severe crev-

ice corrosion conditions.

Applications include seawater-cooled plate heat exchangers and tubes in utility plant surface condensers. Other fields of application can be found within pulp bleach plants, flue gas desulfurization units of fossil-fired utility plants and municipal waste incineration plants and in the handling of acid or neutral halide-containing process media in different types of chemical industries.

UNS S32654

Chemical Composition Limits Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	N	Cu
0.020	2.0	0.030	0.005	0.50	24.0	21.0	7.0	0.45	0.30
Max	4.0	Max	Max	Max	25.0	23.0	8.0	0.55	0.60

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
27.4×10^6	189,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.288	8,000

Electrical Resistivity

<i>Microhm — mm</i>	
68°F (20°C)	780
212°F (100°C)	810
392°F (200°C)	860
572°F (300°C)	910
752°F (400°C)	960

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
68°F (20°C)	8.6
212°F (100°C)	9.8
392°F (200°C)	11.3
572°F (300°C)	12.6
752°F (400°C)	14.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	8.3×10^{-6}
68-392°F	8.6×10^{-6}
68-572°F	8.8×10^{-6}
68-752°F	9.0×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2400-2500	1315-1370

Magnetic Permeability

H/m Annealed
Not magnetizable

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2000-2200	1095-1205

Full Annealing

<i>°F</i>	<i>°C</i>
2100-2190	1150-1200

Cool as rapidly as possible from the annealing temperature.

Hardening

Not hardenable by heat treatment.

UNS S32654

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength <i>ksi(MPa), Min</i>	Yield Strength <i>ksi(MPa), Min</i>	Elongation <i>%, Min</i>	Reduction in Area <i>%, Min</i>	Hardness HB, Max HR, Max
Plate, Sheet & Strip	A240	109(750)	62(430)	40.0	—	250 —

UNS S32750—SAF 2507®

Duplex

S32750 is a duplex (ferritic-austenitic) stainless steel which is designed for demanding applications which require exceptional strength and corrosion resistance, such as chemical process, petrochemical and seawater equipment. The steel has excellent resistance to chloride stress corrosion cracking, high thermal conductivity and a low coefficient of thermal expansion. The high chromium, molybdenum and nitrogen levels provide excellent resistance to pitting, crevice and general corrosion.

The impact strength is also high. The steel is not recommended for applications which require long exposures to temperatures above

570°F (300°C) because of the risk of a reduction in toughness.

Applications include equipment for the gas and oil industry; equipment on offshore platforms—heat exchangers, process and service water systems, fire fighting systems, injection and ballast water systems; heat exchangers and vessels in the chemical industry; high pressure RO-plant and seawater piping for desalination plants; high strength, corrosion-resistant structural components; and absorber towers, ducting and piping for power industry FGD systems, utility and industrial scrubber systems.

UNS S32750

Chemical Composition Limits Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	N	Cu
0.030	1.20	0.035	0.020	0.80	24.0	6.0	3.0	0.24	0.50
Max	Max	Max	Max	Max	26.0	8.0	5.0	0.32	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,800

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
850

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
68°F 8.2	20°C 14.2

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	7.2 × 10 ⁻⁶
68-752°F	8.1 × 10 ⁻⁶
	20-100° C
	20-400° C
	13.0 × 10 ⁻⁶
	14.5 × 10 ⁻⁶

Magnetic Permeability

Magnetizable

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1875-2050	1025-1120

Solution anneal after forging.

Solution Annealing

<i>°F</i>	<i>°C</i>
1925 Min	1050 Min

Rapid air or water quench.

Hardening

Not hardenable by heat treatment.

UNS S32750

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength <i>ksi(MPa), Min</i>	Yield Strength <i>ksi(MPa), Min</i>	Elongation <i>% Min</i>	Reduction in Area <i>% Min</i>	Hardness HB, Max	HR, Max
Plate, Sheet & Strip	A240	116(795)	80(550)	15.0	—	310	C32

ZERON 100 is a highly-alloyed duplex stainless steel for aggressive environments. Its properties include high resistance to pitting and crevice corrosion, excellent resistance to stress corrosion cracking in both chloride and sour environments, high resistance to erosion corrosion and corrosion fatigue, excellent mechanical properties and good weldability.

The steel is not recommended for uses which involve extended exposure to temperatures greater than 572°F (300°C) because of a substantial reduction in toughness.

The steel is used in a range of industries. In the oil and gas industry applications include process, sea water, firewater and subsea pipework systems, with associated risers, manifolds, pressure vessels, valves and heat exchangers. Other applications include pipework systems and associated equipment for pollution control, pulp and paper, power generation, flue gas desulfurization, chemical, pharmaceutical, desalination and marine industries.

UNS S32760
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>	<i>W</i>
0.030	2.0	0.030	0.010	1.0	<u>24.0</u>	<u>6.0</u>	<u>3.0</u>	<u>0.20</u>	<u>0.5</u>
Max	Max	Max	Max	Max	26.0	8.0	4.0	0.30	1.0

Note: Cr + 3.3 Mo + 16 N = 40 min

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
27.6×10^6	190,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.283	7,840

Electrical Resistivity

Microhm — mm

68°F (20°C)	851
212°F (100°C)	897
392°F (200°C)	956
572°F (300°C)	1014

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.115	0.481

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
68°F	7.5
200°F	8.3
300°F	8.9
400°F	9.5
500°F	10.1
20°C	13.0
100°C	14.4
149°C	15.4
204°C	16.4
260°C	17.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
70-200°F	7.0×10^{-6}
70-400°F	7.4×10^{-6}
70-600°F	7.7×10^{-6}
21-93°C	12.6×10^{-6}
21-204°C	13.3×10^{-6}
21-316°C	13.9×10^{-6}

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2010-2335	1100-1280

Solution annealing and water quenching is recommended after hot forming.

Solution Annealing

<i>°F</i>	<i>°C</i>
2010-2085	1100-1140

Water quench after annealing.

Hardening

Not hardenable by heat treatment.

UNSS32760

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A240	108(750)	80(550)	25.0	—	270	—
Tubing	A789	109-130 (750-895)	80(550)	25	—	270	—

7-Mo PLUS is a duplex alloy with austenite distributed within a ferrite matrix. This alloy is an improved version of Type 329 (7-Mo®) which has increased resistance to intergranular corrosion in weld and heat-affected zones, reducing the risk of preferential weld attack. Post-weld heat treatment is not necessary for most applications.

The ferrite matrix helps to minimize the danger of chloride stress-corrosion cracking, and the presence of austenite increases the toughness as compared to a fully ferritic structure.

Chromium and molybdenum impart a high level of resistance to pitting and crevice corrosion. The yield strength is more than twice that of Type 316.

Applications include heat exchangers in petroleum refining, chemical, pulp and paper and allied industries where improved properties in the welded areas are required. Other applications include caustic evaporators, piping systems for cooling water in power generating plants, food processing equipment, and as a possible replacement for Types 316 or 316L in marine environments.

UNS S32950

Chemical Composition Limits Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>
0.03	2.00	0.035	0.010	0.60	<u>26.0</u>	<u>3.5</u>	<u>1.00</u>	<u>0.15</u>
Max	Max	Max	Max	Max	29.0	5.2	2.50	0.35

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
29×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.280	7,750

Electric Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
775

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.114	0.476

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
100°F 8.6	20°C 14.8
200°F 9.4	93°C 16.2
300°F 10.2	149°C 17.7
400°F 11.1	204°C 19.1
500°F 11.8	260°C 20.5
600°F 12.7	316°C 21.9

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
75-400°F 6.39×10^{-6}	24-204°C 11.50×10^{-6}
75-600°F 6.94×10^{-6}	24-316°C 12.49×10^{-6}
75-800°F 7.49×10^{-6}	24-427°C 13.48×10^{-6}
75-1000°F 7.38×10^{-6}	24-538°C 13.28×10^{-6}
75-1200°F 8.08×10^{-6}	24-649°C 14.54×10^{-6}
75-1400°F 8.16×10^{-6}	24-760°C 14.69×10^{-6}
75-1500°F 8.18×10^{-6}	24-816°C 14.72×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
~2670	1465

Magnetic Permeability

<i>H/m Annealed</i>
No Data

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2325-2375	1274-1302

Annealing

<i>°F</i>	<i>°C</i>
1825-1875	996-1024

Annealing

Heat uniformly to above temperature for at least 10 min for thin tubing or 30 min/in of thickness, followed by water quench.

Hardening

Hardenable by cold work only.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S32950

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A240	100(690)	70(485)	15	—	293	C32
Bar							
Annealed	A479	100(690)	70(485)	15	—	297	—

UNS S33228—Nicrofer® 3228
NbCe-alloy AC 66
Austenitic

S33228 is an austenitic nickel-chromium-iron alloy with controlled additions of niobium and cerium. Low levels of silicon and aluminum improve resistance to internal oxidation.

The alloy has excellent resistance to oxidation up to 2010°F (1100°C), including under cyclic conditions, and excellent creep strength at temperatures above 1110°F (600°C).

It also has very good resistance to reducing, sulfur-containing atmospheres. Because of this and the excellent mechanical properties at elevated temperatures, the alloy finds a wide variety of uses in applications including coal gasification, refuse incineration, furnace components and heat exchangers, and high temperature chemical and petrochemical processes.

UNS S33228

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>Cb</i>	<i>Ce</i>
0.04	1.00	0.020	0.015	0.30	26.0	31.0	0.025	0.6	0.05
0.08	Max	Max	Max	Max	28.0	33.0	Max	1.0	0.10

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
27.7 × 10 ⁶	191,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,000

Electrical Resistivity*Microhm — mm*

68°F (20°C)	960
212°F (100°C)	1000
392°F (200°C)	1040
572°F (300°C)	1080
752°F (400°C)	1110
1112°F (600°C)	1170
1472°F (800°C)	1200

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.106	0.445

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
212°F 8.1	100°C 14
392°F 9.2	200°C 16
752°F 11.0	400°C 19
1112°F 12.7	600°C 22
1472°F 14.2	800°C 24.5
1832°F 15.9	1000°C 27.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	8.4 × 10 ⁻⁶
68-392°F	8.6 × 10 ⁻⁶
68-572°F	8.8 × 10 ⁻⁶
68-752°F	9.0 × 10 ⁻⁶
68-932°F	9.2 × 10 ⁻⁶
68-1112°F	9.4 × 10 ⁻⁶
68-1472°F	9.8 × 10 ⁻⁶
68-1832°F	10.2 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2535	1390

Magnetic Permeability

<i>H/m Annealed</i>
1.01

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
1560-2120	850-1160

Full Annealing

<i>°F</i>	<i>°C</i>
2050-2160	1120-1180

Water quenching or rapid air cooling is recommended for thicknesses above 0.06 in (1.5 mm).

Hardening

Not hardenable by heat treatment.

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip	A167, A240	73(500)	27(185)	30.0	—	217	B95

UNS S34565—NIROSTA® 4565 S

Nitrogen-strengthened/Austenitic

S34565 is a high-nitrogen, fully austenitic stainless steel which has high strength and excellent corrosion resistance in a wide range of corrosive media. The steel was developed of applications in high chloride environments, especially sea water. It has outstanding pitting and crevice corrosion resistance in both the as-quenched and as-welded conditions.

Applications include equipment for the chemical and pulp and paper industries as well as for the transport and storage of bulk chemicals. It is also suitable for applications in flue-gas desulfurization systems, sea water desalination plants and other environmental technologies. The steel has been used successfully in the production and transport of oil and gas on on-shore and off-shore facilities.

UNS S34565

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>	<i>Cb</i>
0.030	<u>5.0</u>	0.030	0.010	1.00	<u>23.0</u>	<u>16.0</u>	<u>4.0</u>	<u>0.40</u>	0.10
Max	7.0	Max	Max	Max	25.0	18.0	5.0	0.60	Max

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
28.0×10^6	190,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,000

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
920

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.45

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
68°F 6.9	20°C 12.0

Mean Coefficient of Expansion

Linear Coefficient of Expansion			
<i>in/in/°F</i>		<i>cm/cm/°C</i>	
68-212°F	8.0×10^{-6}	20-100° C	14.5×10^{-6}
68-392°F	8.6×10^{-6}	20-200° C	15.5×10^{-6}
68-572°F	9.0×10^{-6}	20-300° C	16.3×10^{-6}
68-752°F	9.3×10^{-6}	20-400° C	16.8×10^{-6}
68-932°F	9.5×10^{-6}	20-500° C	17.2×10^{-6}

Magnetic Permeability

Slight magnetizability possible after quenching.

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
1650-2200	900-1200

Full Annealing

<i>°F</i>	<i>°C</i>
1120-1170	2050-2140

Hardening

Not hardenable by heat treatment.

UNS S34565

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip	A240	115(795)	60(415)	35.0	—	241	B100

UNS S34700—Type 347
 UNS S34709—Type 347H
 UNS S34800—Type 348
 UNS S34809—Type 348H

Stabilized/Austenitic

Types 347 and 348 are austenitic, chromium-nickel stainless steels containing columbium and tantalum to stabilize the carbon. These grades are suggested for use in certain corrosive environments for parts which are fabricated by welding and cannot be subsequently annealed since they are designed to control intergranular corrosion in the as-welded condition. They have found applications subject to

intermittent heating in the range 800 to 1650°F (425 to 900°C).

Type 348 is used in certain applications which require a restricted tantalum and cobalt content.

Types 347H and 348H are modifications of Types 347 and 348 wherein the carbon content is controlled to a range of 0.04 to 0.10 to provide improved high temperature strength.

See also the Section on Typical Applications

UNS S34700 et al

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Cb+Ta</i>	<i>Ta</i>	<i>Co</i>
Type 347									
0.08	2.00	0.045	0.030	0.75	<u>17.0</u>	<u>9.0</u>	<u>10×C</u>	—	—
Max	Max	Max	Max	Max	19.0	13.0	1.00		
Type 347H									
<u>0.04</u>	2.00	0.045	0.030	0.75	<u>17.0</u>	<u>9.0</u>	<u>8×C</u>	—	—
0.10	Max	Max	Max	Max	19.0	13.0	1.00		
Type 348									
0.08	2.00	0.045	0.030	0.75	<u>17.0</u>	<u>9.0</u>	<u>10×C</u>	0.10	0.20
Max	Max	Max	Max	Max	19.0	13.0	1.00	Max	Max
Type 348H									
<u>0.04</u>	2.00	0.045	0.030	0.75	<u>17.0</u>	<u>9.0</u>	<u>8×C</u>	0.10	0.20
0.10	Max	Max	Max	Max	19.0	13.0	1.00	Max	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
28×10^6	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

Microhm — mm

68°F (20°C)	720
212°F (100°C)	780
392°F (200°C)	860
752°F (400°C)	1000
1112°F (600°C)	1110
1472°F (800°C)	1210
1652°F (900°C)	1260

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F 9.3	100°C 16.1
932°F 12.8	500°C 22.2

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	9.3×10^{-6}
32-600°F	9.5×10^{-6}
32-1000°F	10.3×10^{-6}
32-1200°F	10.6×10^{-6}
32-1500°F	11.1×10^{-6}
0-100°C	16.6×10^{-6}
0-315°C	18.2×10^{-6}
0-538°C	18.6×10^{-6}
0-649°C	19.1×10^{-6}
0-815°C	20.0×10^{-6}

Melting Range	
$^{\circ}\text{F}$	$^{\circ}\text{C}$
2550-2600	1398-1427
Magnetic Permeability	
<i>H/m Annealed</i>	
1.02 Max	

Thermal Treatment

Initial Forging	
$^{\circ}\text{F}$	$^{\circ}\text{C}$
2100-2300	1149-1259

Annealing	
$^{\circ}\text{F}$	$^{\circ}\text{C}$
1850-2050	1008-1120

Annealing
Cool rapidly from these temperatures.

Stabilizing	
$^{\circ}\text{F}$	$^{\circ}\text{C}$
1550-1650	842-898

UNS S34700 et al

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A240	75(517)	30(207)	40	—	201	B92
Bar							
Annealed	A276, A479	75(517)	30(207)	40	50	—	—
Cold Finished ^a	A276	90(621)	45(310)	30	40	—	—
Cold Finished ^b	A 276	75(517)	30(207)	30	40	—	—
Also refer to A493 Cold Heading Quality Bar and A193, A194 and A320 covering bolting material and nuts.							
Wire							
Annealed	A580	75(517)	30(207)	35 ^c	50 ^c	—	—
Cold Finished	A580	90(621)	45(310)	30 ^c	40 ^c	—	—
Forgings							
Annealed	A473	75(517)	30(207)	40	50	—	—
Pipe and Tubing							
	A213, A249, A271						
	A511, A554	75(517)	30(207)	35	—	192	B90
Annealed	A312, A376	75(517)	30(207)	35	—	—	—
Annealed	A409	75(517)	30(207)	—	—	—	—
Annealed	A430	70(483)	30(207)	45 ^d	50 ^d	—	—

Also refer to A358.

^aFor material up to 1/2 in (12.7 mm) inclusive in size.

^bFor material over 1/2 in (12.7 mm) in size.

^cFor material 5/32 in (3.97 mm) and under in size, the minimum elongation and reduction in area shall be 25 and 40 percent, respectively.

^dTransverse limits for elongation and reduction in area are 20 and 30 percent, respectively.

UNS S35000—Type 633; AM 350™

Precipitation Hardening

Type 633 is a chromium-nickel-molybdenum stainless steel which can be hardened by martensitic transformation and/or by precipitation hardening. It has been used for parts requiring high strength at moderately elevated temperatures. The alloy offers superior corrosion resistance to other quench-hardenable martensitic stainless steels. It has good high temperature strength.

Depending upon the heat treatment, the alloy may have an austenitic structure for best formability, or a martensitic structure with strengths comparable to the martensitic steels. The alloy normally contains about 5 to 10 percent delta ferrite.

Typical applications include gas turbine compressor components such as blades, discs, rotor and shafts where high strength is required at room and intermediate temperatures.

UNS S35000

Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	N
0.07	0.50	0.04	0.03	0.50	16.0	4.0	2.5	0.07
0.11	1.25	Max	Max	Max	17.0	5.0	3.25	0.13

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

psi	MPa
29.4 × 10 ⁶	203,000

Density

lb/in ³	kg/m ³
0.282	7,810

Electrical Resistivity

Microhm — mm at 68°F (20°C)
788

Specific Heat

Btu/lb °F	kJ/kg·K
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

Btu/ft·h/°F	W/m·K
100°F	8.4
38°C	14.5

Mean Coefficient of Expansion

in/in/°F		cm/cm/°C	
68-212°F	6.3 × 10 ⁻⁶	20-100°C	11.3 × 10 ⁻⁶
68-572°F	6.8 × 10 ⁻⁶	20-300°C	12.2 × 10 ⁻⁶
68-752°F	7.0 × 10 ⁻⁶	20-400°C	12.6 × 10 ⁻⁶
68-932°F	7.2 × 10 ⁻⁶	20-500°C	13.0 × 10 ⁻⁶
68-1150°F	7.2 × 10 ⁻⁶	20-620°C	13.0 × 10 ⁻⁶
68-1350°F	6.7 × 10 ⁻⁶	20-735°C	12.1 × 10 ⁻⁶
68-1500°F	7.0 × 10 ⁻⁶	20-815°C	13.6 × 10 ⁻⁶
68-1700°F	7.5 × 10 ⁻⁶	20-925°C	13.5 × 10 ⁻⁶

Melting Range

°F	°C
2500-2550	1371-1399

Magnetic Permeability

H/m Subzero Cooled and Tempered
Ferromagnetic

Thermal Treatment

Initial Forging

	°F	°C
Maximum Temperature	2150	1177
Finishing Temperature	1700-1800	927-982

Annealing

°F	°C
1900-1975	1038-1080

Annealing

Heat to above temperature and cool rapidly to room temperature.

Hardening

Type Alloy 350 can be hardened by either subzero cooling and tempering (SCT) or double aging (DA). Subzero cooling and tempering will result in higher strength than double aging. "Conditioning" of the alloy by rapid cooling from 1710°F (932°C) ± 25°F is required before the SCT treatment, and is not required but is recommended before double aging. It is further recommended that following an anneal at 1850 to 1950°F (1010 to 1066°C), Type Alloy 350 can be cooled to -100°F (-73°C) for at least 3 h before hardening.

Subzero Cooling — After conditioning at 1710°F (932°C) ± 25°F (rapid cool) for 90 min/in (25.4 mm) of thickness. Type Alloy 350 is held for a minimum of 3 h at -100°F (-73°C), then tempered at either 850 or 1000°F (454 or 538°C) for a minimum of 3 h. The 850°F (454°C) temper produces the highest strengths and hardnesses, and the 1000°F (538°C) temper produces improved toughness and stress corrosion properties.

Double Age — Hold for 3 h at 1350 to 1400°F (732 to 760°C), air cool to room temperature, heat to 825 to 875°F (440 to 468°C), hold 2 to 3 h, then air cool.

Equalize and Overtemper — Bars and billets are normally shipped in this condition unless otherwise specified. This treatment, 1375 to 1475°F (745 to 801°C), 3 to 4 h air cool to room temperature, then 1000 to 1100°F (538 to 593°C), 3 h, air cool, produces a stable tempered martensitic structure which is most readily machinable.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S35000
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip Solution treated	A693	200(1380) Max	85-90 (585-620) ^a Max	8-12 ^a	—	—	C30
Condition 850		185(1275)	150(1035)	2-8 ^a	—	—	C42 Min
Condition 1000		165(1140)	145(1000)	2-8 ^a	—	—	C36 Min

^aValue depends upon thickness.

353 MA is an austenitic heat resisting alloy with 35% nickel and 25% chromium which was developed for service at 1830°F (1000°C) and above. It is especially suitable for applications with high carbon and/or nitrogen activities.

The alloy has a high scaling temperature, approximately 2140°F (1175°C). It has high creep deformation and rupture strength, good resistance to carbon and nitrogen pick-up in oxidizing as well as reducing atmospheres, and excellent resistance to erosion-corrosion.

Applications are for equipment used in heat treatment processes which require material with high temperature corrosion resistance. Areas of application include the cement industry; gasification (coal, wood, refuse); heat treatment plants; the iron and steel industry; power generation; and thermal destruction. Examples of equipment and components include burners, cyclones, damper and flap valves, furnace inner hoods, muffles and retorts; heat treatment baskets, fixtures and trays, radiant tubes and rotary kilns.

UNS S35315

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>	<i>Ce</i>
0.04	2.00	0.040	0.030	1.20	24.0	34.0	0.12	0.03
0.08	Max	Max	Max	2.00	26.0	36.0	0.18	0.08

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
27.5 × 10 ⁶	190,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.285	7,900

Electrical Resistivity

<i>Microhm — mm</i>	
68°F (20°C)	1000
392°F (200°C)	1070
752°F (400°C)	1140
1112°F (600°C)	1200
1472°F (800°C)	1250
1832°F (1000°C)	1300

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.45

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
68°F	7.0
20°C	12.1

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	8.5 × 10 ⁻⁶
68-392°F	8.7 × 10 ⁻⁶
68-752°F	9.1 × 10 ⁻⁶
68-1112°F	9.4 × 10 ⁻⁶
68-1472°F	9.7 × 10 ⁻⁶
68-1832°F	10.1 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2480-2570	1360-1410

Magnetic Permeability

Nonmagnetizable

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1795-2100	980-1150

Quench Annealing

<i>°F</i>	<i>°C</i>
2010-2100	1100-1150

Stress Relief Annealing

<i>°F</i>	<i>°C</i>
1850-1905	1010-1040

Hardening

Not hardenable by heat treatment.

UNS S35315
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A167, A240	94(650)	39(270)	40.0	—	217	B95

**UNS S35500—Type 634; AM 355™
Alloy 355**

Precipitation Hardening

Type 634 is a chromium-nickel-molybdenum stainless steel which can be hardened by martensitic transformation and/or precipitation hardening. The alloy offers good resistance to atmospheric corrosion and to a number of other mild chemical environments.

The alloy has been used for gas turbine compressor components such as blades, discs, rotors and shafts and for similar parts where high strength is required at intermediate elevated temperatures.

UNS S35500
**Chemical Composition Limits
Cast or Heat Analysis, Percent**

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>	<i>N</i>
<u>0.10</u>	<u>0.50</u>	0.04	0.03	0.50	<u>15.0</u>	<u>4.0</u>	<u>2.5</u>	<u>0.07</u>
0.15	1.25	Max	Max	Max	16.0	5.0	3.25	0.13

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
29.3×10^6	202,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.282	7,810

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
758

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
100°F	8.7 38°C
200°F	9.2 93°C
300°F	9.5 149°C
400°F	9.9 204°C
500°F	10.3 260°C
600°F	10.7 316°C
700°F	11.2 371°C
800°F	11.6 427°C
900°F	12.0 482°C

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	6.4×10^{-6} 20-100°C
68-572°F	6.8×10^{-6} 20-300°C
68-752°F	7.0×10^{-6} 20-400°C
68-932°F	7.2×10^{-6} 20-500°C
68-1150°F	7.2×10^{-6} 20-621°C
68-1350°F	6.5×10^{-6} 20-732°C
68-1500°F	6.7×10^{-6} 20-816°C
68-1700°F	7.1×10^{-6} 20-927°C

Melting Range

<i>°F</i>	<i>°C</i>
2500-2550	1371-1399

Magnetic Permeability

H/m Subzero Cooled and Tempered
Ferromagnetic

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1800-2100	982-1149

Annealing

<i>°F</i>	<i>°C</i>
1850-1900	1010-1038

Annealing

Heat to above temperature and cool rapidly.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

Hardening

Type 634 can be hardened by either subzero cooling or by a double aging treatment. Hardening by subzero cooling will result in higher strength than that obtained by double aging. "Conditioning" of the alloy by rapid cooling from 1710 to 1750°F (932 to 954°C) is required before either hardening treatment.

Subzero Cooling — After conditioning, the alloy is held at -100°F (-73°C) for a minimum of 3 h and then tempered at 850°F (454°C) for the best combination of strength and ductility. If however, applications require better finish machining characteristics, higher impact strengths or higher ductilities than are provided by an 850°F (454°C) temper, tempering temperatures up to 1000°F (538°C) may be employed. Optimum stress corrosion cracking resistance is provided by the 1000°F (538°C) temper.

Double Age — 1350 to 1400°F (732 to 760°C) for 3 to 4 h, rapid cool; 825 to 875°F (440 to 468°C) for 2 to 3 h, air

cool. The 1350 to 1400°F (732 to 760°C) treatment results in carbide precipitation, so that the material will completely transform to martensite when rapidly cooled to room temperature. The treatment at 825 to 875°F (440 to 468°C) after transformation provides further increases in strength and hardness.

Equalized and Overtempered — In this variation of double age, treat at 1375 to 1475°F (732 to 801°C), 3 to 4 h, rapid cool, then treat at 1000 to 1100°F (538 to 593°C), air cool. This treatment imparts high ductility and lower hardness than double aging. It is the condition in which this alloy is most readily machined.

Bar and billets are normally equalized and overtempered before being "conditioned" for hardening. Surface conditions such as nitriding, carburization or decarburization are to be avoided as they will inhibit the response of the material to hardening.

UNS S35500 MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A693						
Solution treated ^a		—	—	—	—	—	C40
Condition 850		190(1310)	165(1140)	10	—	—	—
Condition 1000		170(1170)	150(1035)	12	—	—	C37 Min

^aSolution-treated, equalized, and over-tempered plate only.

UNS S38400—Type 384; No. 10

Austenitic

Type 384 is an austenitic, chromium-nickel stainless steel which has an exceptionally low rate of work hardening which is lower than that of Type 305.

It is used when severe cold heading or cold forming operations are required. The alloy is essentially nonmagnetic when annealed or cold worked.

See also the Section on Typical Applications.

UNS S38400
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>
0.04	2.00	0.045	0.030	1.00	<u>15.0</u>	<u>17.0</u>
Max	Max	Max	Max	Max	17.0	19.0

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
28.0×10^6	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.29	8,027

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
791

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
212°F 9.4	100°C 16.3
932°F 12.4	500°C 21.5

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F 9.6×10^{-6}	0-100°C 17.2×10^{-6}
32-500°F 9.9×10^{-6}	0-260°C 17.9×10^{-6}
32-1000°F 10.2×10^{-6}	0-538°C 18.4×10^{-6}
32-1200°F 10.4×10^{-6}	0-649°C 18.8×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2550-2650	1398-1454

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2100-2250	1149-1231

Do not forge below 1700°F (926°C)

Annealing

<i>°F</i>	<i>°C</i>
1900-2100	1036-1149

Annealing

Cool rapidly from these temperatures.

Hardening

Hardenable by cold work only.

UNS S38400
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Wire ^a							
As annealed	A493	80(550) Max	—	—	—	—	—
Lightly drafted		85(585) Max					

^a This table applies to sizes 0.100 in (2.5 mm) and larger.

UNS S40300—Type 403

Martensitic

Type 403 is a selected quality of martensitic chromium stainless steel which is used for the

production of turbine blades and very highly stressed parts.

See also the Section on Typical Applications.

UNS S40300

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>
0.15	1.00	0.040	0.030	0.50	<u>11.5</u>	0.60
Max	Max	Max	Max	Max	13.0	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm</i>	
68°F (20°C)	570
212°F (100°C)	640
392°F (200°C)	720
752°F (400°C)	880
1112°F (600°C)	1035
1292°F (700°C)	1110

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F 14.4	100°C 24.9
932°F 16.6	500°C 28.7

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	5.5×10^{-6}	0-100°C	9.9×10^{-6}
32-600°F	6.3×10^{-6}	0-315°C	11.4×10^{-6}
32-1000°F	6.4×10^{-6}	0-538°C	11.6×10^{-6}
32-1200°F	6.5×10^{-6}	0-649°C	11.7×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2700-2790	1482-1532

Magnetic Permeability

<i>H/m Annealed</i>
900 Max

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2000-2200	1093-1204

Cool slowly from these temperatures.

Annealing

<i>°F</i>	<i>°C</i>
1500-1650	815-898

Cool slowly from these temperatures.

Process Annealing

<i>°F</i>	<i>°C</i>
1200-1400	649-760

Hardening

<i>°F</i>	<i>°C</i>
1700-1850	926-1008

Cool rapidly from these temperatures.

Tempering

<i>°F</i>	<i>°C</i>
400-1400	204-760

UNS S40300
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>		<i>Cold Bend Degree</i>
						<i>HB, Max</i>	<i>HR, Max</i>	
Plate, Sheet & Strip	A176	70(483)	30(207)	25 ^a	—	217	B96	180
Bar								
Annealed	A276	70(483)	40(276)	20 ^b	45	—	—	—
Annealed	A479	70(483)	40(276)	20 ^c	45 ^c	223	—	—
Condition T	A276	100(689)	80(552)	15 ^d	45 ^d	—	—	—
Condition H	A276	120(827)	90(621)	12	40	—	—	—
Wire								
Annealed	A580	70(483)	40(276)	20 ^b	45	—	—	—
Condition T	A580	100(689)	80(552)	12	40	—	—	—
Condition H	A580	120(827)	90(621)	12	40	—	—	—
Forgings								
Annealed	A473	70(483)	40(276)	20	45	223	—	—
Mechanical Tubing								
Annealed	A511	60(414)	30(207)	20	—	207	B95	—

^aMinimum elongation is 20 percent for material 0.500 in (12.7 mm) and under in thickness.

^bMinimum elongation is 16 percent for cold finish material.

^cFor cold finished material, the minimum elongation and reduction in area shall be 12 and 35 percent, respectively.

^dFor cold finished material, the minimum elongation and reduction in area shall be 12 and 40 percent, respectively.

UNS S40500—Type 405

Ferritic

Type 405 is a 12 percent chromium ferritic stainless steel characterized by its ability to be cooled from elevated temperatures without significant hardening.

It can be used in the as-welded condition and is ideal for fabrications which cannot be annealed after welding.

See also the Section on Typical Applications.

UNS S40500
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Al</i>	<i>Ni</i>
0.08	1.00	0.040	0.030	1.00	<u>11.5</u>	<u>0.10</u>	0.60
Max	Max	Max	Max	Max	14.5	0.30	Max

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
600

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F	100°C
15.6	27.0

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	6.0×10^{-6}	0-100°C	10.8×10^{-6}
32-600°F	6.4×10^{-6}	0-315°C	11.6×10^{-6}
32-1000°F	6.7×10^{-6}	0-538°C	12.1×10^{-6}
32-1500°F	7.5×10^{-6}	0-815°C	13.5×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2700-2790	1482-1532

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
1950-2050	1063-1120

Process Annealing

<i>°F</i>	<i>°C</i>
1350-1500	734-815

Hardening

Not appreciably hardenable by heat treatment.

UNS S40500
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>		<i>Cold Bend Degree</i>
						<i>HB, Max</i>	<i>HR, Max</i>	
Plate, Sheet & Strip								
Annealed	A240	60 (414)	25(172)	20	—	179	B88	180
Bar								
Annealed	A276	—	—	—	—	207 ^a	—	—
Annealed	A479	60 (414)	25(172)	20	45	207	—	—
Wire								
Annealed	A580	70(483)	40(276)	20	45	—	—	—
Cold Finished	A580	70(483)	40(276)	16	45	—	—	—
Forgings								
Annealed	A473	60(414)	30(207)	20	45	207	—	—
Tubing								
Annealed	A268	60(414)	30(207)	20 ^b	—	207	B95	—
Annealed	A511	60(414)	30(207)	20	—	207	B95	—

^aHardness for cold finished material shall be 217 Max.

^bRefer to A268 for elongation of material with wall thickness below 5/16 in (7.94 mm).

UNS S40900—Type 409
UNS S40910, S40920 and S40930

Stabilized/Ferritic

Type 409 is a nonhardenable ferritic stainless steel which is especially useful for applications requiring oxidation or corrosion protection beyond the capability of carbon steels and some coated steels. It is the most widely used ferritic grade of all the nickel-free stainless steels and its price is among the lowest of all stainless steels. The corrosion resistance is about the same as that of hardened Type 410 stainless steel.

S40910, S40920 and S40930 are modifications

of Type 409 stainless steel which were adopted by ASTM in 1997 and published in ASTM A240. These steels are stabilized with columbium or titanium, or both. S40910 is described as having adequate stabilization for muffler service, whereas S40920 and S40930 have higher levels of stabilization.

These steels are intended for automotive exhaust systems, structural and other applications where appearance is not a critical requirement.

See also the Section on Typical Applications.

UNS S40900 et al

Chemical Composition Limits
Cast or Heat Analysis, Percent

UNS	TYPE	C	Mn	P	S	Si	Cr	Ni	N	Other Elements
S40900	409	0.08 Max	1.00 Max	0.045 Max	0.030 Max	1.00 Max	<u>10.5</u> 11.75	0.50 Max	— Max	<u>Ti6 × C</u> 0.75
S40910	—	0.030 Max	1.00 Max	0.040 Max	0.020 Max	1.00 Max	<u>10.5</u> 11.7	0.50 Max	0.030 Max	Ti6 × (C + N) Min; 0.50 Max Cb 0.17 Max
S40920	—	0.030 Max	1.00 Max	0.040 Max	0.020 Max	1.00 Max	<u>10.5</u> 11.7	0.50 Max	0.030 Max	Ti8 × (C + N) Min; 0.15 -0.50 Cb 0.10 Max
S40930	—	0.030 Max	1.00 Max	0.040 Max	0.020 Max	1.00 Max	<u>10.5</u> 11.7	0.50 Max	0.030 Max	(Cb + Ti)0.08+8(C+N)Min; 0.75 Max; Ti 0.05 Min

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
30.2 × 10 ⁶	208,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.275	7,600

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
600

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>		<i>W/m·K</i>	
73°F	14.8	23°C	25.7
212°F	14.9	100°C	25.8
392°F	15.2	200°C	26.4
752°F	15.6	400°C	26.9
932°F	15.9	500°C	27.5
1112°F	15.5	600°C	26.9
1292°F	14.7	700°C	25.4
1472°F	17.7	800°C	30.7
1598°F	18.7	870°C	32.3

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
68-200°F	6.1×10^{-6}	20-93°C	11.0×10^{-6}
68-400°F	6.3×10^{-6}	20-204°C	11.3×10^{-6}
68-600°F	6.5×10^{-6}	20-316°C	11.7×10^{-6}
68-800°F	6.7×10^{-6}	20-427°C	12.1×10^{-6}
68-1000°F	6.9×10^{-6}	20-538°C	12.4×10^{-6}
68-1200°F	7.1×10^{-6}	20-649°C	12.8×10^{-6}
68-1400°F	7.2×10^{-6}	20-760°C	13.0×10^{-6}
68-1600°F	7.3×10^{-6}	20-871°C	13.1×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1425-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2000-2200	1095-1205

Full Annealing

<i>°F</i>	<i>°C</i>
1600-1650	870-900

Air cool from these temperatures.

Hardening

Not appreciably hardened by heat treatment.

UNS S40900 et al
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>		<i>Cold Bend Degree</i>
Plate, Sheet & Strip								
Annealed	A240	55(380)	25(170)	22 ^b	—	179	B88	180
Bar								
Annealed	—	65 (448) ^a	35(241) ^a	25 ^a	—	—	B75 ^a	—
Wire								
Annealed	—	65(448) ^a	35(241) ^a	24 ^a	—	—	—	—
Tubing								
Annealed	A268	55(380)	30(207)	20 ^c	—	207	B95	—

^aTypical value.

^bMaterial 0.050 in (1.27 mm) and under shall have a minimum elongation of 20 percent.

^cRefer to A268 for elongation of material with wall thickness below 5/16 in (7.94 mm).

UNS S40945—Type 409 Cb

Stabilized/Ferritic

Type 409 Cb is a chromium ferritic stainless steel with columbium stabilization and restricted titanium and aluminum contents. As a result of these alloying adjustments the

brazability of the alloy is markedly improved over Type 409. The physical, mechanical and corrosion properties of Type 409 Cb are almost identical to those of Type 409.

UNS S40945
Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	N	Ti
0.030	1.00	0.040	0.030	1.00	10.5	0.030	6(C+N)
Max	Max	Max	Max	Max	11.75	Max	0.75

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
30.2×10^6	208,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.275	7,600

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
600

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
73°F 14.8	23°C 25.7
212°F 14.9	100°C 25.8
392°F 15.2	200°C 26.4
752°F 15.6	400°C 26.9
932°F 15.9	500°C 27.5
1112°F 15.5	600°C 26.9
1292°F 14.7	700°C 25.4
1472°F 17.7	800°C 30.7
1598°F 18.7	870°C 32.3

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-200°F 6.1×10^{-6}	20-93°C 11.0×10^{-6}
68-400°F 6.3×10^{-6}	20-204°C 11.3×10^{-6}
68-600°F 6.5×10^{-6}	20-316°C 11.7×10^{-6}
68-800°F 6.7×10^{-6}	20-427°C 12.1×10^{-6}
68-1000°F 6.9×10^{-6}	20-538°C 12.4×10^{-6}
68-1200°F 7.1×10^{-6}	20-649°C 12.8×10^{-6}
68-1400°F 7.2×10^{-6}	20-760°C 13.0×10^{-6}
68-1600°F 7.3×10^{-6}	20-871°C 13.1×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1425-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2000-2200	1095-1205

Full Annealing

<i>°F</i>	<i>°C</i>
1600-1650	870-900

Air cool from these temperatures.

Hardening

Not appreciably hardened by heat treatment.

UNS S40945
MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength <i>ksi(MPa), Min</i>	Yield Strength <i>ksi(MPa), Min</i>	Elongation <i>%, Min</i>	Reduction in Area <i>%, Min</i>	Hardness <i>HB, Max</i> <i>HR, Max</i>
Sheet, Plate & Strip	A240	55(380)	30(205)	22.0	—	— B80

UNS S40975—409Ni

Ferritic

409Ni is a ferritic chromium stainless steel micro-alloyed with titanium, manganese and nickel. It provides excellent weldability, toughness and fabricating characteristics in sections over 0.120 inch (3.05 mm). It is a cost effective alternative to mild and low alloy steels, providing superior corrosion and/or oxidation resistance. The high temperature strength and oxidation resistance of the alloy are superior to carbon steel. The recommended maximum service temperature is 1350°F (730°C).

Potential coal-handling applications include chutes, hoppers, bunkers, flooring, perforated plate for sizing, flight conveyor wear liners, vibrating screen pans, paddle mixers, screw feeders and dryer components. Potential applications in the transportation industry include hopper car bodies and discharge chutes, trailers, bus frames, dump truck bed liners and automotive exhaust flanges. Other potential applications include noise suppression barriers, slurry pipelines, heat shields, cyclones, silos, belt scraper blades, screens and tanks.

UNS S40975

Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Ti
0.03	1.00	0.040	0.030	1.00	10.5	0.50	6(C+N)
Max	Max	Max	Max	Max	11.75	1.00	0.75

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
30.2×10^6	208,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.275	7,600

Electrical Resistivity

<i>Microhm — mm at 68°F (20°C)</i>
600

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
73°F 14.8	23°C 25.7
212°F 14.9	100°C 25.8
392°F 15.2	200°C 26.4
752°F 15.6	400°C 26.9
932°F 15.9	500°C 27.5
1112°F 15.5	600°C 26.9
1292°F 14.7	700°C 25.4
1472°F 17.7	800°C 30.7
1598°F 18.7	870°C 32.3

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-200°F	6.1×10^{-6}
68-400°F	6.3×10^{-6}
68-600°F	6.5×10^{-6}
68-800°F	6.7×10^{-6}
68-1000°F	6.9×10^{-6}
68-1200°F	7.1×10^{-6}
68-1400°F	7.2×10^{-6}
68-1600°F	7.3×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1425-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2000-2200	1095-1205

Full Annealing

<i>°F</i>	<i>°C</i>
1600-1650	870-900

Air cool from these temperatures.

Hardening

Not appreciably hardened by heat treatment.

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength <i>ksi(MPa), Min</i>	Yield Strength <i>ksi(MPa), Min</i>	Elongation <i>%, Min</i>	Reduction in Area <i>%, Min</i>	Hardness <i>HB, Max HR, Max</i>
Sheet, Plate & Strip	A240	60(415)	40(275)	20.0	—	197 B92

UNS S41000—Type 410
UNS S41008—Type 410S

Martensitic

Type 410 is the basic, general purpose, hardenable martensitic stainless steel. It is used for highly stressed parts with good corrosion resistance and strength. Type 410 resists corrosion in mild atmospheres, steam and many mild chemical environments. The alloy can be heat treated to obtain high strength with good ductility.

Type 410S is a lower carbon modification of Type 410 for improved weldability. When heat treated, it will develop somewhat lower mechanical properties than Type 410.

See also the Section on Typical Applications.

UNS S41000/UNS S41008
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>
Type 410						
0.15	1.00	0.040	0.030	1.00	11.5	0.75
Max	Max	Max	Max	Max	13.5	Max
Type 410S						
0.08	1.00	0.040	0.030	1.00	11.5	0.60
Max	Max	Max	Max	Max	13.5	Max

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm</i>	
68°F (20°C)	570
212°F (100°C)	640
392°F (200°C)	720
752°F (400°C)	880
1112°F (600°C)	1035
1292°F (700°C)	1110

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F 14.4	100°C 24.9
932°F 16.6	500°C 28.7

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	5.5×10^{-6}	0-100° C	9.9×10^{-6}
32-600°F	6.3×10^{-6}	0-315° C	11.4×10^{-6}
32-1000°F	6.4×10^{-6}	0-538° C	11.6×10^{-6}
32-1200°F	6.5×10^{-6}	0-649° C	11.7×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2700-2790	1482-1532

Magnetic Permeability

<i>H/m Annealed</i>
900 Max

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2000-2200	1093-1204

Cool slowly from these temperatures.

Full Annealing

<i>°F</i>	<i>°C</i>
1500-1650	815-898

Cool slowly from these temperatures.

Process Annealing

<i>°F</i>	<i>°C</i>
1200-1400	649-760

Hardening

<i>°F</i>	<i>°C</i>
1700-1850	926-1008

Cool rapidly from these temperatures.

Tempering

<i>°F</i>	<i>°C</i>
400-1400	204-760

**MECHANICAL PROPERTIES
TYPE 410 (UNS S41000)**

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>		<i>Cold Bend Degree</i>
						<i>HB, Max</i>	<i>HR, Max</i>	
Plate, Sheet & Strip								
Annealed	A240	65(448)	30(207)	20	—	217	B96	180
Bar								
Annealed	A276	70(483)	40(276)	20 ^b	45	—	—	—
Annealed	A479	70(483)	40(276)	20 ^c	45 ^c	223	—	—
Condition T	A276	100(689)	80(552)	15 ^d	45 ^d	—	—	—
Condition H	A276	120(827)	90(621)	12	40	—	—	—

Also refer to A193 and A 194 for bolting materials and nuts.

Wire								
Annealed	A580	70(483)	40(276)	20 ^b	45	—	—	—
Condition T	A580	100(689)	80(552)	12	40	—	—	—
Condition H	A580	120(827)	90(621)	12	40	—	—	—

Also refer to A493 for Cold Heading Wire.

Forgings								
Annealed	A473	70(483)	40(276)	20	45	223	—	—
Mechanical Tubing								
Annealed	A511	60(414)	30(207)	20	—	207	B95	—

^aMaterial 0.050 in (1.27 mm) and under in thickness shall have a minimum elongation of 20 percent.

^bMinimum elongation is 16 percent for cold finished material.

^cFor cold finished material, the minimum elongation and reduction in area shall be 12 and 35 percent, respectively.

^dFor cold finished material, the minimum elongation and reduction in area shall be 12 and 40 percent, respectively.

**MECHANICAL PROPERTIES
TYPE 410S (UNS S41008)**

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>		<i>Cold Bend Degree</i>
						<i>HB, Max</i>	<i>HR, Max</i>	
Sheet, Plate & Strip								
Annealed	A240	60(414)	30(207)	22 ^b	—	183	B89	180
Bar								
Annealed	—	70(483) ^a	35(241) ^a	30 ^a	50 ^a	155 ^a	B82 ^a	—
Wire								
Annealed	—	70(483) ^a	40(276) ^a	30 ^a	60 ^a	—	—	—
Forgings								
Annealed	A473	65(450)	35(240)	22	45	217	—	—

^aTypical value.

^bMaterial 0.050 in (1.27 mm) and under in thickness shall have a minimum elongation of 20 percent.

UNS S41003—Duracorr™; 3CR12

Ferritic/Martensitic

S41003 is a non-austenitic, low-carbon, magnetic stainless steel having a chromium content of about 11%. It has a fine grained, dual phase microstructure of ferrite plus tempered martensite.

Although less corrosion resistant than 300 series grades and higher chromium ferritic stainless steels, the steel is substantially more corrosion resistant than weathering, painted or galvanized steels.

The steel is relatively low in cost which permits its use in a wide variety of applications including boat docks, cement plant equipment, coal cars and coal handling equipment, drain covers, fertilizer handling and storage equipment, floor plate, grain hopper cars, manure hoppers and spreaders, ore cars, sewage plant equipment, storage bins, street sweepers, sugar beet processing equipment and truck salt spreaders.

UNS S41003
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>
0.03	1.50	0.040	0.030	1.00	10.5	1.50	0.030
Max	Max	Max	Max	Max	12.5	Max	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.277	7,680

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F 13.3	100°C 23
932°F 14.5	500°C 25

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	6.0 × 10 ⁻⁶
32-572°F	6.3 × 10 ⁻⁶
32-1292°F	6.9 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2605-2750	1430-1510

Magnetic Permeability

Magnetic

UNS S41003

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>HB, Max</i>	<i>HR, Max</i>
Sheet, Plate & Strip	A240	66(455)	40(275)	18	—	223	C20

UNS S41400—Type 414

Martensitic

Type 414 is a martensitic, nickel-bearing, chromium stainless steel with somewhat better corrosion resistance than Type 410.

When heat treated it will attain slightly higher mechanical properties than Type 410.

See also the Section on Typical Applications.

UNS S41400

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>
0.15	1.00	0.040	0.030	1.00	11.5	1.25
Max	Max	Max	Max	Max	13.5	2.50

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
700

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
212°F 14.4	100°C 24.9
932°F 16.6	500°C 28.7

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	5.8×10^{-6}
32-600°F	6.1×10^{-6}
32-1000°F	6.7×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2600-2700	1425-1480

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2200	1149-1204

Slow cool and anneal from these temperatures.

Full Annealing

Not practical.

Process Annealing

<i>°F</i>	<i>°C</i>
1200-1300	649-704

Hardening

<i>°F</i>	<i>°C</i>
1800-1900	981-1036

Cool rapidly from these temperatures.

Tempering

<i>°F</i>	<i>°C</i>
400-1300	204-704

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A276	115(793) ^a	90 (621) ^a	20 ^a	60 ^a	298	—
Condition T	A276	115(793)	90(621)	15	45	—	—
Wire							
Annealed	A580	150(1034) ^b	—	—	—	—	—
Forgings							
Annealed	A473	—	—	—	—	298	—
Condition T	A473	115(793)	90(621)	15	45	321	—
Condition H	A473	125(862)	100(689)	15	45	321	—
Mechanical Tubing							
Annealed	A511	100(689)	65(448)	15	—	235	B99

^aTypical value.

^bMaximum.

UNS S41500—13Cr-4Ni; F6NM

Martensitic

S41500 is a martensitic stainless steel having better toughness than the conventional marten-

sitic stainless steels. This is the wrought version of the cast alloy CA-6NM.

UNS S41500
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>
0.05	0.5	0.030	0.030	0.60	11.5	3.5	0.5
Max	1.0	Max	Max	Max	14.0	5.5	1.0

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

$\frac{\text{psi}}{\text{MPa}}$

No Data

Density

$\frac{\text{lb/in}^3}{\text{kg/m}^3}$

No Data

Electrical Resistivity

$\frac{\text{Microhm} \cdot \text{mm}}{68^\circ\text{F} (20^\circ\text{C})}$

No Data

Specific Heat

$\frac{\text{Btu/lb} \cdot ^\circ\text{F}}{\text{kJ/kg} \cdot \text{K}}$

No Data

Thermal Conductivity

$\frac{\text{Btu/ft} \cdot \text{h} \cdot ^\circ\text{F}}{\text{W/m} \cdot \text{K}}$

No Data

Mean Coefficient of Expansion

$\frac{\text{in/in} \cdot ^\circ\text{F}}{\text{cm/cm} \cdot ^\circ\text{C}}$

No Data

Melting Range

$\frac{^\circ\text{F}}{^\circ\text{C}}$

No Data

Magnetic Permeability

$\frac{\text{H/m}}{\text{Annealed}}$

Magnetic

Thermal Treatment

Initial Forging

$\frac{^\circ\text{F}}{^\circ\text{C}}$

No Data

Annealing

$\frac{^\circ\text{F}}{^\circ\text{C}}$

1450-1500 790-815

Annealing

Furnace cool or slow cool to 1150°F (620°C) after which may air cool.

Hardening

Heat to 1750°F (955°C), air cool to 200°F (93°C) or lower, temper between 1050°F (565°C) and 1150°F (620°C)

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S41500
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi (MPa), Min</i>	<i>Yield Strength ksi (MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A240	115(795)	90(620)	15	—	302	C32
Bar							
Normalized and Tempered	A276, A479	115(795)	90(620)	15	45	295	—

UNS S41600—Type 416

Free machining/Martensitic

Type 416 is a hardenable, martensitic chromium stainless steel to which elements have been added to improve the machining and nonseizing characteristics. It is the original free-machining version of Type 410 stainless steel.

It is the most readily machinable of all the stainless steels and is suitable for use in automatic screw machines.

See also the Section on Typical Applications.

UNS S41600
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>
0.15	1.25	0.060	0.15	1.00	12.0
Max	Max	Max	Min	Max	14.0

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
570

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F 14.4	100°C 24.9
932°F 16.6	500°C 28.7

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	5.5×10^{-6}
32-600°F	6.1×10^{-6}
32-1000°F	6.4×10^{-6}
32-1200°F	6.5×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2700-2790	1483-1532

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100-2300	1149-1260

Slow cool from these temperatures.

Full Annealing

<i>°F</i>	<i>°C</i>
1500-1650	815-898

Cool slowly from these temperatures.

Process Annealing

<i>°F</i>	<i>°C</i>
1200-1400	649-760

Hardening

<i>°F</i>	<i>°C</i>
1700-1850	926-1008

Cool rapidly from these temperatures.

Tempering

<i>°F</i>	<i>°C</i>
400-1400	204-760

UNS S41600
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A582	75(517) ^a	40(276) ^a	30 ^a	60 ^a	262	—
Condition T	A582	110(758) ^a	85(586) ^a	18 ^a	55 ^a	248-302 ^b	—
Condition H	A582	—	—	—	—	293-352 ^b	—
Also refer to A194 for nuts.							
Wire							
Annealed	A581	85-125(586-862) ^b	—	—	—	—	—
Condition T	A581	115-145(793-1000) ^b	—	—	—	—	—
Condition H	A581	140-175(965-1206) ^b	—	—	—	—	—
Forgings							
Annealed	A473	70(483)	40(276)	20	45	223	—

^aTypical value.

^bRange required.

UNS S42000—Type 420

Martensitic

Type 420 is a martensitic chromium stainless steel capable of being heat treated to a maximum hardness of approximately Rockwell C50.

It has better corrosion resistance, in general, in the hardened and tempered condition than in the annealed condition.

See also the Section on Typical Applications.

UNS S42000

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>
0.15	1.00	0.040	0.030	1.00	12.0
Min	Max	Max	Max	Max	14.0

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Modulus of Elasticity in Torsion

<i>psi</i>	<i>MPa</i>
11.7×10^6	81,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
550

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F	100°C
14.4	24.9

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	5.7×10^{-6}	0-100° C	10.3×10^{-6}
32-600°F	6.0×10^{-6}	0-315° C	10.8×10^{-6}
32-1000°F	6.5×10^{-6}	0-538° C	11.7×10^{-6}
32-1200°F	6.8×10^{-6}	0-649° C	12.2×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2650-2750	1454-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2000-2200	1093-1204

Slow cool and anneal from these temperature.

Full Annealing

<i>°F</i>	<i>°C</i>
1550-1650	842-898

Cool slowly from these temperatures.

Process Annealing

<i>°F</i>	<i>°C</i>
1300-1450	734-787

Hardening

<i>°F</i>	<i>°C</i>
1800-1900	981-1036

Cool rapidly from these temperatures.

Tempering

<i>°F</i>	<i>°C</i>
300-700	149-371

UNS S42000
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip							
Annealed	A176	100(690)Max	—	15	—	217	B96
Bar							
Annealed	A276	95(655) ^a	50(345) ^a	25 ^a	55 ^a	241 ^b	—
Forgings							
Annealed	A473	—	—	—	—	223	—

^aTypical value.

^bFor cold finished material, the maximum hardness shall be 255.

UNS S42010—TrimRite®; 420L

Martensitic

S42010 is a martensitic stainless steel that provides a moderately high level of corrosion resistance. It can be heat treated to a hardness of approximately Rockwell C51. The alloy can be hot worked, cold worked, machined and heat treated using the same equipment and methods used for Type 410 stainless steel. It is balanced to be fully martensitic in the hardened condition and it is magnetic in all conditions. The steel has good formability.

The alloy has the hardness capability of Type 420 but it has superior corrosion resistance and better ductility.

Applications include fasteners, especially self-drilling types, cutlery, food processing equipment, valve parts, gauges, guides, shafting, conveyor chain and instruments.

UNS S42010
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Mo</i>
<u>0.15</u>	1.00	0.04	0.03	1.00	<u>13.5</u>	<u>0.35</u>	<u>0.40</u>
0.30	Max	Max	Max	Max	15.0	0.85	0.85

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.280	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
557

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
No Data	

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	0-100°C
5.6×10^{-6}	10.1×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
~2660	1460

Magnetic Permeability

<i>H/m Annealed</i>
Ferromagnetic

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2200-2250	1204-1232

Annealing

<i>°F</i>	<i>°C</i>
1350-1400	732-760

Annealing

Heat to above temperature and cool to room temperature.
Or for lowest hardness, heat to 1560°F (2 h) and cool in furnace at a rate not exceeding 50°F/h. Remove at 1200°F and cool to room temperature.

Hardening

Heat treatable — heat to 1900°F and quench in oil.
Temper 350 to 600°F.

UNS S42010
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A276	—	—	—	—	235	—
Annealed	—	88(607) ^a	54(372) ^a	28 ^a	66 ^a	—	B88 ^a
Plate	A895	—	—	—	—	262	—

^aTypical value.

UNS S42020—Type 420F
UNS S42023—Type 420FSe

Free machining/Martensitic

Types 420F and 420FSe are martensitic 12 percent chromium stainless steels. They are free-machining versions of Type 420. These steels have higher strength, greater hardness and better wear resistance than Type 410 stainless steel.

They have maximum corrosion resistance in the hardened and tempered condition and are magnetic in all conditions.

See also the Section on Typical Applications.

UNS S42020/UNS S42023
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Se</i>	<i>Ni</i> ^a	<i>Cu</i> ^a
Type 420F								
<u>0.30</u>	1.25	0.06	0.15	1.00	<u>12.0</u>	—	0.50	0.60
0.40	Max	Max	Min	Max	14.0		Max	Max
Type 420FSe								
<u>0.20</u>	1.25	0.06	0.06	1.00	<u>12.0</u>	0.15	0.50	0.60
0.40	Max	Max	Max	Max	14.0	Min	Max	Max

^aAt manufacturer's option, reported only when intentionally added.

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0 × 10 ⁶	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
550

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
80°F	14.5
27°C	25.1

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	5.7 × 10 ⁻⁶
0-100°C	10.3 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2650-2750	1454-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2050-2250	1121-1231

Annealing

<i>°F</i>	<i>°C</i>
1550-1650	842-898

Cool slowly from these temperatures.

Process Annealing

<i>°F</i>	<i>°C</i>
1350-1450	734-787

Hardening

<i>°F</i>	<i>°C</i>
1800-1900	981-1036

Cool rapidly from these temperatures.

Tempering

<i>°F</i>	<i>°C</i>
300-700	149-371

UNS S42020/UNS S42023
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A582	95(655) ^a	55(379) ^a	22 ^a	50 ^a	262	—
Wire							
Annealed	—	100(689) ^a	80(552) ^a	15 ^a	45 ^a	—	B99 ^a

^aTypical value.

UNS S42200—Type 422; Type 616

Martensitic

Type 422 is a hardenable martensitic chromium stainless steel designed for service temperatures up to 1200°F (650°C). It has a good combi-

nation of strength and toughness and is usually used for turbine blades and bolting applications.

UNS S42200
Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	V	W
0.20	0.50	0.025	0.025	0.50	11.0	0.50	0.90	0.20	0.90
0.25	1.00	Max	Max	Max	12.5	1.00	1.25	0.30	1.25

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

psi	MPa
29.8 × 10 ⁶	205,000

Density

lb/in ³	kg/m ³
0.28	7,750

Specific Heat

Btu/lb °F	kJ/kg·K
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

Btu/ft·h/°F	W/m·K
212°F 13.8	100°C 23.9
932°F 15.8	500°C 27.4

Mean Coefficient of Expansion

in/in/°F	cm/cm/°C
32-212°F	6.2 × 10 ⁻⁶
32-600°F	6.3 × 10 ⁻⁶
32-1000°F	6.6 × 10 ⁻⁶
32-1200°F	6.7 × 10 ⁻⁶

Melting Range

°F	°C
2675-2700	1468-1482

Thermal Treatment

Initial Forging

°F	°C
2100	1149

Annealing

°F	°C
1350-1450	734-787

Air cool from these temperatures.

Hardening

°F	°C
1900	1036

Air cool or oil quench from these temperatures.

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength ksi(MPa), Min	Yield Strength ksi(MPa), Min	Elongation %, Min	Reduction in Area %, Min	Hardness HB, Max	HR, Max	Minimum V-Notch Impact Strength Min ft lb
Sheet and Strip Condition HT ^b	—	180(1241) ^a	140(965) ^a	5 ^a	—	—	C38 ^a	—
Bar								
Annealed Condition HT ^c	A565	—	—	—	—	248	—	—
	A565	140(965)	110(758)	13	30	302-352 ^d	—	8

Also refer to AMS 5655.

^aTypical value.

^bHeat treated 1900°F (1038°C), air cooled and tempered 1100°F (593°C) for 1 h.

^cHeat treated 1900°F (1038°C), air or oil quench and tempered 1050°F (621°C) minimum for 2 h minimum.

^dRange specified. Hardness taken at the surface for control purposes only. For acceptance purposes, tensile properties govern.

UNS 42900—Type 429

Ferritic

Type 429 is a ferritic chromium stainless steel developed for better weldability than Type 430.

See also the Section on Typical Applications.

UNS 42900
Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni
0.12	1.00	0.040	0.030	1.00	14.0	0.75
Max	Max	Max	Max	Max	16.0	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
590

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F	100°C
14.8	25.6

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	0-100°C
5.7×10^{-6}	10.3×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2650-2750	1454-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1900-2050	1036-1120

Process Annealing

<i>°F</i>	<i>°C</i>
1450-1550	788-842

Hardening

Slightly hardenable by heat treatment.

UNS 42900
MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength <i>ksi(MPa), Min</i>	Yield Strength <i>ksi(MPa), Min</i>	Elongation <i>% , Min</i>	Reduction in Area <i>% , Min</i>	Hardness <i>HB, Max HR, Max</i>		Cold Bend <i>Degree</i>
Plate, Sheet & Strip								
Annealed	A240	65(448)	30(207)	22 ^a	—	183	B89	180
Bar								
Annealed	A276	70(483)	40(276)	20	45	—	—	—
Cold Finished	A276	70(483)	40(276)	16	45	—	—	—
Wire								
Annealed	A493	85(586)	—	—	—	—	—	—
Lightly Drafted	A493	90(621)	—	—	—	—	—	—
Forgings								
Annealed	A473	65(448)	35(241)	23	45	207	—	—
Pipe and Tubing								
Annealed	A268, A511, A554	60(414)	35(241)	20	—	190	B90	—

^aMaterial 0.050 in (1.27 mm) and under in thickness shall have a minimum elongation of 20 percent.

UNS S43000—Type 430

Ferritic

Type 430 is a ferritic chromium stainless steel with corrosion and heat resistance superior to Types 409 and 410. It has a lower alloy content than Type 304 and it is used for highly polished trim applications in mild atmospheres.

The hardness can be increased moderately by cold working, but the alloy cannot be hardened by heat treatment. The steel is normally used in the annealed condition.

See also the Section on Typical Applications.

UNS S43000
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>
0.12	1.00	0.040	0.030	1.00	16.0	0.75
Max	Max	Max	Max	Max	18.0	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

	<i>Microhm — mm</i>
68°F (20°C)	600
212°F (100°C)	675
392°F (200°C)	770
752°F (400°C)	925
1112°F (600°C)	1050
1452°F (700°C)	1150

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
68-212°F	13.8 20-100°C
68-932°F	15.0 20-500°C
	23.9 26.0

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	5.8×10^{-6} 0-100°C
32-600°F	6.1×10^{-6} 0-315°C
32-1000°F	6.3×10^{-6} 0-538°C
32-1200°F	6.6×10^{-6} 0-649°C
32-1500°F	6.9×10^{-6} 0-815°C

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1425-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1900-2050	1036-1120

Annealing

<i>°F</i>	<i>°C</i>
1400-1500	760-815

Hardening

Not appreciably hardenable by heat treatment.

UNS S43000
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>		<i>Cold Bend Degree</i>
						<i>HB, Max</i>	<i>HR, Max</i>	
Plate, Sheet & Strip								
Annealed	A240	65(448)	30(207)	22 ^a	—	183	B89	180
Bar								
Annealed	A276, A479	70(483)	40(276)	20	45	—	—	—
Cold Finished	A276	70(483)	40(276)	16	45	—	—	—
Cold Finished	A479	70(483)	40(276)	12	35	190	—	—
Wire								
Annealed	A580	70(483)	40(276)	20	45	—	—	—
Cold Finished	A580	70(483)	40(276)	16	45	—	—	—
Cold Heading	A493							
Annealed		75(520) Max	—	—	—	—	—	—
Lightly drafted		86(595) Max	—	—	—	—	—	—
Forgings								
Annealed	A473	70(483)	35(241)	20	45	217	—	—
Pipe and Tubing								
Annealed	A268, A511, A554	60(414)	35(241)	20	—	190	B90	—
Water Tube	A651	60(414)	30(241)	—	—	—	—	—

^aMaterial 0.050 in (1.27 mm) and under in thickness shall have a minimum elongation of 20 percent.

UNS S43020—Type 430F
UNS S43023—Type 430FSe

Free machining/Ferritic

Types 430F and 430FSe are free-machining versions of Type 430. They are ferritic, chromium stainless steels and they are suitable for the production of parts on automatic screw machines.

Type 430FSe is used when better machined surfaces are desired and when some light cold upsetting or cold forming is required.

See also the Section on Typical Applications.

UNS S43020/UNS S43023
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Se</i>
Type 430F						
0.12	1.25	0.06	0.15	1.00	<u>16.0</u>	—
Max	Max	Max	Min	Max	18.0	
Type 430FSe						
0.12	1.25	0.06	0.06	1.00	<u>16.0</u>	0.15
Max	Max	Max	Max	Max	18.0	Min

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
600

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F	15.1
932°F	15.2
100°C	26.1
500°C	26.3

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	5.8×10^{-6}
32-600°F	6.1×10^{-6}
32-1000°F	6.3×10^{-6}
32-1200°F	6.6×10^{-6}
32-1500°F	6.9×10^{-6}
0-100°C	10.4×10^{-6}
0-315°C	11.0×10^{-6}
0-538°C	11.4×10^{-6}
0-649°C	11.9×10^{-6}
0-815°C	12.4×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1427-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1950-2100	1063-1149

Process Annealing

<i>°F</i>	<i>°C</i>
1250-1400	675-760

Hardening

Not appreciably hardenable by heat treatment.

UNS S43020/UNS S43023
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A582	80(552) ^a	55(379) ^a	25 ^a	60 ^a	262	—
Wire							
Annealed	A581	85-125 ^b (585-860) ^b	80(552) ^a	15 ^a	50 ^a	—	B92 ^a
Forgings							
Annealed	A473	70(483)	40(276)	20	45	223	—

^aTypical value.

^bRange specified.

UNS S43035—Type 439; HWT®

Stabilized/Ferritic

Type 439 is a titanium-stabilized 18% chromium, ferritic stainless steel designed to resist corrosion in a variety of oxidizing conditions from fresh water to boiling acids. It may be used in either the annealed, cold formed or as-welded condition in many applications where other stainless steels, such as Types 304, 409, 410 and 430, are used.

Type 439 may be used in many oxidizing environments where Type 304 is considered adequate in terms of general corrosion resistance but is subject to stress corrosion cracking.

This composition of this steel has been balanced to provide a completely ferritic structure at all temperature in order to avoid the loss of ductility after welding and to provide resistance

to intergranular corrosion. Similar stainless steels, such as Types 430 and 434, are susceptible to brittle martensite formation after welding and to intergranular corrosion sensitivity in the as-welded condition. Type 439 does not require annealing after welding to restore ductility or to provide intergranular corrosion resistance.

Excellent resistance to stress corrosion cracking, good weldability, high thermal conductivity and low thermal expansion characteristics make Type 439 stainless steel an ideal material for many applications including residential furnaces, automotive exhaust system components, heat exchanger tubes, feedwater heating, power plant condensers and moisture separator reheater tubes in nuclear stations.

UNS S43035

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Ti</i>	<i>Al</i>	<i>N</i>
0.07	1.00	0.040	0.030	1.00	<u>17.0</u>	0.50	<u>0.20+4(C+N)</u>	0.15	0.04
Max	Max	Max	Max	Max	19.0	Max	1.10	Max	Max

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
630

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
68-392°F	5.9×10^{-6}	20-200°C	10.6×10^{-6}
68-1112°F	6.5×10^{-6}	20-600°C	11.7×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2650-2750	1427-1510

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
1900-2050	1038-1121

Annealing

<i>°F</i>	<i>°C</i>
1450-1700	788-926

Hardening

Not hardenable by heat treatment.

UNS S43035
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(Mpa), Min</i>	<i>Yield Strength ksi(Mpa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness</i>	
						<i>HB, Max</i>	<i>HR, Max</i>
Bar							
Annealed	A479	70 (483)	40 (276)	20	45	192	—
Plate, Sheet & Strip							
Annealed	A240	60(415)	30(207)	22	—	183	B89
Tubing							
Annealed	A268	60(414)	30(207)	20	—	190	B90

UNS S43100—Type 431

Martensitic

Type 431 is a hardenable, martensitic, nickel-bearing stainless steel. It has corrosion resistance superior to that of Types 410, 420 and 440.

The steel is primarily used for fasteners.
See also the Section on Typical Applications.

UNS S43100
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>
0.20	1.00	0.040	0.030	1.00	<u>15.0</u>	<u>1.25</u>
Max	Max	Max	Max	Max	17.0	2.50

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electric Resistivity

<i>Microhm — mm 68°F (20°C)</i>
720

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
212°F 11.7	100°C 20.2

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	5.6×10^{-6}	0-100°C	10.2×10^{-6}
32-600°F	6.7×10^{-6}	0-315°C	12.1×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1427-1510

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
2100-2250	1149-1231

Slow cool and anneal at these temperatures.

Full Annealing

Not practical.

Process Annealing

<i>°F</i>	<i>°C</i>
1150-1225	620-663

Hardening

<i>°F</i>	<i>°C</i>
1800-1950	981-1063

Cool rapidly from these temperatures.

Tempering

<i>°F</i>	<i>°C</i>
400-1200	204-649

UNS S43100
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A276	125 (862) ^a	95 (655) ^a	20 ^a	55 ^a	285	—
Wire							
Annealed	A580	140(965) ^b	115(793) ^a	10 ^a	50 ^a	—	C29 ^a
Cold Heading	A493						
Annealed		110(760) Max	—	—	—	—	—
Lightly drafted		115(795) Max	—	—	—	—	—
Forgings							
Annealed	A473	—	—	—	—	277	—
Condition T	A473	115(793)	90(621)	15	—	321	—
Condition H	A473	175(1207))	135(931)	13	—	440	—

^aTypical value.^bMaximum.

UNS S43400—Type 434

Ferritic

Type 434 is a molybdenum-bearing modification of Type 430 stainless steel. It is designed especially for use as automotive trim to resist at-

mospheric corrosion in the presence of winter road conditioning and dust-laying compounds. See also the Section on Typical Applications.

UNS 43400

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Mo</i>
0.12	1.00	0.040	0.030	1.00	16.0	0.75
Max	Max	Max	Max	Max	18.0	1.25

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm</i>	
68°F (20°C)	720
212°F (100°C)	780
392°F (200°C)	860
752°F (400°C)	1000
1112°F (600°C)	1110
1472°F (800°C)	1210

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
68-212°F 13.8	20-100°C 23.9
68-932°F 15.0	20-500°C 26.0

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	5.8×10^{-6}
32-600°F	6.1×10^{-6}
32-1000°F	6.3×10^{-6}
32-1200°F	6.6×10^{-6}
32-1500°F	6.9×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1427-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1900-2050	1036-1120

Annealing

<i>°F</i>	<i>°C</i>
1400-1600	760-871

Hardening

Not appreciably hardenable by heat treatment.

UNS S43400

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>
Plate, Sheet & Strip Annealed	A240	65(450)	35 (240)	22	—	— B89

S43600—Type 436**Ferritic**

Type 436 is a variation of Type 434 to which columbium has been added to minimize “roping”

or “ridging” during stretch forming operations. See also the Section on Typical Applications.

S43600

**Chemical Composition Limits
Cast or Heat Analysis, Percent**

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Mo</i>	<i>Cb+Ta</i>
0.12	1.00	0.040	0.030	1.00	<u>16.0</u>	<u>0.75</u>	<u>5×C</u>
Max	Max	Max	Max	Max	18.0	1.25	0.70

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
600

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F 13.8	100°C 23.9
932°F 15.0	500°C 26.0

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F 5.2×10^{-6}	0-100°C 9.3×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1427-1510

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
1900-2050	1036-1120

Annealing

<i>°F</i>	<i>°C</i>
1400-1600	760-871

Hardening

Not appreciably hardenable by heat treatment.

S43600

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(Mpa), Min</i>	<i>Yield Strength ksi(Mpa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip Annealed	A240	65(450)	35(240)	22	—	—	B89

UNS S44002—Type 440A
UNS S44003—Type 440B
UNS S44004—Type 440C

Martensitic

Types 440A, 440B and 440C are highly hardenable chromium martensitic stainless steels, with progressively increasing carbon contents. As the carbon content increases, the attainable hardness also increases, but at some sacrifice to corrosion resistance. These steels are used in the hardened and tempered condition. The maximum hardnesses attainable are: Rockwell C 56 for Type 440A, C58 for Type 440B and C60 for Type 440C.

These steels resist corrosion from mild atmospheres, fresh water, steam, ammonia, many petroleum products and organic materials and several mild acid environments.

For best corrosion resistance the tempering temperature should be below 800°F (427°C).

See also the Section on Applications.

UNS S44002 et al

Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Mo</i>
Type 440A						
<u>0.60</u>	1.00	0.040	0.030	1.00	<u>16.0</u>	0.75
0.75	Max	Max	Max	Max	18.0	Max
Type 440B						
<u>0.75</u>	1.00	0.040	0.030	1.00	<u>16.0</u>	0.75
0.95	Max	Max	Max	Max	18.0	Max
Type 440C						
<u>0.95</u>	1.00	0.040	0.030	1.00	<u>16.0</u>	0.75
1.20	Max	Max	Max	Max	18.0	Max

Physical Properties in the Annealed Condition**Modulus of Elasticity in Tension**

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.276	7,650

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
600

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F 14.0	100°C 24.2

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
68-392°F	5.7×10^{-6}	20-200°C	10.3×10^{-6}
68-1112°F	6.5×10^{-6}	20-600°C	11.7×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2500-2750	1371-1510

Thermal Treatment**Initial Forging**

<i>°F</i>	<i>°C</i>
1900-2200	1036-1204

Slow cool and anneal from these temperatures.

Full Annealing

<i>°F</i>	<i>°C</i>
1550-1600	842-870

Cool slowly from these temperatures.

Process Annealing

<i>°F</i>	<i>°C</i>
1350-1400	734-760

Hardening

<i>°F</i>	<i>°C</i>
1850-1950	1008-1063

Preheat to 1400-1500°F (760-816°C); soak at hardening temperature; quench in warm oil or cool in air.

Do not overheat.

Tempering

<i>°F</i>	<i>°C</i>
300-800	149-426

**MECHANICAL PROPERTIES
TYPE 440 (UNS S44002)**

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A276	105(723) ^a	60(414) ^a	20 ^a	45 ^a	269	—
Cold Finished	A276 ^b	115(793) ^a	60(621) ^a	12 ^a	20 ^a	285	—
Strip							
Annealed	—	100(689) ^a	60(414) ^a	20 ^a	—	—	B95 ^a
Wire							
Annealed	A580	140(965) ^c	60(414) ^a	18 ^a	55 ^a	—	B95 ^a
Forgings							
Annealed	A473	—	—	—	—	269	—
Mechanical Tubing							
Annealed	A511	95(655)	55(379)	15	—	215	B95

^aTypical value.^bCold drawn.^cMaximum.

**MECHANICAL PROPERTIES
TYPE 440B (UNS S44003)**

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A276	107(738)	62(427)	18 ^a	35 ^a	269	—
Cold Finished ^b	A276	120(827)	95(655)	9 ^a	20 ^a	285	—
Wire							
Annealed	A580	140(965) ^c	62(427)	16 ^a	40 ^a	—	B96 ^a
Forgings							
Annealed	A473	—	—	—	—	269	—

^aTypical value.^bCold drawn.^cMaximum.

**MECHANICAL PROPERTIES
TYPE 440C (UNS S44004)**

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Bar							
Annealed	A276	110(758) ^a	62(448) ^a	14 ^a	25 ^a	269	—
Cold Finished ^b	A276	125(862) ^a	100(689) ^a	7 ^a	20 ^a	285	—
Wire							
Annealed	A580	140(965) ^c	65(448)	13 ^a	30 ^a	—	B97 ^a
Cold Heading	A493						
Annealed		110(760) ^c	—	—	—	—	—
Lightly		120(830) ^c	—	—	—	—	—
drafted							
Forgings							
Annealed	A473	—	—	—	—	269	—

^aTypical value.^bCold drawn.^cMaximum.

UNS S44020—Type 440F
UNS S44023—Type 440FSe

Free machining/Martensitic

Type 440F is a free-machining, high carbon, martensitic, chromium stainless steel designed to provide corrosion resistance with maximum hardness. It is easy to grind and polish and has certain nongalling and nonseizing properties in metal-to-metal contact. It can be heat treated to a maximum hardness of about Rockwell C60.

Type 440FSe is similar but contains selenium instead of sulfur to impart the free-machining

properties. It has provided better machined surface finishes.

Types 440F and 440FSe should be considered for machined parts which require higher hardness values than possible with other free-machining grades. These alloys are not recommended for vessels containing gases or liquids under high pressure.

UNS S44020/UNS S44023
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>Se</i>	<i>Cu</i>
Type 440F								
<u>0.95</u>	1.25	0.06	0.15	1.00	<u>16.0</u>	0.5 ^a	—	0.6 ^a
1.20	Max	Max	Min	Max	18.0	Max		Max
Type 440FSe								
<u>0.95</u>	1.25	0.06	0.06	1.00	<u>16.0</u>	0.5 ^a	0.15	0.6 ^a
1.20	Max	Max	Max	Max	18.0	Max	Min	Max

^aAt manufacturer's option, reported only when intentionally added.

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
29.0 × 10 ⁶	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.275	7,620

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
600

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.275	0.460

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
No Data	

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	0-100°C
5.6 × 10 ⁻⁶	10.1 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
~2550	1400

Magnetic Permeability

H/m Annealed
 Ferromagnetic

Thermal Treatment

Initial Forging

	<i>°F</i>	<i>°C</i>
Preheat	1400-1500	760-816
Heat slowly to	1900-2100	1038-1149
Do not forge below	1700	927

Annealing

<i>°F</i>	<i>°C</i>
1550-1600	843-871

Annealing

For maximum softness, heat uniformly to 1550 to 1600°F. Soak and cool very slowly.

Hardening

Heat to 1850 to 1950°F. Soak; quench in warm oil or cool in air. Temper 300 to 600°F min for 1 h and cool in air.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S44020/UNS S44023
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Typical</i>	
Hardened 1900°F Oil quench, tempered 600°F	—	285(1965) ^a	275(1896) ^a	2 ^a	10 ^a	578 ^a	C57 ^a
Bar							
Annealed	A582	—	—	—	—	285	—

^aTypical value.

UNS S44200—Type 442

Ferritic

Type 442 is a high chromium ferritic stainless steel with good corrosion and heat resistance. It is used principally for the manufacture of

parts which must resist scaling up to a temperature of 1800°F (980°C). See also the Section on Typical Applications.

UNS S44200
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>
0.20	1.00	0.040	0.040	1.00	18.0	0.6
Max	Max	Max	Max	Max	23.0	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
640

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.11	0.46

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F 12.5	100°C 21.6
932°F 14.2	500°C 24.6

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
68-212°F	20-100°C
5.6×10^{-6}	10.2×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1427-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1600-2100	871-1149

Process Annealing

<i>°F</i>	<i>°C</i>
1350-1500	734-815

Hardening

Not appreciably hardenable by heat treatment.

UNS S44200
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>	<i>Cold Bend Degree</i>
Plate, Sheet & Strip								
Annealed	A176	65(450)	40(276)	20	—	217	B96	180
Bar								
Annealed	—	80(552) ^a	45(310) ^a	25 ^a	40 ^a	—	B90 ^a	—

^aTypical value.

UNS S44400—Type 444

Ferritic

Type 444 is a weldable ferritic, chromium-molybdenum stainless steel containing columbium and/or titanium. This alloy provides good resistance to pitting, crevice corrosion and stress cor-

rosion cracking.

Typical applications include heat exchanger tubing, hot water tanks, solar collector panels and chemical process equipment.

UNS S44400
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Mo</i>	<i>N</i>	<i>Ti+Cb</i>
0.025	1.00	0.040	0.030	1.00	17.5	1.75	0.035	0.20+4(C+N)
Max	Max	Max	Max	Max	19.5	2.5	Max	0.80

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0 × 10 ⁶	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
620

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.102	0.427

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
212°F 15.5	100°C 26.8

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	0-100°C
6.1 × 10 ⁻⁶	11.0 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1427-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1900-2000	1036-1093

Annealing

<i>°F</i>	<i>°C</i>
1500-1650	816-899

Hardening

Not hardenable by heat treatment.

UNS S44400
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip							
Annealed	A240	60(414)	40(276)	20	—	217	B96
Tubing							
Annealed	A268	60(414)	45(310)	20	—	217	B95

S44500 is a 20% chromium ferritic stainless steel. It has good resistance to pitting and crevice corrosion in the presence of chlorides and resistance to oxidation at elevated temperatures.

An addition of 0.5% copper enhances the corrosion resistance, and the elevated temperature strength is increased by the addition of 0.5% columbium which also provides resistance to intergranular corrosion.

The resistance to corrosion and oxidation and the elevated temperature strength are superior

to those of Types 409 and 430 stainless steels which have lower chromium contents.

The formability and weldability of the alloy are very good and are similar to Types 409 and 430 in this respect.

Applications include elevated temperature use in automotive exhaust systems as well as in other situations where a combination of resistance to chlorides and oxidation, improved elevated temperature strength and fabricability are required.

UNS S44500
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>Ni</i>	<i>N</i>	<i>Cu</i>	<i>Cb</i>
0.020	1.00	0.040	0.012	1.00	<u>19.00</u>	0.60	0.03	<u>0.30</u>	<u>10(C+N)</u>
Max	Max	Max	Max	Max	21.00	Max	Max	0.60	0.80

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,756

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.114	0.48

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
68°F	14.4
20°C	24.9

Mean Coefficient of Expansion

	<i>in/in/°F</i>		<i>cm/cm/°C × 10⁻⁶</i>
68-212°F	6.0×10^{-6}	20-100°C	10.8×10^{-6}
68-500°F	6.1×10^{-6}	20-260°C	11.0×10^{-6}
68-900°F	6.3×10^{-6}	20-482°C	11.3×10^{-6}
68-1200°F	6.4×10^{-6}	20-849°C	11.5×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2660-2730	1460-1499

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2000-2150	1093-1177

Full Annealing

<i>°F</i>	<i>°C</i>
1600-1750	871-954

UNS S44500
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>
Plate, Sheet & Strip	A240	62(427)	30(205)	22	—	—	B83

UNS S44600—Type 446

Ferritic

Type 446 is a heat resisting ferritic, chromium stainless steel. It is used principally for the manufacture of parts which must resist scaling

at high temperatures. It resists destructive scaling up to 2000°F (1095°C). See also the Section on Typical Applications.

UNS S44600
Chemical Composition Limits
Cast or Heat Analysis, Percent

<i>C</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Si</i>	<i>Cr</i>	<i>N</i>	<i>Ni</i>
0.20	1.50	0.040	0.030	1.00	23.0	0.25	0.75
Max	Max	Max	Max	Max	27.0	Max	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0×10^6	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.27	7,473

Electrical Resistivity

<i>Microhm — mm</i>	
68°F (20°C)	670
212°F (100°C)	740
392°F (200°C)	830
752°F (400°C)	980
1112°F (600°C)	1110
1472°F (800°C)	1190
1832°F (1000°C)	1260

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F	12.1
932°F	14.1
100°C	20.9
500°C	24.4

Mean Coefficient of Expansion

<i>in/in/°F</i>		<i>cm/cm/°C</i>	
32-212°F	5.8×10^{-6}	0-100°C	10.4×10^{-6}
32-600°F	6.0×10^{-6}	0-315°C	10.8×10^{-6}
32-1000°F	6.2×10^{-6}	0-538°C	11.2×10^{-6}
32-1200°F	6.4×10^{-6}	0-649°C	11.6×10^{-6}
32-1800°F	6.7×10^{-6}	0-981°C	12.1×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1427-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1950-2050	1063-1120

Annealing

<i>°F</i>	<i>°C</i>
1450-1600	787-871

Hardening

Not appreciably hardenable by heat treatment.

MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max</i>	<i>HR, Max</i>	<i>Cold Bend Degree</i>
Plate, Sheet & Strip								
Annealed	A176	65(450)	40(276)	20	—	217	B96	135
Bar								
Annealed	A276	65(450)	40(276)	20	45	219	—	—
Cold Finished	A276	65(450)	40(276)	16	45	219	—	—
Wire								
Annealed	A580	70(483)	40(276)	20	45	—	—	—
Cold Finished	A580	70(483)	40(276)	16	45	—	—	—
Forgings								
Annealed	A473	70(483)	40(276)	20	45	223	—	—
Tubing								
Annealed	A268, A511	70(483)	40(276)	18	—	207	B95	—

UNS S44627—XM-27; E-BRITE®

Ferritic

Type XM-27 is a high-purity ferritic stainless steel which combines excellent resistance to corrosion with good fabrication characteristics. It offers outstanding resistance to stress corrosion cracking along with superior pitting and crevice corrosion resistance. Because of its high chromium content the alloy offers substantial resistance to oxidation and sulfidation at elevated temperatures.

Applications are found in chemical process plants, food processing and oil refineries for equipment such as valve trim, heat exchangers, pressure vessels, filter cloth, piping, conveyor systems, fasteners, air preheaters, furnace parts, thermocouple sheathing, sour gas coolers, tubesheets, steam generators, weak acid condensers, and vapor recovery systems.

UNS S44627
Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	N	Cb	Cu	Ni+Cu
0.010	0.40	0.020	0.020	0.40	25.0	0.50	0.75	0.015	0.05	0.20	0.50
Max	Max	Max	Max	Max	27.5	Max	1.50	Max	0.20	Max	Max

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

psi	MPa
29.0 × 10 ⁶	200,000

Density

lb/in ³	kg/m ³
0.28	7,660

Electrical Resistivity

Microhm — mm 68°F (20°C)
520-570

Specific Heat

Btu/lb °F	kJ/kg·K
32-212°F	0-100°C
0.102	0.427

Thermal Conductivity

Btu/ft·h/°F	W/m·K
125°F 11.6	52°C 20.0

Mean Coefficient of Expansion

in/in/°F	cm/cm/°C
70-212°F	5.5 × 10 ⁻⁶
21-100°C	9.9 × 10 ⁻⁶

Melting Range

°F	°C
~2750	1510

Magnetic Permeability

H/m Annealed
Ferromagnetic

Thermal Treatment

Initial Forging

°F	°C
2100	1150

Annealing

°F	°C
1400-1750	760-954

Hardening

Not hardenable.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S44627
MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength ksi(MPa), Min	Yield Strength ksi(MPa), Min	Elongation %, Min	Reduction in Area %, Min	Hardness HB, Max	HR, Max	Cold Bend Degree
Plate, Sheet & Strip	A240	65(450)	40(275)	22	—	187	B90	180
Bars and Shapes	A276							
Annealed		65(450)	40(275)	20	45	—	—	—
Cold finished		65(450)	40(275)	15	45	—	—	—

UNS S44660—Sea-Cure®; SC-1

Sea-Cure is a ferritic stainless steel that has a combination of high strength, low work hardening and good ductility. Because of the addition of nickel, the alloy has a lower ductile-to-brittle transition temperature than similar ferritic steels without nickel. The alloy is specifically designed where chloride-induced pitting and crevice or stress-corrosion cracking may be encountered.

Sea-Cure has many uses including electric

power plant condensers and feedwater heaters; various heat exchangers in chemical, petrochemical and refining applications; desalination heat exchangers and flue gas handling systems such as the secondary heat exchangers in high efficiency furnaces. The American gas Association has approved the alloy for flue gas concentrate applications. The alloy has better resistance to general corrosion over a broader range of conditions than the austenitic stainless steels.

UNS S44660

Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	N	Ti+Cb
0.030	1.00	0.040	0.030	1.00	25.0	1.0	3.0	0.040	0.20-1.00
Max	Max	Max	Max	Max	28.0	3.5	4.0	Max	6(C+N)

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
31.0×10^6	214,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.28	7,660

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
536

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50

Thermal Conductivity

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
70°F 9.4	21°C 16.1
600°F 12.9	316°C 22.3

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
70-200°F	5.38 × 10 ⁻⁶
70-300°F	5.43 × 10 ⁻⁶
70-500°F	5.81 × 10 ⁻⁶
70-700°F	5.95 × 10 ⁻⁶

Annealing

<i>°F</i>	<i>°C</i>
1700-1750	930-955

Annealing

Water quench from the annealing temperature.

Hardening

Not hardenable by heat treatment.

UNS S44660

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength <i>ksi(MPa), Min</i>	Yield Strength <i>ksi(MPa), Min</i>	Elongation <i>%, Min</i>	Reduction in Area <i>%, Min</i>	Hardness <i>HB, Max HR, Max</i>
Sheet, Plate & Strip	A240	85(585)	65(450)	18.0	—	241 B100
Tube	A268	85(585)	65(450)	20 ^a	—	265 C25

^aFor wall thickness 5/16 in (8 mm) and over.

29-4C is a highly alloyed material known as a superferritic stainless steel. It has extreme resistance to chloride ion pitting, crevice corrosion, chloride stress corrosion cracking and general corrosion in oxidizing and moderately reducing environments. The steel has relatively high strength.

The alloy is not produced as plate since brittle impact behavior is observed at ambient temperatures in thick sections.

The material has been used in the brine heat exchangers of the most advanced geothermal power plant.

Applications in the power industry include condensers, geothermal exchangers and feedwater heaters. In the chemical process industry applications include tower packing and heat exchangers. Applications in petroleum refining include desalters, fractionator overhead condensers, CO₂ precoolers and tower packing. The material has also been used for condensing flue gases in residential home heating furnaces.

UNS S44735

Chemical Composition Limits Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	N	Ti+Cb
0.030	1.00	0.040	0.030	1.00	<u>28.0</u>	1.0	<u>3.6</u>	0.045	<u>0.20-1.00</u>
Max	Max	Max	Max	Max	30.0	Max	4.2	Max	6(C+N)

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
30×10^6	207,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.277	7,660

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
720

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
0.107	0.448

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
68°F 8.8	20°C 15.2
500°F 11.0	260°C 19.0

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
32-212°F	5.2×10^{-6}
70-392°F	5.4×10^{-6}
70-752°F	5.8×10^{-6}

Melting Range

<i>°F</i>	<i>°C</i>
2750	1510

Magnetic Permeability

<i>H/m Annealed</i>
Ferromagnetic

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
2100	1150

Annealing

<i>°F</i>	<i>°C</i>
1850-1950	1010-1066

Hardening

Not hardenable.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength <i>ksi(MPa), Min</i>	Yield Strength <i>ksi(MPa), Min</i>	Elongation <i>%, Min</i>	Reduction in Area <i>%, Min</i>	Hardness <i>HB, Max</i>	<i>HR, Max</i>
Sheet and Strip	A240	80(550)	60(415)	18	—	255	C25
Tube	A268	75(515)	60(415)	18	—	—	B100

UNS S45000—Type XM-25; Custom 450®

S45000 is a martensitic age hardenable stainless steel combining the very good corrosion resistance of Type 304 and the moderate strength characteristics of Type 410.

The alloy has a yield strength somewhat greater than 100 ksi (689 MPa) in the annealed condition, but it is easily fabricated.

Precipitation Hardening

A single-step aging treatment develops higher strength with good ductility and toughness. The steel can be used in the annealed or the hardened condition.

The steel can be machined, hot worked and cold formed in the same manner as the other martensitic age hardenable stainless steels. A particular advantage is the ease of welding and brazing.

UNS S45000
Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Cb
0.05	1.00	0.03	0.03	1.00	14.0	5.0	0.5	1.25	8 × C
Max	Max	Max	Max	Max	16.0	7.0	1.0	1.75	Min

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
28.0 × 10 ⁶	193,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.280	7,750

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
992

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
73-216°F 0.114	23-103°C 0.477

Thermal Conductivity—Condition H900

<i>Btu/ft/h/°F</i>	<i>W/m·K</i>
73°F 8.7	23°C 15.0
212°F 9.2	100°C 16.4
392°F 10.5	200°C 18.4
572°F 11.5	300°C 19.9
752°F 12.3	400°C 21.3
932°F 14.1	500°C 24.4

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
75-200°F 5.88 × 10 ⁻⁶	24-93°C 10.58 × 10 ⁻⁶
75-300°F 5.62 × 10 ⁻⁶	24-149°C 10.12 × 10 ⁻⁶
75-400°F 5.68 × 10 ⁻⁶	24-204°C 10.22 × 10 ⁻⁶
75-500°F 5.80 × 10 ⁻⁶	24-260°C 10.44 × 10 ⁻⁶
75-600°F 5.91 × 10 ⁻⁶	24-316°C 10.64 × 10 ⁻⁶
75-700°F 5.98 × 10 ⁻⁶	24-371°C 10.76 × 10 ⁻⁶
75-800°F 6.09 × 10 ⁻⁶	24-427°C 10.96 × 10 ⁻⁶
75-900°F 6.13 × 10 ⁻⁶	24-482°C 11.03 × 10 ⁻⁶
75-1000°F 6.08 × 10 ⁻⁶	24-538°C 10.94 × 10 ⁻⁶
75-1100°F 6.17 × 10 ⁻⁶	24-593°C 11.11 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
~2700	~1480

Magnetic Permeability

<i>H/m Annealed</i>
Ferromagnetic

Thermal Treatment

Initial Forging

	<i>°F</i>	<i>°C</i>
	1650-2300	900-1260
Optimum	2100-2150	1150-1177

Annealing

<i>°F</i>	<i>°C</i>
1875-1925	1024-1052

Annealing

Hold at above temperature and cool rapidly. Water or oil quenching is preferred, but air cooling is suitable for thin sections.

Hardening

Age solution annealed material at 900 to 1150°F or 4 h and air cool. The 900°F age produces the optimum combination of strength, ductility and toughness. Overaging at temperatures up to 1150°F increases the ductility and decreases the strength.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S45000
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A693						
Solution treated (0.010 in [0.25 mm] and over)		165(1205)	150(1035)	4	—	255	C25
Condition 900 ^a		180(1240)	170(1170)	3	—	—	C40 Min
Condition 1000 ^a		160(1105)	150(1035)	7	—	—	C36 Min
Condition 1150 ^a		125(860)	75(515)	10	—	—	C26 Min
Bars and Shapes	A564						
Solution Treated		130(895) ^b	95(655)	10	40	321	C32
Condition H 900 ^c		180(1240)	170(1170)	10	40	363 Min	C39 Min
Condition H1000 ^c		160(1100)	150(1030)	12	45	331 Min	C36 Min
Condition H1150 ^c		125(860)	75(520)	15	50	285 Min	C26 Min

^aFor thicknesses over 0.062 in (1.57 mm). See A693 for thicknesses 0.062 in (1.57 mm) and under.

^b130-165 ksi (895-1140 MPa) for sizes up to 0.5 in (13 mm).

^cFor thicknesses up to 8 in (200 mm). See A693 for thicknesses over 8 in (200 mm).

UNS S45500—Type XM-16; Custom 455®

Precipitation hardening

Type XM-16 is the highest strength, highest hardness martensitic age-hardenable stainless steel available. The steel is relatively soft and formable in the annealed condition. It has good

corrosion resistance. A single-step aging treatment develops exceptionally high yield strength with good ductility and toughness. It can be hardened to approximately Rockwell C 50.

UNS S45500
Chemical Composition Limits
Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Cb+Ta	Ti
0.05	0.50	0.04	0.03	0.50	11.0	7.5	0.50	1.50	0.10	0.80
Max	Max	Max	Max	Max	12.5	9.5	Max	2.50	0.50	1.40

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension^a

<i>psi</i>	<i>MPa</i>
29.0 × 10 ⁶	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.280	7,760

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
906

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
No Data	

Thermal Conductivity

<i>Btu/ft·h/°F</i>	<i>W/m·K</i>
212°F 10.4	100°C 18.0
392°F 11.4	200°C 19.7
572°F 12.3	300°C 21.3
752°F 13.5	400°C 23.4
932°F 14.3	500°C 24.7

Mean Coefficient of Expansion

<i>in/in/°F</i>	<i>cm/cm/°C</i>
72-200°F 5.90 × 10 ⁻⁶	22-93°C 10.6 × 10 ⁻⁶
72-300°F 6.03 × 10 ⁻⁶	22-149°C 10.9 × 10 ⁻⁶
72-500°F 6.20 × 10 ⁻⁶	22-260°C 11.2 × 10 ⁻⁶
72-700°F 6.45 × 10 ⁻⁶	22-371°C 11.6 × 10 ⁻⁶
72-900°F 6.68 × 10 ⁻⁶	22-482°C 12.0 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2630-2645	1443-1451

Magnetic Permeability

H/m Annealed
Ferromagnetic

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1900-2100	1038-1149

Annealing

<i>°F</i>	<i>°C</i>
1500	816

Annealing

1/2 h at 1500°F and water quench.

Hardening

Heat solution-annealed material between 900 to 1050°F, hold for 4 h and air cool.

^aAs cold worked, the modulus is lowered. By stress relief heat treatment, the lowered modulus may be increased.

UNS S45500
MECHANICAL PROPERTIES

<i>Form and Condition</i>	<i>ASTM Specification</i>	<i>Tensile Strength ksi(MPa), Min</i>	<i>Yield Strength ksi(MPa), Min</i>	<i>Elongation %, Min</i>	<i>Reduction in Area %, Min</i>	<i>Hardness HB, Max HR, Max</i>	
Plate, Sheet & Strip	A693						
Solution treated (0.010 in [0.25 mm] and over)		175(1205)	160(1105)	3	—	331	C36
Condition 950							
Up to 0.02 in (0.51 mm)		222(1525)	205(1410)	—	—	—	C44 Min
Over 0.020 to 0.062 in (0.51 to 1.57 mm)		222(1525)	205(1410)	3	—	—	C44 Min
Over 0.062 in (1.57 mm)		222(1525)	205(1410)	4	—	—	C44 Min
Bars and Shapes	A564						
Solution Treated		—	—	—	—	331	C36
Condition H 900		235(1620)	220(1520)	8	30	444 Min	C47 Min
Condition H 950		220(1520)	205(1410)	10	40	415 Min	C44 Min
Condition H1000		205(1410)	1855(1280)	10	40	363 Min	C40 Min

This is a new dual-stabilized, 18% chromium ferritic stainless steel specifically designed for applications where temperatures or corrosive conditions are too severe for Type 409 stainless steel to be useful. By dual stabilizing with titanium and columbium, the alloy chemistry is balanced to provide a titanium level which is lower than that typically found in Type 439 (UNS S43035). This results in improved surface quality and reduced abrasiveness, which leads to a reduction in rates of die wear.

The alloy exhibits comparable general corrosion resistance, oxidation resistance, weldability, formability and thermophysical properties to Type 439. For elevated temperature service the alloy exhibits slightly higher strength and better resistance to creep than Type 439.

Excellent resistance to stress corrosion cracking, high temperature oxidation resistance, high thermal conductivity and low thermal expansion make the steel an ideal consideration for many applications, particularly those currently served by Type 439, including automotive exhaust system components.

UNS S46800

Chemical Composition Limits Cast or Heat Analysis, Percent

C	Mn	P	S	Si	Cr	Ni	Ti	Cb	N	Ti+Cb
0.030	1.00	0.040	0.030	1.00	<u>18.0</u>	0.50	<u>0.07</u>	<u>0.10</u>	0.030	<u>0.20+4(C+N)</u>
Max	Max	Max	Max	Max	20.0	Max	0.30	0.60	Max	0.80

Physical Properties in the Annealed Condition

Modulus of Elasticity in Tension

<i>psi</i>	<i>MPa</i>
29.0 × 10 ⁶	200,000

Density

<i>lb/in³</i>	<i>kg/m³</i>
0.278	7,695

Electrical Resistivity

<i>Microhm — mm 68°F (20°C)</i>
630

Specific Heat

<i>Btu/lb °F</i>	<i>kJ/kg·K</i>
32-212°F	0-100°C
0.12	0.50
0.13	

Thermal Conductivity

<i>Btu/ft·h·°F</i>	<i>W/m·K</i>
120°F 12.2	49°C 21.2
207°F 12.6	97°C 21.8
385°F 12.9	196°C 22.4
565°F 13.3	296°C 23.1
727°F 13.8	386°C 23.9
989°F 14.1	476°C 24.4
1039°F 14.3	559°C 24.8
1134°F 14.7	612°C 25.4

Mean Coefficient of Expansion

<i>in/in/°F × 10⁻⁶</i>	<i>cm/cm/°C</i>
68-122°F	5.5 × 10 ⁻⁶
68-212°F	5. × 10 ⁻⁶
68-392°F	5 × 10 ⁻⁶
68-752°F	6.5 × 10 ⁻⁶
68-1292°F	7.0 × 10 ⁻⁶

Melting Range

<i>°F</i>	<i>°C</i>
2600-2750	1425-1510

Thermal Treatment

Initial Forging

<i>°F</i>	<i>°C</i>
1900-2050	1040-1120

Annealing

<i>°F</i>	<i>°C</i>
1775-1875	970-1025

Annealing

Cool rapidly from these temperatures.

Hardening

Not hardenable by heat treatment

MECHANICAL PROPERTIES

Form and Condition	ASTM Specification	Tensile Strength ksi(MPa), Min	Yield Strength ksi(MPa), Min	Elongation %, Min	Reduction in Area %, Min	Hardness HB, Max HR, Max
Plate, Sheet & Strip	A240	60(415)	30(205)	22	—	— B90

SEMIFINISHED PRODUCTS: BLOOMS, BILLETS, SLABS AND RODS

Stainless steels are produced in the form of blooms, billets and slabs for forging or rerolling.

Stainless Steel Blooms and Billets. These are the products of blooming, billet, bar mills and continuous casting machines, as well as pressed or hammer forged products which are shipped without further work other than cutting to length or surface conditioning. These products are used for rerolling, forging or other processing into steel mill products: bars, rods, wire, etc. Bloom and billet size includes products 4 in.² (2,581 mm²) or larger. Billets are 16 to 36 in.² (10,323 to 22,226 mm²), squares or rectangles, with a width less than twice the thickness. Blooms are over 36 in.², squares or rectangles, with a width less than twice the thickness.

Stainless Steel Slabs and Sheet Bars. These are the products of a primary mill, such as blooming, slabbing or sheet bar mills or continuous or pressure casting machines which are shipped without further work other than cutting to length or surface conditioning. These products are used *only for rerolling* into sheet, strip or plate.

Rods. These are produced in the form of rounds, squares, octagons, hexagons and other shapes; in coils either as hot rolled or hot rolled and annealed for subsequent cold drawing or cold rolling.

Tube Rounds. These are produced in some of the stainless steels.

Size. The nominal cross-sectional dimensions of blooms, billets and slabs are designated in inches and fractions of an inch.

Tolerances for cross-sectional dimensions and corner radii are not appropriate for stainless steel blooms, billets and slabs because they are semifinished products.

Annealing. Blooms, billets and slabs of the 4xx series of stainless steel types which are highly hardenable, such as Types 414, 420, 420F, 422, 431, 440A, 440B and 440C, are annealed prior to shipment to avoid the possibility of thermal cracking. Other hardenable grades, such as Types 403, 410 and 416, may also require annealing, depending on their composition and size.

Cutting. In general, practice blooms, billets and slabs are cut to length by *hot shearing*. Other acceptable methods, such as hot sawing or flame cutting, are used depending upon the composition of the steel.

When the end distortion or burrs normally encountered in regular mill cutting methods are not satisfactory to the purchaser, end preparation can be performed by grinding or other means:

Machine Cut Lengths. Blooms, billets and slabs can be machine cut to length.

Cold Sawing. All stainless steels can also be cold-sawed, although some grades may require annealing before cold sawing.

Surface Conditioning and Testing. Blooms, billets, tube rounds and slabs for hot rolling, hot forging, hot extruding or hot piercing are surface-conditioned by grinding or turning. They can be tested for internal soundness by macroetch testing or ultrasonic inspection. For any one or more of these methods of testing or inspection, the procedures and the interpretation of results should be established in each instance.

BAR SIZE SHAPES, STRUCTURAL SHAPES, HOT EXTRUSIONS

Stainless steels are produced in angles, channels, tees or zees as hot rolled, hot rolled annealed or hot rolled annealed and blast cleaned, or chemically cleaned, or both. Tolerances for the foregoing products and for hot extrusions are shown in Tables 5-1 through 5-7.

Table 5-1

PERMISSIBLE VARIATIONS FOR HOT-FINISHED ANGLES

(ASTM A484/A484M)

NOTE—For unequal leg angles, the longer leg determines the tolerance for the length of each leg.

Weight:^A

For angles of 6 lb/ft [9.0 kg/m] or less, the weight tolerances shall not exceed $\pm 7\frac{1}{2}\%$. For angles over 6 lb/ft [9 kg/m], the weight tolerance shall not exceed $\pm 4\frac{1}{2}\%$.

Length of Legs:

For angles having legs or flanges up to 6 in. [150 mm], incl, the length tolerance shall not exceed $\pm \frac{1}{8}$ in. [3.00 mm]. For angles having legs or flanges over 6 in., the length tolerance shall not exceed $+\frac{3}{16}$ in. [5.00 mm] and $-\frac{1}{8}$ in.

Squareness of Legs:

The tolerance for the right angle between the legs is $\pm 2^\circ$.

^A For equal leg angles, the theoretical weight per foot is:

$$\text{Weight/foot} = (24 W \times t - 12t^2) (0.2871 \text{ lb/ft})$$

where W is the specified length of the leg, and t is the specified thickness, both in inches.

For unequal leg angles, the theoretical weight per foot is:

$$\text{Weight/foot} = [12 W_1 \times t + 12 W_2 \times t - 12t^2] (0.2871 \text{ lb/ft})$$

where W_1 and W_2 are the specified leg lengths, and t is the specified leg thickness, all in inches.

Table 5-2

PERMISSIBLE VARIATIONS IN SIZE OF HOT-FINISHED CHANNELS

(ASTM A484/A484M)

Specified Size of Channel, in. [mm]	Size Tolerances, Over and Under, in. [mm]				
	Depth of Section ^A	Width of Flanges	Thickness of Web for Thickness Given		Out-of-Square ^B of Either Flange, in./in. [mm/mm] of Flange Width
			To $\frac{3}{16}$ incl [5.00 mm]	Over $\frac{3}{16}$ [5.00 mm]	
To $1\frac{1}{2}$ [38.00], incl	$\frac{3}{64}$ [1.20]	$\frac{3}{64}$ [1.20]	0.015 [0.41]	0.023 [0.60]	$\frac{3}{64}$ [1.20]
Over $1\frac{1}{2}$ to 3 [38.00 to 75.00], excl	$\frac{3}{32}$ [2.40]	$\frac{3}{32}$ [2.40]	0.023 [0.60]	0.030 [0.80]	$\frac{3}{64}$ [1.20]

^A Channel depth is measured at back of web.

^B For channels $\frac{5}{8}$ in. [15.50 mm] and under in depth, the out-of-square tolerance is $\frac{5}{64}$ in./in. [2.00 mm/mm] of depth. Out-of-squareness is determined by placing a square against the bottom surface of the web and measuring the amount of toe-in or toe-out of either flange. Measurements for depth of section and width of flanges are over-all.

Table 5-3

PERMISSIBLE VARIATIONS IN SIZE OF HOT-FINISHED TEES

(ASTM A484/A484M)

Specified Size of Tee, in. [mm] ^A	Width or Depth, in.		Thickness of Flange, in. [mm]		Thickness of Stem, in. [mm]		Stem Out-of-Square ^C in. [mm]
	Over	Under	Over	Under	Over	Under	
To 1½ [38.00], incl.	⅜ [2.00]	⅜ [2.00]	0.015 [0.38]	0.015 [0.38]	0.008 [0.20]	0.030 [0.75]	⅜ [1.20]
Over 1½ to 2 [38.00 to 50.00], incl.	⅜ [2.40]	⅜ [2.40]	0.018 [0.46]	0.018 [0.46]	0.015 [0.38]	0.030 [0.75]	⅜ [2.40]
Over 2 to 3 [50.00 to 75.00], excl.	⅜ [3.60]	⅜ [3.60]	0.023 [0.60]	0.023 [0.60]	0.023 [0.60]	0.030 [0.75]	⅜ [3.60]

^A The longer member of an unequal tee determines the size for tolerances.^B Measurements for both width and depth are over-all.^C Stem out-of-square is the variation from its true position of the center line of stem measured at the point.

Table 5-4

PERMISSIBLE VARIATIONS IN SIZE OF HOT-EXTRUDED SHAPES

(ASTM A484/A484M)

Specified Size, in [mm]	Section Tolerances, in. [mm]	
	Over	Under
Dimensions under 1 [25]	0.020 [0.50]	0.020 [0.50]
Dimensions 1 to 3 [25 to 75], excl.	0.031 [0.80]	0.031 [0.80]
Dimensions 3 to 4 [75 to 100], incl.	0.046 [1.20]	0.046 [1.20]
Over 4 [100]	0.062 [1.60]	0.062 [1.60]

Table 5-5

ANGULARITY TOLERANCE FOR EXTRUDED SHAPES

(ASTM A484/A484M)

Plus and minus	max 2°
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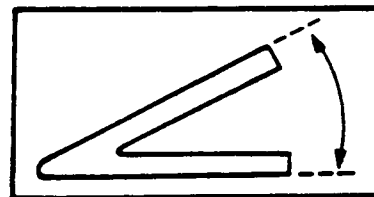


Table 5-6

LENGTH TOLERANCES FOR EXTRUDED SHAPE LENGTH^{A,B}

(ASTM A484/A484M)

Specified Size	For Lengths up to 12 ft [4 m], incl.		For Lengths over 12 ft [4 m]	
	Over	Under	Over	Under
Up to 3 in. [75 mm], excl.	⅜ in. [4.8 mm]	0	¼ in. [6.5 mm]	0

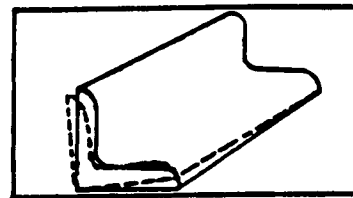
^A Multiple Lengths—Unless otherwise specified, ¼ in. [6.5 mm] is added to the total length of each piece for each multiple contained.^B Random Lengths—When ordered as random lengths, permissible variation is 2 ft [0.6 m] over and under the specified length. When ordered as random lengths subject to a minimum length requirement, permissible variation is 2 ft [0.6 m] over and nothing under the specified length.

Table 5-7

TWIST TOLERANCES

(ASTM A484/A484M)

NOTE—The amount of spiraling in an extruded shape is called twist. It can be measured by the height of the high corner from a flat reference base (established rise).

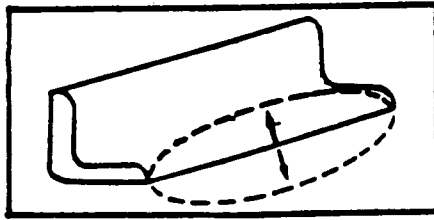


Using the following calculation, the twist tolerance must not exceed what is shown in the table.

$$\text{Rise in 5 ft.} = \frac{\text{established rise} \times \text{number of ft in length}}{5}$$

Section Width	Rise in 5 ft
½ in. [13 mm] to 1½ in. [39 mm]	0.125 in. [3.00 mm]
Over 1½ in. [39 mm] to 4 in. [100 mm]	0.188 in. [4.80 mm]
Over 4 in. [100 mm]	0.250 in. [6.50 mm]

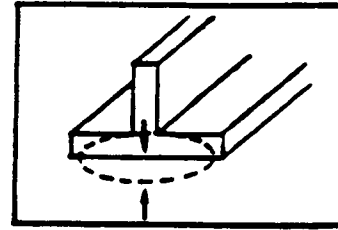
Fig. 8 Camber or Bow Tolerances
(ASTM A484/A484M)



Camber or bow tolerances shall not exceed 0.025 in. [0.60 mm] $\times$ length in ft $\left[\frac{m}{3}\right]$.

NOTE—Camber tolerances for hot finished or extruded shapes camber (or bow) is the greatest deviation of a side from a straight line. Measurement is taken on the concave side of the shapes with a straight edge.

Fig. 9 Transverse Flatness Tolerances
(ASTM A484/A484M)



Allowable deviation from flat is max 0.010 in. [0.25 mm] per 1 in. [25 mm] of width. Maximum deviation on dimensions of less than 1 in. [25 mm] is 0.010 in. [0.250 mm].

NOTE—The transverse flatness tolerance is the maximum deviation from a reference base across any cross-section flat surface.

6

HOT FINISHED BARS AND COLD FINISHED BARS

Many of the types of stainless steels are produced in the form of bars. They can be produced in a variety of cross sections, shapes, sizes and finishes. By definition,¹ bar products are produced in straight lengths. For coiled product, see rod and wire in Sections 4 and 10.

Hot finished bars are commonly produced by hot rolling, forging or pressing ingots to intermediate size blooms or billets, which are subsequently hot rolled, forged or extruded to final dimensions. The selection of rolling or forging or extruding as the finishing method depends on several factors including the composition of the steel and the final size.

Following hot rolling or forging, hot finished bars may be subject to various operations, including annealing or other heat treating, cleaning by pickling, blast cleaning or other methods of descaling, rough turning and machine straightening.

When only improved surface is required, as for bars intended for forging, bars can be turned or ground.

Cold finished bars are produced from hot finished bars by additional operations to give close tolerance, improved surface finish or mechanical properties.

Cold finished round bars are commonly machine straightened; after machine straightening they can be centerless ground, or centerless ground and polished. Centerless grinding or polishing does not essentially alter the mechanical properties of cold finished bars. Those treatments are used to give improved surface finish or tolerance only. Some increase in hardness, more marked at the surface, particularly in the 2xx and 3xx series stainless steel types, results from the machine straightening operation. The amount of this increase varies with composition, size and other factors.

Because of their shape, cold finished square, flat, hexagon, octagon and special shape bars are produced from hot finished bars commonly by cold drawing or cold rolling.

When cold finished bars are required to have higher strength and hardness, they are cold drawn or heat treated, depending upon the composition, section and properties indicated. Such bars, if round sections, can also be subjected to subsequent centerless grinding or centerless grinding and polishing.

Tolerances. Tolerances for size, width, thickness, length and straightness are given in Tables 6-2 to 6-11.

Size tolerances of hot finished bars produced by hot rolling are shown in Tables 6-2, 6-3 and 6-4. Size tolerances of hot finished bars produced by hot forging are not included in this manual section. Size tolerances for round forged bars, rough turned after forging, are shown in Table 6-2. Bars are produced to exact lengths, multiple lengths and random lengths.

Multiple Lengths. Bars which are to be parted by the purchaser can be produced in multiple lengths. For such lengths, $\frac{1}{4}$ in. (6.35 mm) is added to the length of each multiple to provide for parting.

Specific Lengths (Exact or Dead Lengths). Tolerances for specific lengths for hot rolled or cold finished bars are given in Table 6-9. When greater accuracy in length or freedom from end distortion is required, bars can be machine cut, after machine straightening, to the tolerances shown in Table 6-10.

Turning Allowances for Machine Straightened Round Bars. When bars are to be turned, allowances for finishing from hot rolled diameters of not less than the amounts shown in Table 6-1 are recommended.

Conditions and Surface Finishes. Stainless steel bars are produced in the following conditions and with the following surface finishes. It is important that the condition be associated with the appropriate finish because each finish is not applicable to every condition.

¹Straight lengths, regardless of size, are classified as bar product.

<i>Conditions</i>	<i>Surface Finishes^a</i>
1. Hot worked only	(a) Scale not removed (excluding spot conditioning) (b) Rough turned ^b (c) Descaled or blast cleaned and descaled
2. Annealed or otherwise heat treated	(a) Scale not removed (excluding spot conditioning) (b) Rough turned (c) Pickled or blast cleaned and pickled (d) Cold drawn or cold rolled (e) Centerless ground (f) Polished
3. Annealed and cold worked to high tensile strength	(d) Cold drawn or cold rolled (e) Centerless ground (f) Polished

^aSurface finishes (b), (e) and (f) are applicable to round bars only. ^bBars of the 4xx series stainless steels which are highly hardenable, such as Types 414, 420, 420F, 431, 440A, 440B and 440C, are annealed before rough turning. Other hardenable grades, such as Types 403, 410 and 416, may also require annealing depending on their composition and size.

Tolerances for bars having surface finishes (a), (b) and (c) are shown in Tables 6-2, 6-3 and 6-4. Tolerances for bars having surface finishes (d), (e) and (f) are shown in Tables 6-6, 6-7 and 7-8. Cold drawn or cold rolled bars can be annealed or otherwise heat treated and descaled after cold working. Cold finished bars produced in this way require larger tolerance limits, as shown in the footnotes of Tables 6-6, 6-7 and 6-8 because of metal loss in heat treating and cleaning.

Mechanical Properties and Tests. Bars in the heat treated or cold-worked condition can be produced with certain mechanical property values including tensile and hardness. In the full-annealed or cold-worked condition, a maximum or minimum hardness limit or tensile property limit or both, if consistent, can be developed for each grade. In the case of the martensitic chromium hardenable steels, produced in the hardened and tempered condition (heat treated), either maximum or minimum limits or both can be developed when the range is equivalent to or greater than a Brinell indentation diameter of at least three-tenths of a millimeter (for example, 4.0 to 4.3 mm) at an identified location. Brinell numbers are commonly used so that the diameter of the impression is in increments of 0.05 mm, as shown in ASTM A370, Mechanical Testing of Steel Products.

Straightening and Cutting. Stainless steel round bars and shape bars in straight lengths are produced in sizes about 0.031 to 0.750 in. (0.79 to 19.05 mm) inclusive by machine straightening and automatic cutting from coils. The straightening operation alters the mechanical properties, especially the tensile strength. The extent of the changes in mechanical properties depends on the alloy composition, initial properties before straightening and on the normal variations in the working, which the bar receives in the straightening operation. Bar in smaller sizes may require special mechanical setups and such product does not always compare favorably in straightness with machine cut bar of larger diameter.

Total length tolerance is shown in Table 6-9 for round bars which are not subject to further operations. If, after straightening and cutting, the cut length is then subjected to additional working, such as polishing or centerless grinding, the length of the small bars may have changed so that they no longer conform to that tolerance. Consequently, the length tolerance for such cut lengths should be established in each instance. Where exact lengths are required, they are obtained by reshearing cut bar, and can be produced to the tolerances shown in Table 6-10.

Centerless Grinding and Polishing. The grinding or grinding and polishing of stainless round bars is generally done for improvement of surface finish and dimensional tolerances, and the removal of surface imperfections. Tolerances for size and out-of-round of centerless ground and centerless ground and polished bar are shown in Table 10-8.

Free Machining Stock. This is produced for machining in automatic screw machines or other types of machining equipment. The principal types used are 303, 303Se, 416, 420F and 430F. The bar is commonly produced in straightened and cut lengths with a cold drawn or centerless ground finish, and with a hardness range appropriate for the machining operations involved.

Table 6-1

TURNING ALLOWANCES FOR MACHINE STRAIGHTENED ROUND BARS Stainless Steels

Nominal Diameter of Hot Rolled Bar, in. (mm)		Minimum Allowance on Diameter for Turning, in. (mm)	
Up to $\frac{3}{4}$	(19.05), incl.	1/16	(1.59)
Over $\frac{3}{4}$ to 1 $\frac{1}{2}$	(19.05 to 38.10), incl.	1/16	(1.59)
Over 1 $\frac{1}{2}$ to 2 $\frac{3}{4}$	(38.10 to 69.85), incl.	1/8	(3.18)
Over 2 $\frac{3}{4}$ to 4	(69.85 to 101.6), incl.	1/4	(6.35)
Over 4 to 5	(102 to 127), incl.	1/4	(6.35)
Over 5 to 6	(127 to 152), incl.	1/4 ^a	(6.35)
Over 6 to 8	(152 to 203), incl.	3/8 ^a	(9.53)
Over 8 to 10	(203 to 254), incl.	1/2 ^a	(12.70)

^aSome producers press the product on sizes over 5 $\frac{1}{2}$ in. (139.7 mm) and the producers should be consulted for allowances. It should be recognized that the amount of removal is affected by the out-of-round condition of the bar, surface roughness of the bar and straightness of the bar.

Table 6-2

PERMISSIBLE VARIATIONS IN SIZE OF HOT-FINISHED ROUND, TURNED,^b AND SQUARE BARS

(ASTM A484/A484M)

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm]		Out-of-Round ^a or Out-of-Square, ^b in. [mm]
	Over	Under	
$\frac{5}{16}$ to $\frac{7}{16}$ [8.00 to 11.00], incl. ^c	0.006 [0.15]	0.006 [0.15]	0.009 [0.23]
Over $\frac{7}{16}$ to $\frac{1}{2}$ [11.00 to 15.50], incl. ^c	0.007 [0.18]	0.007 [0.18]	0.010 [0.26]
Over $\frac{1}{2}$ to $\frac{3}{4}$ [15.50 to 22.00], incl.	0.008 [0.20]	0.008 [0.20]	0.012 [0.30]
Over $\frac{3}{4}$ to 1 [22.00 to 25.00], incl.	0.009 [0.23]	0.009 [0.23]	0.013 [0.34]
Over 1 to 1 $\frac{1}{8}$ [25.00 to 28.00], incl.	0.010 [0.25]	0.010 [0.25]	0.015 [0.38]
Over 1 $\frac{1}{8}$ to 1 $\frac{1}{4}$ [28.00 to 31.50], incl.	0.011 [0.28]	0.011 [0.28]	0.016 [0.42]
Over 1 $\frac{1}{4}$ to 1 $\frac{3}{8}$ [31.50 to 34.50], incl.	0.012 [0.30]	0.012 [0.30]	0.018 [0.46]
Over 1 $\frac{3}{8}$ to 1 $\frac{1}{2}$ [34.50 to 38.00], incl.	0.014 [0.35]	0.014 [0.35]	0.021 [0.53]
Over 1 $\frac{1}{2}$ to 2 [38.00 to 50.00], incl.	$\frac{1}{64}$ [0.40]	$\frac{1}{64}$ [0.40]	0.023 [0.60]
Over 2 to 2 $\frac{1}{2}$ [50.00 to 63.00], incl.	$\frac{1}{32}$ [0.80]	0	0.023 [0.60]
Over 2 $\frac{1}{2}$ to 3 $\frac{1}{2}$ [63.00 to 90.00], incl.	$\frac{3}{64}$ [1.20]	0	0.035 [0.90]
Over 3 $\frac{1}{2}$ to 4 $\frac{1}{2}$ [90.00 to 115.00], incl.	$\frac{1}{16}$ [1.60]	0	0.046 [1.20]
Over 4 $\frac{1}{2}$ to 5 $\frac{1}{2}$ [115.00 to 140.00], incl.	$\frac{5}{64}$ [2.00]	0	0.058 [1.50]
Over 5 $\frac{1}{2}$ to 6 $\frac{1}{2}$ [140.00 to 165.00], incl.	$\frac{1}{8}$ [3.00]	0	0.070 [1.80]
Over 6 $\frac{1}{2}$ to 8 [165.00 to 200.00], incl.	$\frac{5}{32}$ [4.00]	0	0.085 [2.20]
Over 8 to 12 [200.00 to 300.00], incl. ^d	$\frac{3}{16}$ [4.80]	0	$\frac{3}{32}$ [2.40]
Over 12 to 15 [300.00 to 400.00], incl. ^d	$\frac{7}{32}$ [5.50]	0	$\frac{7}{64}$ [2.80]
Over 15 to 25 [400.00 to 625.00], incl. ^d	$\frac{1}{4}$ [6.50]	0	$\frac{1}{8}$ [3.20]

^a Out-of-round is the difference between the maximum and minimum diameters of the bar measured at the same cross section.

^b Out-of-square section is the difference in the two dimensions at the same cross section of a square bar, each dimension being the distance between opposite faces.

^c Size tolerances have not been evolved for round sections in the size range of $\frac{5}{16}$ in. [8.00 mm] to approximately $\frac{1}{8}$ in. [15.5 mm] in diameter which are produced on rod mills in coils.

^d Turned bars are generally available from 2 to 25 in. [50 to 625 mm] in diameter, over 8 in. [200 mm] only turned bars are available.

Table 6-3

PERMISSIBLE VARIATIONS IN SIZE OF HOT-FINISHED HEXAGONAL AND OCTAGONAL BAR

(ASTM A484/A484M)

Specified Sizes Measured Between Opposite Sides, in. [mm]	Permissible Variations from Specified Size, in. [mm]		Maximum Difference in 3 Measurements for Hexagons Only, in. [mm]
	Over	Under	
$\frac{1}{4}$ to $\frac{1}{2}$ [6.50 to 13.00], incl.	0.007 [0.18]	0.007 [0.18]	0.011 [0.28]
Over $\frac{1}{2}$ to 1 [13.00 to 25.00], incl.	0.010 [0.25]	0.010 [0.25]	0.015 [0.38]
Over 1 to 1 $\frac{1}{2}$ [25.00 to 38.00], incl.	0.021 [0.53]	0.021 [0.53]	0.025 [0.64]
Over 1 $\frac{1}{2}$ to 2 [38.00 to 50.00], incl.	$\frac{1}{32}$ [0.80]	$\frac{1}{32}$ [0.80]	$\frac{1}{32}$ [0.80]
Over 2 to 2 $\frac{1}{2}$ [50.00 to 63.00], incl.	$\frac{3}{64}$ [1.20]	$\frac{3}{64}$ [1.20]	$\frac{3}{64}$ [1.20]
Over 2 $\frac{1}{2}$ to 3 $\frac{1}{2}$ [63.00 to 90.00], incl.	$\frac{1}{16}$ [1.60]	$\frac{1}{16}$ [1.60]	$\frac{1}{16}$ [1.60]

Table 6-4

PERMISSIBLE VARIATIONS IN THICKNESS AND WIDTH FOR HOT-FINISHED FLAT BARS ROLLED AS BARS

(ASTM A484/A484M)

Specified Width, in. [mm]	Permissible Variations in Thickness for Thicknesses Given, in. [mm]												Permissible Variations in Width, in, [mm]	
	1/8 to 1/2 [3.2 to 13], incl		Over 1/2 to 1 [13 to 25], incl		Over 1 to 2 [25 to 50], incl		Over 2 to 4 [50 to 100], incl		Over 4 to 6 [100 to 150], incl		Over 6 to 8 [150 to 200], incl			
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under		
To 1 [25.00], incl	0.008 [0.20]	0.008 [0.20]	0.010 [0.25]	0.010 [0.25]	...	...	...	...	...	...	...	...	0.015 [0.40]	0.015 [0.40]
Over 1 to 2 [25.00 to 50.00], incl	0.012 [0.30]	0.012 [0.30]	0.015 [0.40]	0.015 [0.40]	0.031 [0.80]	0.031 [0.80]	...	...	...	...	...	...	0.031 [0.80]	0.031 [0.80]
Over 2 to 4 [50.00 to 100.00], incl	0.015 [0.40]	0.015 [0.40]	0.020 [0.50]	0.020 [0.50]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	...	...	...	...	0.062 [1.60]	0.031 [0.80]
Over 4 to 6 [100.00 to 150.00], incl	0.015 [0.40]	0.015 [0.40]	0.020 [0.50]	0.020 [0.50]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	0.093 [2.40]	0.062 [1.60]	...	...	0.093 [2.40]	0.062 [1.60]
Over 6 to 8 [150.00 to 200.00], incl	0.016 [0.40]	0.016 [0.40]	0.025 [0.65]	0.025 [0.65]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	0.093 [2.40]	0.062 [1.60]	0.125 [3.20]	0.156 [4.00]	0.125 [3.20]	0.156 [4.00]
Over 8 to 10 [200.00 to 250.00], incl	0.020 [0.50]	0.020 [0.50]	0.031 [0.80]	0.031 [0.80]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	0.093 [2.40]	0.062 [1.60]	0.125 [3.20]	0.156 [4.00]	0.156 [4.00]	0.187 [4.80]

Table 6-5

PERMISSIBLE VARIATIONS IN DIMENSIONS FOR FLAT BARS CUT FROM STRIP OR PLATE

(ASTM A484/A484M)

Order Thickness	Permissible Variation in Thickness, in. [mm]		Permissible Variation ^A in Width				Permissible Variation in Length ^B	
	Over	Under	Widths to 4 [100]		Widths Over 4 [100]		Over	Under
			Over	Under	Over	Under		
Over 0.114 to 0.130 [2.90 to 3.30], incl	0.010 [0.25]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
Over 0.130 to 0.145 [3.30 to 3.70], incl	0.012 [0.30]	0.012 [0.30]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
Over 0.145 to less than 3/16, [3.70 to 4.80]	0.014 [0.35]	0.014 [0.35]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
3/16 to 3/8 [4.80 to 9.00], excl	0.050 [1.25]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
3/8 to 1/2 [9.00 to 19.00], excl	0.060 [1.50]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
1/2 to 1 [19.00 to 25.00], excl	0.065 [1.65]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
1 to 2 [25.00 to 50.00], excl	0.075 [1.90]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
2 to 3 [50.00 to 75.00], excl	0.150 [3.80]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
3 to 4 [75.00 to 100.00], excl	0.210 [5.30]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
4 to 6 [100.00 to 150.00], excl	0.300 [7.60]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
6 to 8 [150.00 to 200.00], excl	0.420 [10.65]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
8 to 10 [200.00 to 250.00], excl	0.540 [13.70]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0

^A By agreement between purchaser and seller, tolerances can be shifted as desired to any combination of plus-minus tolerance between all minus and all plus.^B Not applicable when bars are ordered random length.

Table 6-6

PERMISSIBLE VARIATIONS IN SIZE OF COLD-FINISHED ROUND BARS

(ASTM A484/A484M)

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm] ^{A,B}	
	Over	Under
1/16 to 1/8 [1.50 to 8.00], excl	0.001 [0.03]	0.001 [0.03]
1/8 to 1/2 [8.00 to 13.00], excl	0.0015 [0.04]	0.0015 [0.04]
1/2 to 1 [13.00 to 25.00], excl	0.002 [0.05]	0.002 [0.05]
1 to 1 1/2 [25.00 to 38.00], excl	0.0025 [0.06]	0.0025 [0.06]
1 1/2 to 4 [38.00 to 100.00], incl ^C	0.003 [0.08]	0.003 [0.08]

^A Unless otherwise specified, size tolerances are over and under as shown in the above table. When required, however, they may be specified all over and nothing under, or all under and nothing over, or any combination of over and under, if the total spread in size tolerance for a specified size is not less than the total spread shown in the table.

^B When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

^C Cold-finished bars over 4 in. [100 mm] in diameter are produced; size tolerances for such bars are not included herein.

Table 6-8

PERMISSIBLE VARIATIONS IN WIDTH AND THICKNESS OF COLD-FINISHED FLAT BARS

(ASTM A484/A484M)

Width, in. [mm]	Permissible Variations in Width, Over and Under, in. [mm] ^A	
	For Thicknesses 1/4 in. [6.5] and Under	For Thicknesses Over 1/4 in. [6.5]
1/16 to 1/8 [1.50 to 9.50], incl	0.005 [0.12]	0.005 [0.12]
Over 1/8 to 1 [9.50 to 25.00], incl	0.004 [0.10]	0.004 [0.10]
Over 1 to 2 [25.00 to 50.00], incl	0.006 [0.15]	0.004 [0.10]
Over 2 to 3 [50.00 to 75.00], incl	0.008 [0.20]	0.004 [0.10]
Over 3 to 4 1/2 [75.00 to 115.00], incl	0.010 [0.25]	0.005 [0.13]

Thickness, in. [mm]	Permissible Variations in Thickness, Over and Under, in. [mm] ^A
Up to .029 [0.70], incl	0.001 [0.03]
Over .029 to .035 [0.70 to 1.00], incl	0.0015 [0.04]
Over .035 to 1 [1.00 to 25.00], incl	0.002 [0.05]
Over 1 to 2 [25.00 to 50.00], incl	0.003 [0.08]
Over 2 to 3 [50.00 to 75.00], incl	0.004 [0.10]
Over 3 to 4 1/2 [75.00 to 115.00], incl ^B	0.005 [0.13]

^A When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

^B Cold-finished flat bars over 4 1/2 in. [115 mm] wide or thick are produced; width and thickness tolerances for such bars are not included herein.

Table 6-7

PERMISSIBLE VARIATIONS IN SIZE OF COLD-FINISHED HEXAGONAL, OCTAGONAL, AND SQUARE BARS

(ASTM A484/A484M)

Specified Size, ^A in. [mm]	Permissible Variations from Specified Size, in. [mm] ^B	
	Over	Under
1/16 to 1/8 [3.00 to 8.00], excl	0	0.002 [0.05]
1/8 to 1/2 [8.00 to 13.00], excl	0	0.003 [0.08]
1/2 to 1 [13.00 to 25.00], incl	0	0.004 [0.10]
Over 1 to 2 [25.00 to 50.00], incl	0	0.006 [0.15]
Over 2 to 3 [50.00 to 75.00], incl	0	0.008 [0.20]
Over 3 [75.00]	0	0.010 [0.25]

^A Distance across flats.

^B When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

Table 6-9

PERMISSIBLE VARIATIONS IN LENGTH OF HOT-FINISHED OR COLD-FINISHED BARS

(ASTM A484/A484M)

Specified Size of Rounds, Squares, Hexagons, Octagons, and Widths of Flats, ^B in. [mm]	Permissible Variations in Length, in. [mm] ^A			
	For Lengths up to 12 ft ^C [4 m], incl		For Lengths Over 12 to 25 ft [4 to 8 m], incl	
	Over	Under	Over	Under
Up to .500 [13.00], incl	1/16 [1.5]	0	1/8 [3.0]	0
Over .500 to 2 [13.00 to 50.00], incl	1/2 [13]	0	3/4 [19.0]	0
Over 2 to 4 [50.00 to 100.00], incl	3/4 [19]	0	1 [25.00]	0
Over 4 to 6 [100.00 to 150.00], incl	1 [25]	0	1 1/4 [31.50]	0
Over 6 to 9 [150.00 to 225.00], incl	1 1/4 [31.5]	0	1 1/2 [38.00]	0
Over 9 to 12 [225.00 to 300.00], incl	1 1/2 [38]	0	2 [50.00]	0

^A Random Lengths—When ordered as random lengths, permissible variation is 2 ft [0.6 m] over and under the specified length. When ordered as random lengths subject to a minimum length requirement, permissible variation is 2 ft [0.6 m] over and nothing under the specified length.

^B The maximum width of bar flats is 10 in. [250 mm].

^C For lengths under 3 ft [1 m] and sizes up to 1/2 in. [13.00 mm] incl., the permissible variation in length is 1/2 in. [0.80 mm] over and nothing under.

Table 6-10

**PERMISSIBLE VARIATIONS IN LENGTH OF
HOT-FINISHED OR COLD-FINISHED BARS
MACHINE CUT AFTER MACHINE
STRAIGHTENING**

(ASTM A484/A484M)

NOTE—These tolerances are not applicable when bars are ordered random length.

Specified Size of Rounds, Squares, Hexagons, Octa- gons, and Width of Flats, ^A in. [mm]	Permissible Variations in Length, in. [mm]			
	For Lengths up to 12 ft [4 m], incl		For Lengths Over 12 to 25 ft [4 to 8 m], incl	
	Over	Under	Over	Under
To 3 [75], incl	1/8 [3.0]	0	3/16 [4.8]	0
Over 3 to 6 [75 to 150], incl	3/16 [4.8]	0	1/4 [6.5]	0
Over 6 to 9 [150 to 225], incl	1/4 [6.5]	0	5/16 [8.0]	0
Over 9 to 12 [225 to 300], incl	1/2 [13.0]	0	1/2 [13.0]	0

^A The maximum width of bar flats is 10 in. [250 mm].

Table 6-11

**PERMISSIBLE VARIATIONS IN
STRAIGHTNESS OF MACHINE STRAIGHT-
ENED HOT-FINISHED OR COLD-FINISHED
BARS^A**

(ASTM A484/A484M)

Measurement is taken on the concave side of the bar with a straightedge. Unless otherwise specified, hot-finished or cold-finished bars for machining purposes are furnished machine straightened to the following tolerances:

Hot finished:

1/8 in. [3.00 mm] in any 5 ft [1.50 m]; but may not exceed
1/8 in. [3.00 mm] × (length in ft/5) [m/1.50]

Cold finished:

1/8 in. [1.5 mm] in any 5 ft [1.5 m]; but may not exceed
1/8 in. [1.5 mm] × (length in ft/5) [m/1.50]

^A Straightness tolerances have not been established for sizes less than 1/2 in. [6.50 mm].

PLATES

Stainless steel plates usually are produced by hot rolling from slabs, which have been directly cast or rolled from ingots and usually have been conditioned to improve plate surface. Some plates may be produced by direct rolling from the ingot. They are termed sheared plates or sheared mill plates when rolled between horizontal rolls and trimmed on all edges. They are termed universal plates or universal mill plates (abbreviation "U.M. plates") when rolled between horizontal and vertical rolls and trimmed on the ends.

Plates are generally produced in the annealed condition and are either blast cleaned or pickled. When blast cleaned, the plates are generally subjected to further cleaning in appropriate acids to remove possible contaminants such as iron.

This product finds widespread application in such industries as chemical, chemical processing, petroleum refining, synthetic rubber, paper, textile and industrial heating.

Designating Sizes. The greater of the two surface dimensions is generally considered the length. When direction of rolling is important, the dimension required as length should be definitely indicated.

Width and Length. Accuracy is promoted by indicating the widths and lengths of plate in inches or millimeters.

Thickness. Stainless steel plates are produced to thickness and not to weight-per-unit area.

Cutting. Plates can be cut by any of several methods, including shearing, flame cutting, abrasive cutting or machining. Square and rectangular plates up to 1 in. (25.4 mm) thick, inclusive, and shaped plates up to 5/8 in. (15.88 mm) thick, inclusive, usually are sheared to size.

The purchaser should include appropriate allowances for machining when ordering specific sizes of circles, rings and special cut pieces that are flame cut from plate.

Tolerances. Tolerances for thickness, width, length, diameter for circular plates, camber, flatness and torch cutting are given in Tables 7-1 to 7-8.

Producers' publications provide data for estimating plate weights.

ASTM and ASME Boiler Code specifications limit under thickness tolerance to 0.010 in. (0.25 mm); because of this limiting tolerance, plates are generally produced somewhat thicker than ordered, but within the over thickness tolerances shown in Table 7-1.

Plates over 2 in. (50.8 mm) thick often involve special consideration as to thickness allowances for machining; and such allowances should be established in each instance. Plates can be produced with mill edge and uncropped ends. The dimensional details of such plates should be established in each instance.

Conditions and Finishes. Stainless steel plates can be produced in the following conditions and surface finishes:

<i>Condition and Finish</i>	<i>Description and Remarks</i>
Hot or cold rolled	Scale not removed. Not heat treated. Plates not recommended for final use in this condition. ^a
Hot or cold rolled, annealed or heat treated	Scale not removed. Use of plates in this condition is generally confined to heat resisting applications. Scale impairs corrosion resistance. ^a
Hot or cold rolled, annealed or heat treated, blast cleaned and/or pickled	Condition and finish commonly preferred for corrosion resisting and most heat resisting applications.
Hot or cold rolled, annealed, descaled and temper passed	Smoother finish for specialized applications.
Hot or cold rolled, annealed, descaled, cold rolled, annealed, descaled, optionally temper passed	Smooth finish with greater freedom from surface imperfections than the above.
Hot or cold rolled, annealed or heat treated, surface cleaned and polished	Polished finishes.

^aSurface inspection is not practical on plates which have not been pickled or otherwise descaled.

Surface Conditioning. Plates are commonly conditioned by the producer for the removal of surface imperfections on either or both surfaces by grinding, provided the ground area is well flared and the grinding does not reduce the thickness below the thickness tolerance.

Table 7-1

PERMISSIBLE VARIATIONS IN THICKNESS FOR PLATES^{A,B}

(ASTM A480/A480M)

Specified Thickness, in. [mm]	Width, in. [mm]			
	To 84 [2134], incl	Over 84 [2134] to 120 [3048], incl	Over 120 [3048] to 144 [3658], incl	Over 144 [3658]
	Tolerance Over Specified Thickness, ^C in. [mm]			
3/16 [4.76] to 1/8 [9.52], excl	0.045 [1.14]	0.050 [1.27]	...	...
1/8 [9.52] to 1/4 [19.05], excl	0.055 [1.40]	0.060 [1.52]	0.075 [1.90]	0.090 [2.29]
1/4 [19.05] to 1 [254.0], excl	0.060 [1.52]	0.065 [1.65]	0.085 [2.16]	0.100 [2.54]
1 [25.40] to 2 [50.80], excl	0.070 [1.78]	0.075 [1.90]	0.095 [2.41]	0.115 [2.92]
2 [50.80] to 3 [76.20], excl	0.125 [3.18]	0.150 [3.81]	0.175 [4.44]	0.200 [5.08]
3 [76.20] to 4 [101.6], excl	0.175 [4.44]	0.210 [5.33]	0.245 [6.22]	0.280 [7.11]
4 [101.6] to 6 [152.4], excl	0.250 [6.35]	0.300 [7.62]	0.350 [8.89]	0.400 [10.16]
6 [152.4] to 8 [203.2], excl	0.350 [8.89]	0.420 [10.67]	0.490 [12.45]	0.560 [14.22]
8 [203.2] to 10 [254.0], excl	0.450 [11.43]	0.540 [13.72]	0.630 [16.00]	...

^A Thickness is measured along the longitudinal edges of the plate at least 3/16 in. [9.52 mm], but not more than 3 in. [76.20 mm], from the edge.^B For plates up to 10 in. [254.0 mm], excl, in thickness, the tolerance under the specified thickness is 0.010 in. [0.25 mm].^C For circles, the over thickness tolerances in this table apply to the diameter of the circle corresponding to the width ranges shown. For plates of irregular shape, the over thickness tolerances apply to the greatest width corresponding to the width ranges shown.

Table 7-2

PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR RECTANGULAR SHEARED MILL PLATES AND UNIVERSAL MILL PLATES

(ASTM A480/A480M)

Width, in. [mm]	Length, in. [mm]	Tolerances Over Specified Width and Length for Given Width, Length, and Thickness, ^A in. [mm]					
		Under 3/16 in. [9.52 mm] in Thickness		3/16 [9.52] to 1/2 [12.70 mm] in., incl, in Thickness		Over 1/2 [12.70 mm] to 1 in. [25.40 mm] in Thickness	
		Width	Length	Width	Length	Width	Length
48 [1219] and under	144 [3658] and under	3/16 [3.18]	3/16 [4.76]	3/16 [4.76]	1/4 [6.35]	3/16 [7.94]	3/16 [9.52]
Over 48 [1219] to 60 [1524], incl		3/16 [4.76]	1/4 [6.35]	1/4 [6.35]	3/16 [7.94]	3/16 [9.52]	7/16 [11.11]
Over 60 [1524] to 84 [2134], incl		1/4 [6.35]	3/16 [7.94]	3/16 [7.94]	3/16 [9.52]	7/16 [11.11]	1/2 [12.70]
Over 84 [2134] to 108 [2743], incl		3/16 [7.94]	3/16 [9.52]	3/16 [9.52]	7/16 [11.11]	1/2 [12.70]	3/16 [14.29]
Over 108 [2743]		3/16 [9.52]	7/16 [11.11]	7/16 [11.11]	1/2 [12.70]	3/16 [15.88]	1 1/16 [17.46]
48 [1219] and under	over 144 [3658] to 240 [6096]	3/16 [4.76]	3/16 [9.52]	1/4 [6.35]	1/2 [12.70]	3/16 [7.94]	3/16 [15.88]
Over 48 [1219] to 60 [1524], incl		1/4 [6.35]	7/16 [11.11]	3/16 [7.94]	3/16 [15.88]	3/16 [9.52]	3/4 [19.05]
Over 60 [1524] to 84 [2134], incl		3/16 [9.52]	1/2 [12.70]	7/16 [11.11]	1 1/16 [17.46]	1/2 [12.70]	3/4 [19.05]
Over 84 [2134] to 108 [2743], incl		7/16 [11.11]	3/16 [14.29]	1/2 [12.70]	3/4 [19.05]	3/16 [15.88]	7/8 [22.22]
Over 108 [2743]		1/2 [12.70]	3/16 [15.88]	3/16 [15.88]	7/8 [22.22]	1 1/16 [17.46]	1 [25.40]
48 [1219] and under	over 240 [6096] to 360 [9144]	1/4 [6.35]	1/2 [12.70]	3/16 [7.94]	3/16 [15.88]	3/16 [9.52]	3/4 [19.05]
Over 48 [1219] to 60 [1524], incl		3/16 [7.94]	3/16 [15.88]	3/16 [9.52]	3/4 [19.05]	1/2 [12.70]	3/4 [19.05]
Over 60 [1524] to 84 [2134], incl		7/16 [11.11]	1 1/16 [17.46]	1/2 [12.70]	3/4 [19.05]	3/16 [15.88]	7/8 [22.22]
Over 84 [2134] to 108 [2743], incl		3/16 [14.29]	3/4 [19.05]	3/16 [15.88]	7/8 [22.22]	3/4 [19.05]	1 [25.40]
Over 108 [2743]		3/16 [15.88]	7/8 [22.22]	1 1/16 [17.46]	1 [25.40]	7/8 [22.22]	1 [25.40]
60 [1524] and under	over 360 [9144] to 480 [12192]	7/16 [11.11]	1 1/8 [28.58]	1/2 [12.70]	1 1/4 [31.75]	3/16 [15.88]	1 3/8 [34.92]
Over 60 [1524] to 84 [2134], incl		1/2 [12.70]	1 1/4 [31.75]	3/16 [15.88]	1 3/8 [34.92]	3/4 [19.05]	1 1/2 [38.10]
Over 84 [2134] to 108 [2743], incl		3/16 [14.29]	1 1/4 [31.75]	3/4 [19.05]	1 3/8 [34.92]	7/8 [22.22]	1 1/2 [38.10]
Over 108 [2743]		3/4 [19.05]	1 3/8 [34.92]	7/8 [22.22]	1 1/2 [38.10]	1 [25.40]	1 3/8 [41.28]
60 [1524] and under	over 480 [12192] to 600 [15240]	7/16 [11.11]	1 1/4 [31.75]	1/2 [12.70]	1 1/2 [38.10]	3/16 [15.88]	1 3/8 [41.28]
Over 60 [1524] to 84 [2134], incl		1/2 [12.70]	1 3/8 [34.92]	3/16 [15.88]	1 1/2 [38.10]	3/4 [19.05]	1 3/8 [41.28]
Over 84 [2134] to 108 [2743], incl		3/16 [15.88]	1 3/8 [34.92]	3/4 [19.05]	1 1/2 [38.10]	7/8 [22.22]	1 3/8 [41.28]
Over 108 [2743]		3/4 [19.05]	1 1/2 [38.10]	7/8 [22.22]	1 3/8 [41.28]	1 [25.40]	1 3/8 [44.45]
60 [1524] and under	over 600 [15240]	1/2 [12.70]	1 3/4 [44.45]	3/16 [15.88]	1 7/8 [47.62]	3/4 [19.05]	1 7/8 [47.62]
Over 60 [1524] to 84 [2134], incl		3/16 [15.88]	1 3/4 [44.45]	3/4 [19.05]	1 7/8 [47.62]	7/8 [22.22]	1 7/8 [47.62]
Over 84 [2134] to 108 [2743], incl		3/16 [15.88]	1 3/4 [44.45]	3/4 [19.05]	1 7/8 [47.62]	7/8 [22.22]	1 7/8 [47.62]
Over 108 [2743]		7/8 [22.22]	1 3/4 [44.45]	1 [25.40]	2 [50.80]	1 3/8 [28.58]	2 1/4 [57.15]

^A The tolerance under specified width and length is 1/4 in. [6.35 mm].

Table 7-3

PERMISSIBLE VARIATIONS IN FLATNESS FOR ANNEALED PLATES

(ASTM A480/A480M)

NOTE 1—Tolerances in this table apply to plates up to 15 ft (4572 mm) in length, or to any 15 ft (4572 mm) of longer plates.

NOTE 2—If the longer dimension is under 36 in. [914 mm], the tolerance is not greater than 1/4 in. [6.35 mm].

NOTE 3—For plates with specified minimum yield strengths of 35 ksi [240 MPa] or more, and all steels of Specification A 693, the permissible variations are increased to 1 1/2 times the amounts shown below.

Specified Thickness, in. [mm]	Flatness Tolerance (Deviation from a Horizontal Flat Surface) for Thicknesses and Widths Given, in. [mm]								
	Width, in. [mm]								
	48 [1219] or Under	Over 48 [1219] to 60 [1524], excl	60 [1524] to 72 [1829], excl	72 [1829] to 84 [2134], excl	84 [2134] to 96 [2438], excl	96 [2438] to 108 [2743], excl	108 [2743] to 120 [3048], excl	120 [3048] to 144 [3658], excl	144 [3658] and Over
1/8 [4.76] to 1/4 [6.35], excl	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	...
1/4 [6.35] to 3/8 [9.52], excl	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	1/4 [19.05]	...
3/8 [9.52] to 1/2 [12.70], excl	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/4 [44.45]
1/2 [12.70] to 3/4 [19.05], excl	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/4 [44.45]
3/4 [19.05] to 1 [25.40], excl	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/4 [44.45]
1 [25.40] to 1 1/2 [38.10], excl	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/2 [12.70]	1/4 [44.45]
1 1/2 [38.10] to 4 [101.60], excl	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	1 [25.40]
4 [101.60] to 6 [152.40], excl	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	3/4 [19.05]	1 [25.40]

Table 7-4

WAVINESS TOLERANCES FOR PLATES

(ASTM A480/A480M)

NOTE—Waviness denotes the deviation of the top or bottom surface from a horizontal line contacting the surface, when the plate is resting on a flat surface, as measured in an increment of less than 15 ft [4.6 m] of length.

Tolerance, expressed as % of Table 19 Tolerance	Number of Waves in 15 ft (4.6 m)							
	1	2	3	4	5	6	7	8
	100	100	80	70	60	50	40	40

Table 7-5

PERMISSIBLE VARIATIONS IN CAMBER FOR SHEARED MILL AND UNIVERSAL MILL PLATES^A

(ASTM A480/A480M)

Maximum camber = 1/8 in. in any 5 ft
= 3.18 mm in any 1.524 m

^A Camber is the deviation of a side edge from a straight line, and measurement is taken by placing a 5-ft straightedge on the concave side and measuring the greatest distance between the plate and the straightedge.

Table 7-6

PERMISSIBLE VARIATIONS IN DIAMETER FOR CIRCULAR PLATES

(ASTM A480/A480M)

Specified Diameter, in. [mm]	Tolerance Over Specified Diameter for Given Diameter and Thickness, ^A in. [mm]		
	To 3/8 [9.52] in., excl in Thickness	3/8 [9.52] to 1/2 [12.70] in., excl in Thickness	1/2 [12.70] and Over in Thickness ^B
To 60 [1524], excl	1/4 [6.35]	3/8 [9.52]	1/2 [12.70]
60 [1524 mm] to 84 [2134 mm], excl	3/8 [9.52]	1/2 [12.70]	3/4 [19.05]
84 [2134 mm] to 108 [2743 mm], excl	3/8 [9.52]	1/2 [12.70]	3/4 [19.05]
108 [2743 mm] to 180 [4572 mm], excl	1/2 [12.70]	3/4 [19.05]	1/2 [12.70]

^A No tolerance under.^B Circular and sketch plates over 1/2 in. [12.70 mm] in thickness are not commonly sheared but are machined or flame cut.

Table 7-7

PERMISSIBLE VARIATIONS IN ABRASIVE CUTTING WIDTH AND LENGTH FOR PLATES

(ASTM A480/A480M)

Specified Thickness, in.	Tolerance, in.		Cleanup Allowance ^B per Edge, in.
	Outside Dimension	Inside Dimension	
2 and under	+3/8, -0	-3/8, +0	±1/4
Over 2 to 3 incl	+1/2, -0	-1/2, +0	±3/8
Over 3 to 6 incl	+3/4, -0	-3/4, +0	±1/2

^A Tolerances to apply unless otherwise agreed. Note that for some applications user may wish to specify minus rather than plus tolerance or vice versa.

^B Recommended cleanup allowance which, unless otherwise specified, will be applied by supplier to purchasers ordered size.

Table 7-8

TORCH CUTTING TOLERANCES^A AND RECOMMENDED CLEANUP ALLOWANCE FOR RECTANGULAR PLATES, CIRCLES, RINGS, AND SKETCHES

(ASTM A480/A480M)

Specified Thickness, in. [mm]	Tolerance over Specified Width and Length ^A	
	Width	Length
Up to 1 [25.40], incl	1/8 [3.18]	1/8 [3.18]
1 [25.40] to 2 [50.80], incl	3/16 [4.76]	3/16 [4.76]
2 [50.80] to 3 [76.20], incl	1/4 [6.35]	1/4 [6.35]
3 [76.20] to 4 [101.6], incl ^B	5/16 [7.94]	5/16 [7.94]

^A The tolerances under specified width and length are 1/8 in. [3.18 mm].

^B Width and length tolerances for abrasive cut plates over 4 in. [101.6 mm] thick are not included in the table; consult producer.

SHEETS — HOT ROLLED AND COLD ROLLED

The production of stainless steel sheets commonly involves conversion of slabs (hot rolled or forged from ingots or cast into slab form) into hot rolled coils called hot bands. Alternatively, slabs or sheet bars may be hot rolled directly to sheet product on hand mills. Hot band or hand mill sheet is further processed by annealing, descaling and cold rolling to specified thickness, then final annealing and descaling. Coils or lengths cut from coils may then be subjected to light cold rolling for finish on dull or bright rolls. Cut lengths can be flattened by roller leveling or stretcher leveling.

Sheet Finishes.¹ Distinctions are made in the finishes of stainless steel sheets by a system of numbers; the rolled finishes being No. 1, No. 2D and No. 2B, and the polished finishes being No. 3, No. 4, No. 6, No. 7 and No. 8. They are described broadly by the finishing operations employed in their manufacture. However, each of the rolled finishes is in itself a category of finishes, with variations in appearance and smoothness depending upon the composition, thickness and method of manufacture. Generally, the thinner the sheet, the smoother the surface. The chromium-nickel and chromium-nickel-manganese compositions have a characteristically different appearance than the straight chromium types for a corresponding finish. Further, sheets produced continuously (in coil form) generally differ from the product of hand mills.

The appearance or "color" of the ground and polished finishes, No. 3, No. 4, No. 6, No. 7 and No. 8, may differ slightly among the 2xx, 3xx and 4xx series of stainless steel types.

Because of the foregoing, as well as the importance of visual evaluation in the selection of finishes where finish or ability to be polished is important for new applications, consultation and examination of representative finishes with producers is recommended.

¹This is applicable to widths in the unpolished finishes rolled 24 in. (610 mm) and wider and any widths in the polished finishes. For description of finishes for cold rolled strip (product less than 24 in. (610 mm) wide), see Section 10. No. 2D and No. 2B finishes for sheet approximate, respectively, No. 1 and No. 2 finishes for strip in the corresponding chromium-nickel or chromium-nickel-manganese types.

The practicability of describing any of the finishes in terms of measured limits, such as for smoothness or reflectance, has not been established.

See "Cold Rolled Tempers" below for finish of sheets produced in cold rolled tempers.

Rolled Finishes

No. 1 Finish. This is a hot rolled, annealed and descaled finish, produced by hot rolling followed by annealing and descaling.

It is generally used in industrial applications, such as for heat or corrosion resistance, where smoothness of finish is not of particular importance.

No. 2D Finish. This is a dull cold rolled finish produced by cold rolling, annealing and descaling. The dull finish may result from the descaling or pickling operation, or may be developed by a final light cold roll pass on dull rolls. The dull finish is favorable for the retention of lubricants on the surface in deep drawing operations.

This finish is generally used in forming deep drawn articles which may be polished after fabrication.

No. 2B Finish. This is a bright cold rolled finish commonly produced in the same manner as No. 2D, except that the annealed and descaled sheet receives a final light cold rolled pass on polished rolls.

This is a general purpose cold rolled finish. It is commonly used for all but exceptionally difficult deep drawing applications. This finish is more readily polished than a No. 1 or No. 2D finish.

Polished Finishes

Sheets can be produced with one or two sides polished. When polished on one side only, the other side may be rough ground in order to obtain the necessary flatness.

No. 3 Finish. This is a polished finish obtained with abrasives approximately 100 mesh, and which may or may not be additionally polished during fabrication.

No. 4 Finish. This is a general purpose, polished finish widely used for restaurant equipment, kitchen equipment, store fronts, dairy equipment, etc. Following initial grinding with coarser abrasives, sheets are generally finished last with abrasives approximately 120 to 150 mesh.

No. 6 Finish. This is a dull satin finish having lower reflectivity than a No. 4 finish. It is produced by Tampico brushing No. 4 finish sheets in a medium of abrasives and oil.

It is used for architectural applications and ornamentation where a high luster is undesirable; it is also used effectively to contrast with brighter finishes.

No. 7 Finish. This has a high degree of reflectivity. It is produced by buffing of a finely ground surface, but the grit lines are not removed. It is chiefly used for architectural and ornamental purposes.

No. 8 Finish. This is the most reflective finish that is commonly produced. It is obtained by polishing with successively finer abrasives and buffing extensively with very fine buffing rouges. The surface is essentially free of grit lines from preliminary grinding operations. This finish is most widely used for press plates, as well as for small mirrors and reflectors.

Cold Rolled Tempers. Minimum tensile strength or yield strength or hardness higher than that normally obtained on sheets in the annealed condition, or a combination of those properties, can be attained. Tempers are based on minimum values for tensile strength or yield strength, or both.

Chromium-nickel and chromium-nickel-manganese, high tensile sheets (usually Types 301 and 201) are produced in the following tempers:

Temper	Tensile Strength Min		Yield Strength Min	
	ksi	MPa	ksi	MPa
¼ hard	125	862	75	517
½ hard	150	1,034	110	758
¾ hard	175	1,207	135	931
Full hard	185	1,276	140	965

Tension and bend test specimens are normally taken in the direction transverse to the rolling direction. Refer to Figure 10.

The finish of sheets produced in each cold rolled temper is that obtained by the cold rolling necessary to develop the required mechanical properties.

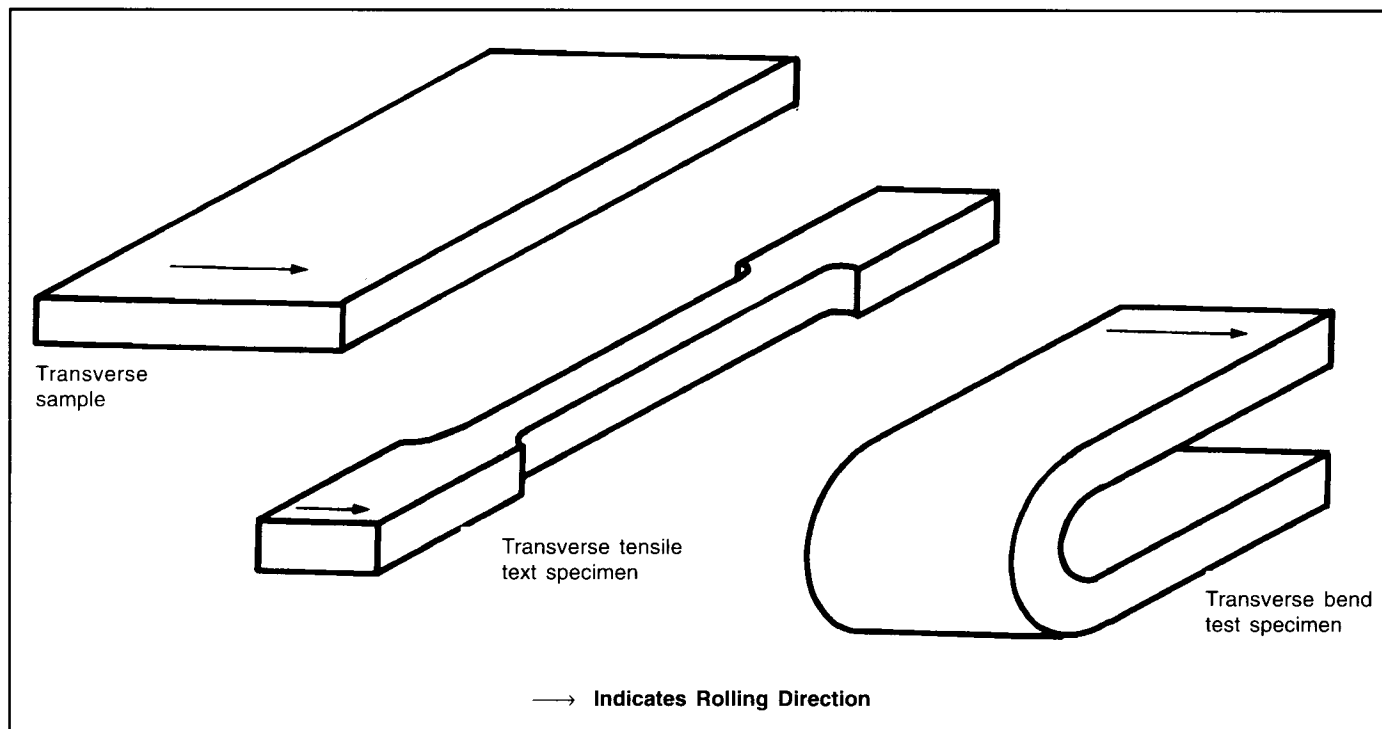


Fig. 10 - Transverse test specimens.

Designating Sizes. The greater of the two surface dimensions is generally considered length. When the direction of rolling is important, the dimension required as length should definitely be indicated.

Width and Length. Accuracy is promoted by indicating the widths and lengths in inches or millimeters.

Thickness. It is common practice to indicate the thickness of sheets by decimal parts of an inch or millimeter.

Weight. It is not practicable to produce rolled and cold rolled heats to exact theoretical weight, as weight is affected by dimensions and dimensional tolerances.

For determining estimated weights, the following factors are used.

Stainless steel sheets:

Chromium-Manganese-Nickel	41 lb/ft ² /in. (7.9 kg/m ² /mm) thickness
Chromium-Nickel	41 lb/ft ² /in. (7.9 kg/m ² /mm) thickness
Chromium	40 lb/ft ² /in. (7.7 kg/m ² /mm) thickness

Table 8-1

PERMISSIBLE VARIATIONS IN THICKNESS FOR HOT-ROLLED SHEET IN CUT LENGTHS, COLD-ROLLED SHEET IN CUT LENGTHS AND COILS

(ASTM A480/A480M)

Specified Thickness, ^a in. [mm]	Permissible Variations, Over and Under ^b	
	in.	mm
Over 0.145 [3.68] to less than 3/16 [4.76]	0.014	0.36
Over 0.130 [3.30] to 0.145 [3.68], incl	0.012	0.30
Over 0.114 [2.90] to 0.130 [3.30], incl	0.010	0.25
Over 0.098 [2.49] to 0.114 [2.90], incl	0.009	0.23
Over 0.083 [2.11] to 0.098 [2.49], incl	0.008	0.20
Over 0.072 [1.83] to 0.083 [2.11], incl	0.007	0.18
Over 0.058 [1.47] to 0.072 [1.83], incl	0.006	0.15
Over 0.040 [1.02] to 0.058 [1.47], incl	0.005	0.13
Over 0.026 [0.66] to 0.040 [1.02], incl	0.004	0.10
Over 0.016 [0.41] to 0.026 [0.66], incl	0.003	0.08
Over 0.007 [0.18] to 0.016 [0.41], incl	0.002	0.05
Over 0.005 [0.13] to 0.007 [0.18], incl	0.0015	0.04
0.005 [0.13]	0.001	0.03

^a Thickness measurements are taken at least 3/16 in. [9.52 mm] from the edge of the sheet.

^b Cold-rolled sheets in cut lengths and coils are produced in some type numbers and some widths and thickness to tolerances less than those shown in the table.

Dimensional Tolerances. Accuracy of dimensions is influenced by many factors such as mill design, heating practice, reduction between passes, roll wear, roll pressure and composition of steel. The cumulative effect of those, as well as other factors, preclude rolling sheets to exact ordered size and thickness and requires that provisions be made for tolerances.

Tolerances for thickness, width, length, camber, flatness for sheets and diameter of sheared circles are given in Tables 8-1 through 8-10.

Tolerances for annealed sheets, when produced in coils and slit to width and cut to length, are shown in Tables 8-4, 8-5 and 8-6.

Flatness tolerances for stainless and heat resisting steel sheets in coil form are not appropriate.

Table 8-1 shows thickness tolerances that reasonably can be expected regardless of the above factors. If required, closer tolerances should be established in each instance.

Table 8-2

PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR HOT-ROLLED AND COLD-ROLLED RESQUARED SHEETS (STRETCHER LEVELED STANDARD OF FLATNESS)

(ASTM A480/A480M)

NOTE—Polished sheets with Finishes No. 4 and higher are produced to tolerances given in this table.

Specified Dimensions, in. [mm]	Tolerances		
	Over		Under
	in.	mm	
For thicknesses under 0.131 [3.33]:			
Widths up to 48 [1219] excl	1/16	1.59	0
Widths 48 [1219] and over	1/8	3.18	0
Lengths up to 120 [3048] excl	1/16	1.59	0
Lengths 120 [3048] and over	1/8	3.18	0
For thicknesses 0.131 [3.33] and over:			
All widths and lengths	1/4	6.35	0

Table 8-3

**PERMISSIBLE VARIATIONS IN WEIGHT
FOR HOT-ROLLED AND COLD-ROLLED
SHEETS**

(ASTM A480/A480M)

Any item of five sheets or less, or any item estimated to weigh 200 lb [90.72 kg] or less, may actually weigh as much as 10 % over the theoretical weight	weigh 200 lb [90.72 kg] or less
Any item of more than five sheets and estimated to weigh more than 200 lb [90.72 kg], may actually weigh as much as 7½ % over the theoretical weight	weigh more than 200 lb [90.72 kg]
Chromium-manganese-nickel	40.7 lb/ft ² ·in. thickness [7.82 kg/m ² ·mm thick]
Chromium-nickel	42.0 lb/ft ² ·in. thickness [8.07 kg/m ² ·mm thick]
Chromium	41.2 lb/ft ² ·in. thickness [7.92 kg/m ² ·mm thick]

Table 8-5

**PERMISSIBLE VARIATIONS IN LENGTH
FOR HOT-ROLLED AND COLD-ROLLED
SHEETS NOT RESQUARED**

(ASTM A480/A480M)

Length, ft [mm]	Tolerances, in. [mm]
Up to 10 [3048], incl	¼ [6.35] over, 0
Over 10 [3048] to 20 [6096], incl	½ [12.70] over, 0 under

Table 8-7

**PERMISSIBLE VARIATIONS IN FLATNESS
FOR HOT-ROLLED AND COLD-ROLLED
SHEETS SPECIFIED TO STRETCHER-
LEVELED STANDARD OF FLATNESS (NOT
INCLUDING HARD TEMPER OF 2XX AND
3XX SERIES)**

(ASTM A480/A480M)

Specified Thickness, in. [mm]	Width, in. [mm]	Length, in. [mm]	Flatness Tolerance, ^A in. [mm]
Under ⅜ [4.76]	to 48 [1219], incl	to 96 [2438], incl	⅜ [3.18]
Under ⅜ [4.76]	to 48 [1219], incl	over 96 [2438]	¼ [6.35]
Under ⅜ [4.76]	over 48 [1219]	to 96 [2438], incl	¼ [6.35]
Under ⅜ [4.76]	over 48 [1219]	over 96 [2438]	¼ [6.35]

^A Maximum deviation from a horizontal flat surface.

Table 8-4

**PERMISSIBLE VARIATIONS IN WIDTH FOR
HOT-ROLLED AND COLD-ROLLED
SHEETS NOT RESQUARED AND COLD-
ROLLED COILS**

(ASTM A480/A480M)

Specified Thickness, in. [mm]	Tolerances for Specified Width, in. [mm]	
	24 [610] to 48 [1219], excl	48 [1219] and Over
Less than ⅜ [4.76]	⅜ [1.59] over, 0 under	⅜ [3.18] over, 0 under

Table 8-6

**PERMISSIBLE VARIATIONS IN CAMBER
FOR HOT-ROLLED AND COLD-ROLLED
SHEETS NOT RESQUARED AND COLD-
ROLLED COILS^A**

(ASTM A480/A480M)

Specified Width, in. [mm]	Tolerance per Unit Length of Any 8 ft [2438 mm], in. [mm]
24 [610] to 36 [914], incl	⅜ [3.18]
Over 36 [914]	⅝ [2.38]

^A Camber is the greatest deviation of a side edge from a straight line and measurement is taken by placing an 8-ft [2438-mm] straightedge on the concave side and measuring the greatest distance between the sheet edge and the straightedge.

Table 8-8

**PERMISSIBLE VARIATIONS IN FLATNESS
FOR HOT-ROLLED AND COLD-ROLLED
SHEETS NOT SPECIFIED TO
STRETCHER-LEVELED STANDARD OF
FLATNESS (NOT INCLUDING HARD TEM-
PERS OF 2XX AND 3XX SERIES, DEAD-
SOFT SHEETS AND DEEP-DRAWING
SHEETS)**

(ASTM A480/A480M)

Specified Thickness, in. [mm]	Width, in. [mm]	Flatness Tolerance, ^A in. [mm]
0.062 [1.57] and over	to 60 [1524], incl over 60 [1524] to 72 [1829], incl over 72 [1829]	½ [12.70] ¾ [19.05] 1 [25.40]
Under 0.062 [1.57]	to 36 [914], incl over 36 [914] to 60 [1524], incl over 60 [1524]	½ [12.70] ¾ [19.05] 1 [25.40]

^A Maximum deviation from a horizontal flat surface.

Table 8-9

PERMISSIBLE VARIATIONS IN FLATNESS FOR COLD-ROLLED SHEETS OF 2XX AND 3XX SERIES SPECIFIED TO ¼ AND ½ HARD TEMPER

(ASTM A480/A480M)

Specified Thickness, in. [mm]	Width, in. [mm]	Flatness Tolerance, ^A in. [mm]	
		¼ Hard	½ Hard
0.016 [0.41] and under	24 [610] to 36 [914], excl	½ [12.70]	¾ [19.05]
Over 0.016 [0.41] to 0.030 [0.76], incl		¾ [15.88]	1 [22.22]
Over 0.030 [0.76]		1 [19.05]	1 ½ [22.22]
0.016 [0.41] and under	36 [914] to 48 [1219], incl	¾ [15.88]	1 [25.40]
Over 0.016 [0.41] to 0.030 [0.76], incl		1 [19.05]	1 ½ [28.58]
Over 0.030 [0.76]		1 ½ [25.40]	2 [28.58]

^A Maximum deviation from a horizontal flat surface.

Table 8-10

PERMISSIBLE VARIATIONS IN DIAMETER FOR HOT-ROLLED AND COLD-ROLLED SHEETS, SHEARED CIRCLES

(ASTM A480/A480M)

Specified Thickness, in. [mm]	Tolerance Over Specified Diameter (No Tolerance Under), in. [mm]		
	Diameters Under 30 in. [762]	Diameters 30 [762] to 48 in. [1219]	Diameters Over 48 in. [1219]
0.0972 [2.46] and thicker	¼ [3.18]	¼ [4.76]	¼ [6.35]
0.0971 [2.46] to 0.0568 [1.45], incl	⅜ [2.38]	⅜ [3.97]	⅜ [5.56]
0.0567 [1.45] and thinner	½ [1.59]	½ [3.18]	¾ [4.76]

STRIP AND FOIL — COLD ROLLED

Cold Rolled Strip

Cold rolled stainless steel strip is manufactured from hot rolled, annealed and pickled strip by cold rolling on polished rolls. Depending on the thickness desired, the cold rolling requires various numbers of passes through the mill to effect the necessary reduction and to secure the desired surface characteristics and mechanical properties.

Hot rolled stainless steel strip is a semifinished product obtained from the hot rolling of slabs or billets and is produced for conversion by cold rolling.

Designating Sizes. The greater of the two surface dimensions is generally considered length. When direction of rolling is important, the dimension required as length should be definitely indicated.

Tolerances. Tolerances for thickness, crown, width, length and camber are given in Tables 9-1 to 9-5.

Edges. Cold rolled strip is commonly produced with an as-slit edge (No. 3 edge). Other types of edges are described below:

- No. 1 either round or square as specified, produced by rolling or filing
- No. 3 edge is an edge produced by slitting
- No. 5 edge is an approximately square edge produced by rolling or filing after slitting.

Cold Rolled Strip Finishes.¹ The two finishes for stainless cold rolled strip are No. 1 and No. 2. They are described broadly by the finishing operations employed in their manufacture. However, each in itself is a category of finishes, with variations in appearance and smoothness, depending upon composition, thickness and method of manufacture. Generally, the thinner the strip, the smoother the surface. The chromium-nickel and chromium-nickel-manganese

compositions have a characteristically different appearance than the straight chromium types for a corresponding finish.

Consultation with producers and examination of representative finishes are recommended because of the foregoing, as well as the importance of visual evaluation in the selection of finishes when finish is important for new applications.

No. 1 Finish. Cold rolled, annealed and pickled. Appearance varies from a dull gray matte finish to a fairly reflective surface, depending largely upon composition. This finish is used for severely drawn or formed parts, as well as for applications where the brighter No. 2 finish is not required, such as in parts for heat resistance.

No. 2 Finish. This treatment is the same as the No. 1 finish followed by a final light cold rolled pass, generally on highly polished rolls. This light pass produces a smoother and more reflective surface, the appearance of which varies with composition. This is a general purpose finish, widely used for household and automotive trim, tableware, utensils, trays, etc.

Bright Annealed Finish. This is a bright cold rolled, highly reflective finish retained by final annealing in a controlled atmosphere furnace. The purpose of the atmosphere is to prevent scaling or oxidation during annealing. The atmosphere usually comprises either dry hydrogen or a mixture of dry hydrogen and dry nitrogen (sometimes known as dissociated ammonia). The finish has its largest application in strip widths for automotive trim.

Mill-Buffered Finish. This is a bright cold rolled, highly reflective finish obtained on either the No. 2 finish or on bright annealed strip by continuously buffing in coil form. The purpose of mill-buffing is to provide a uniform finish with regard to color and reflectivity. It can also provide a surface receptive to chromium plating. The finish has wide use in automotive trim, household trim, tableware, utensils, fire extinguishers, plumbing fixtures, etc.

¹Applicable to widths less than 24 in. (610 mm). For a description of cold rolled sheet finishes (product 24 in. (609.6 mm) and wider), and polished sheet finishes, see Section 9. No. 1 and No. 2 finishes for strip approximate, respectively, No. 2D and No. 2B finishes for sheet in the corresponding chromium-nickel or chromium-nickel-manganese types.

Conditions and Tempers. All types of stainless steel strip are commonly produced in either the soft annealed condition or annealed and skin passed temper, depending on requirements. When severe forming, bending and drawing operations are involved, it is recommended that such requirements be indicated as a guide in the application of the proper type and condition. When stretcher strains are objectionable in ferritic types such as Type 430, they can be minimized by the use of a No. 2 finish. Cold rolled strip in Types 410, 414, 420, 431, 440A, 501, and 502 can be produced in the hardened and tempered condition.

Chromium-nickel and chromium-nickel-manganese, high tensile cold rolled strip (usually

Types 301 and 201) is produced in the following tempers:

Temper	Tensile Strength, Min		Yield Strength, Min	
	ksi	MPa	ksi	MPa
1/4 hard	125	862	75	517
1/2 hard	150	1,034	110	758
3/4 hard	175	1,207	135	931
Full hard	185	1,276	140	965

Tempers are based on minimum values for tensile strength or yield strength or both.

Lengths. Cold rolled stainless steel strip is available in coils or cut lengths. Length tolerances for cut length strip are shown in Table 9-4.

Table 9-1

PERMISSIBLE VARIATIONS IN THICKNESS FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS

(ASTM A480/A480M)

NOTE 1—Thickness measurements are taken at least $\frac{3}{16}$ in. [9.52 mm] in from the edge of the strip, except on widths less than 1 in. [25.4 mm] the measurements should be taken at least $\frac{1}{8}$ in. [3.18 mm] from the strip edge.

NOTE 2—The tolerance in this table include crown tolerances.

Specified Thickness, in. [mm]	Thickness Tolerances, for the Thickness and Widths Given, Over and Under, in. [mm]		
	Width, in. [mm]		
	$\frac{3}{16}$ [4.76] to 6 [152], incl	Over 6 [152] to 12 [305], incl	Over 12 [305] to 24 [610], excl
Thickness Tolerances ^A			
0.005 [0.13] to 0.010 [0.25], incl	10 %	10 %	10 %
Over 0.010 [0.25] to 0.011 [0.28], incl	0.0015 [0.04]	0.0015 [0.04]	0.0015 [0.04]
Over 0.011 [0.28] to 0.013 [0.33], incl	0.0015 [0.04]	0.0015 [0.04]	0.002 [0.05]
Over 0.013 [0.33] to 0.017 [0.43], incl	0.0015 [0.04]	0.002 [0.05]	0.002 [0.05]
Over 0.017 [0.43] to 0.020 [0.51], incl	0.0015 [0.04]	0.002 [0.05]	0.0025 [0.06]
Over 0.020 [0.51] to 0.029 [0.74], incl	0.002 [0.05]	0.0025 [0.06]	0.0025 [0.06]
Over 0.029 [0.74] to 0.035 [0.89], incl	0.002 [0.05]	0.003 [0.08]	0.003 [0.08]
Over 0.035 [0.89] to 0.050 [1.27], incl	0.0025 [0.06]	0.0035 [0.09]	0.0035 [0.09]
Over 0.050 [1.27] to 0.069 [1.75], incl	0.003 [0.08]	0.0035 [0.09]	0.0035 [0.09]
Over 0.069 [1.75] to 0.100 [2.54], incl	0.003 [0.08]	0.004 [0.10]	0.005 [0.13]
Over 0.100 [2.54] to 0.125 [2.98], incl	0.004 [0.10]	0.0045 [0.11]	0.005 [0.13]
Over 0.125 [2.98] to 0.161 [4.09], incl	0.0045 [0.11]	0.0045 [0.11]	0.005 [0.13]
Over 0.161 [4.09] to under $\frac{3}{16}$ [4.76]	0.005 [0.13]	0.005 [0.13]	0.006 [0.15]

^A Thickness tolerances given in in. [mm] unless otherwise indicated.

Table 9-2

PERMISSIBLE VARIATIONS IN WIDTH FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS FOR EDGE NOS. 1 AND 5

(ASTM A480/A480M)

Specified Edge No.	Width, in. [mm]	Thickness, in. [mm]	Width Tolerance for Thickness and Width Given, in. [mm]	
			Over	Under
1 and 5	$\frac{3}{32}$ [7.14] and under	$\frac{1}{16}$ [1.59] and under	0.005 [0.13]	0.005 [0.13]
1 and 5	over $\frac{3}{32}$ [7.14] to $\frac{1}{4}$ [19.05], incl	$\frac{3}{32}$ [2.38] and under	0.005 [0.13]	0.005 [0.13]
1 and 5	over $\frac{1}{4}$ [19.05] to 5 [127], incl	$\frac{1}{8}$ [3.18] and under	0.005 [0.13]	0.005 [0.13]
5	over 5 [127.00] to 9 [228.60], incl	$\frac{1}{8}$ [3.18] to 0.008 [0.20], incl	0.010 [0.25]	0.010 [0.25]
5	over 9 [228.60] to 20 [508.00], incl	0.105 [2.67] to 0.015 [0.38]	0.010 [0.25]	0.010 [0.25]
5	over 20 [508.00]	0.080 [2.03] to 0.023 [0.58]	0.015 [0.38]	0.015 [0.38]

Table 9-3

PERMISSIBLE VARIATIONS IN WIDTH FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS FOR EDGE NO. 3

(ASTM A480/A480M)

Specified Thickness, in. [mm]	Width Tolerance, Over and Under, for Thickness and Width Given, in. [mm]					
	Under ½ [12.70] to ⅜ [4.76], incl	½ [12.70] to 6 [152.40], incl	Over 6 [152.40] to 9 [228.60], incl	Over 9 [228.60] to 12 [304.80], incl	Over 12 [304.80] to 20 [508.00], incl	Over 20 [508.00] to 24 [609.60], incl
Under ⅜ [4.76] to 0.161 [4.09], incl	...	0.016 [0.41]	0.020 [0.51]	0.020 [0.51]	0.031 [0.79]	0.031 [0.79]
0.160 [4.06] to 0.100 [2.54], incl	0.010 [0.25]	0.010 [0.25]	0.016 [0.41]	0.016 [0.41]	0.020 [0.51]	0.020 [0.51]
0.099 [2.51] to 0.069 [1.75], incl	0.008 [0.20]	0.008 [0.20]	0.010 [0.25]	0.010 [0.25]	0.016 [0.41]	0.020 [0.51]
0.068 [1.73] and under	0.005 [0.13]	0.005 [0.13]	0.005 [0.13]	0.010 [0.25]	0.016 [0.41]	0.020 [0.51]

Table 9-4

PERMISSIBLE VARIATIONS IN LENGTH FOR COLD-ROLLED STRIP IN CUT LENGTHS

(ASTM A480/A480M)

Specified Length, ft [mm]	Tolerance Over Specified Length (No Tolerance Under), in. [mm]
To 5 [1524], incl	⅜ [9.52]
Over 5 [1524] to 10 [3048], incl	½ [12.70]
Over 10 [3048] to 20 [6096], incl	¾ [15.88]

Table 9-5

PERMISSIBLE VARIATIONS IN CAMBER FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS^a

(ASTM A480/A480M)

Specified Width, in. [mm]	Tolerance per Unit Length of Any 8 ft [2438 mm], in. [mm]
To 1½ [38.10], incl	½ [12.70]
Over 1½ [38.10] to 24 [609.60], excl	¼ [6.35]

^a Camber is the deviation of a side edge from a straight line and measurement is taken by placing an 8-ft [2438-mm] straightedge on the concave side and measuring the greatest distance between the strip edge and the straightedge.

Foil

Stainless steel foil is a flat rolled product in coil form 0.005 in. (0.13 mm) and under in thickness and under 24 in. (609.6 mm) in width.

Foil is made from various types such as 201, 202, 301, 302, 304, 304L, 305, 316, 316L, 321, 347, 430 and 442, as well as from certain proprietary alloys.

As compared with strip of the more usual gages, there are differences in the finishes, the tolerances and the mechanical properties, because of the limitations associated with the manufacture of the foil.

For stainless steel foil, the nomenclature for finishes, as well as the tolerances for widths and thicknesses, varies among producers.

Edges. The foil is produced in slit widths with edges corresponding to No. 3 and No. 5 strip edges.

Finishes. The finishes for foil are described by the finishing operations employed in their manufacture. However, each finish in itself is a

category of finishes, with variations in appearance and smoothness, depending upon composition, thickness and method of manufacture. The chromium-nickel and chromium-nickel-manganese compositions have a characteristically different appearance than the straight chromium types for a corresponding finish designation.

Consultation with producers and examination of representative finishes are recommended because of the foregoing, as well as the importance of visual evaluation in the selection of finishes when finish is important for new applications.

Mechanical Properties. In general, the mechanical property values of foil vary with the thickness. The tensile strength values are increased somewhat and the ductility values are lowered by a decrease in thickness. The determination of tensile properties of foil requires special care and methods.

10

WIRE

Stainless steel wire is a product derived by cold finishing a coiled, hot rolled and annealed rod for the purpose of obtaining desired size with dimensional accuracy, improved surface and specific mechanical properties. When wire, regardless of size, is straightened and cut, it is classified as bar (see Section 6).

The various sections of wire are customarily known as *round wire* when the contour is completely cylindrical and *shape wire* when the contour is other than cylindrical and comprising such sections as half-round, half-oval, oval, square, rectangular, hexagonal, octagonal and triangular. Shape wire is cold finished either by drawing or by a combination of drawing and rolling.

Methods of Manufacture

In the production of wire, a rod, which is a coiled, hot rolled product, is drawn through the tapered hole of a die or a series of dies. The smallest size of hot rolled rod commonly made is $\frac{7}{32}$ in. (5.5 mm). Sections smaller than this are produced by cold work, the number of dies employed depending upon the finished diameter required.

Before drawing, hot rolled coils are commonly annealed and cleaned by pickling, blast cleaning or other methods of descaling and the surface prepared by methods which provide a lubricant coating.

A carbide die consists of a nib encased in a supporting ring of steel, as shown in Figure 11. The nib consists of one or more carbides (tungsten, tantalum, titanium, etc.) mixed with a bonding agent, such as cobalt, pressed into the desired shape and heat treated or sintered into its hardened rough form, after which it is mounted, sized and polished. Coarse round wire is commonly drawn in carbide dies. Fine round wire is drawn in either carbide or diamond dies.

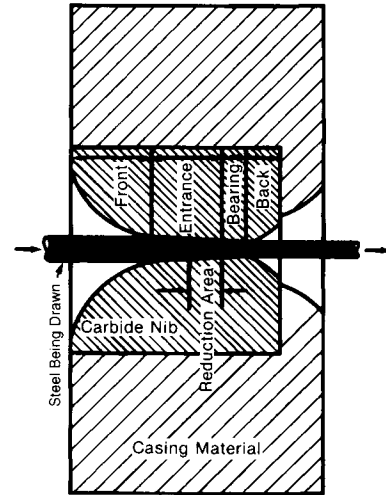


Fig. 11 Section through wire drawing die.

In single draft drawing, the wire is drawn through one die at a time, the wire being removed from the block and redrawn through the next smaller die, until the desired size is reached.

In continuous wire drawing, the wire is drawn continuously through a series of dies with power-driven blocks between dies. The speed increases on each successive block until the wire is coiled on the last block as in single draft drawing. In the drawing operation, various materials are employed as lubricants to produce different finishes on the surface of the wire and to minimize die wear.

In dry drawing, the coating may be lime baked on the surface of cleaned rods supplemented by dry soap lubricants of various types in the die box or die container. Metallic coatings, such as copper or special oxide coatings, may also be used.

In oil or grease drawing, the lubricant is commonly an oil or grease in the die box or die container.

In wet drawing, which is employed in the manufacture of some classes of fine wire, the wire may be drawn bare or with a coating and with a liquid lubricating solution.

Sizes and Sections. Stainless round wire is commonly produced in a size of 0.003 in. (0.08 mm) and larger. Shape wire, except cold finished flat wire, is commonly produced in a size of 0.044 in. (1.12 mm) and larger, although the particu-

lar type of shape will govern the specific range of sizes that can be produced. Cold finished flat wire is produced from round wire by drawing or by a combination of drawing and rolling.

Due to the mechanics of the drawing operation, the size of the wire controls the diameter of the block employed. Coarse wire is drawn on large diameter blocks and fine wire on relatively smaller blocks. When fine wire is drawn on large diameter blocks, there is a tendency for the coils to twist into the form of a figure 8.

Wire and Coil Size Designation. The wire is produced in full catchweight, split catchweight and exact weight coils. Round wire is generally wound in a counterclockwise direction. Shape wire can be wound clockwise or counterclockwise. The size of wire is designated in common fractions of an inch or by decimal. The common designations of round wire size, block diameters and approximate coil weights are shown in Table 10-1.

Coarse Round Wire. This is generally drawn 0.044 in. (1.12 mm) and larger. The wire drawing block diameter for a given wire size varies among producers.

The inside diameter of the coil of wire after stripping from the block is generally slightly different from the block diameter. This contraction or expansion varies and is dependent upon the type and size of wire, and the coil weight.

Full Catchweight Coils. These are of variable weight and comprise one piece or length. The weight of the coil varies, depending upon the weight of the original rod coil, the size of the wire and the limitations of the equipment.

Split Catchweight Coils. These are produced by dividing the full mill catchweight coils into approximately equal weight coils.

Exact Weight Coils. These can be produced.

Tolerances. Size tolerances for coarse round wire, fine round wire and square wire produced to decimal dimensions are shown in Table 10-8 and for drawn wire in hexagons and octagons

in Table 10-9. Size tolerances for wire for which the final operation is a surface treatment for the purpose of removing scale or drawing lubricant, are shown in Tables 10-8 and 10-9. Width and thickness tolerances for cold finished flat wire are shown in Table 10-10.

Fine Round Wire. This is drawn in sizes of 0.043 in. (1.09 mm) and finer on 8 and 12 in. (203 and 305 mm) diameter blocks or spools of various designs and dimensions. Certain kinds, including spring wire, can be produced in re-straightened 16 in. (406 mm) diameter coils. The size and temper of the wire govern the choice of coil or spool. In the lower size range, annealed or soft drawn wire is furnished on spools.

Spring Temper Fine Wire. This is generally produced in 8, 12 and 16 in. (203, 305 and 406 mm) diameter coils within the range of 0.015 to 0.043 in. (0.38 to 1.09 mm) inclusive. Wire finer than 0.015 in. (0.38 mm) is produced on spools or in coils.

Shape Wire. This is designated according to the particular contour and, because of specific individual requirements, has no commonly recognized coarse and fine subdivisions by size. Shape wire is produced in conventional coils or hank wound or vibrated coils. The conventional coils have block diameters of 16 and 22 in. (406 and 559 mm).

Vibrated coils or hank wound coils have block diameters of 16 and 20 in. (406 and 508 mm). The actual inside diameters of the coils are commonly 2 to 4 in. (51 to 102 mm) less than the block diameters. Requirements for specific inside coil diameters should be established in each instance.

Temper

Annealed Temper. This is the condition of the soft wire in which there is no further cold drawing after the last annealing treatment. Wire of this temper is made by annealing in open fired furnaces or molten salt, followed by pickling which produces a clean, gray matte finish. It is

Table 10-1

COMMON WIRE DRAWING BLOCK DIAMETERS AND APPROXIMATE COIL WEIGHTS COARSE ROUND WIRE STAINLESS AND HEAT RESISTING STEELS

Wire Size, in. (mm)	Common Block Diameters, in. (mm)	Approx. Coil Weights, lb (kg)
0.044 to 0.067 (1.12 to 1.70), excl.	12 (305), 16 (406), 22 (559)	25 to 100 (11.3 to 45.4)
0.067 to 0.099 (1.70 to 2.51), excl.	16 (406), 22 (559)	30 to 125 (13.6 to 56.7)
0.099 to 0.192 (2.51 to 4.88), excl.	16 (406), 22 (559), 26 (660)	100 to 300 (45.4 to 136)
0.192 to 3/8 (4.88 to 9.53), excl.	22 (559), 26 (660), 30 (762)	100 to 350 (45.4 to 159)
3/8 to 0.500 (9.53 to 12.70), incl.	22 (559), 26 (660), 28 (711), 30 (762)	100 to 350 (45.4 to 159)

also made with a bright finish by annealing wet, oil or grease drawn wire in a protective atmosphere, and is sometimes described as "bright annealed wire."

Soft Temper. This is a condition of wire given a single light draft following the final annealing operation, and generally produced to a maximum limit of tensile strength or hardness. Wire of this temper is produced with various dry drawn finishes, including lime soap, lead, copper, oxide and other special coatings. It may also be furnished with a bright finish produced by oil or grease drawing.

Intermediate Temper. This is a condition of wire drawn one or more drafts after annealing, as required, to produce minimum strength or hardness. The properties of such wire can be varied between those of soft temper and those approaching spring temper wire. Wire in this temper is usually produced in a variety of dry drawn finishes.

Spring Temper. This is a condition of wire drawn several drafts, as required, to produce the high tensile strengths required for spring wire, as shown in Tables 10-2 through 10-7.

Finishes

Oil or Grease Drawn Finish. This is a special bright finish intended for uses, such as racks and handles, where the finish supplied is that of the end product. In producing this finish, slower drawing speeds are necessary and additional care is needed in processing to provide a surface with a minimum of scratching and lubricant.

Diamond Drawn Finish. This is a very bright finish and, in general, is limited to wet drawing of fine sizes of stainless steel wire. Drafting speeds are necessarily reduced to obtain the final results.

Copper Coated Stainless Steel Wire. This is furnished when a special finish is required for lubrication in an operation, such as spring coiling or cold heading. Generally, copper coated wire is drawn after coating, the amount depending upon the desired temper of the wire.

Tinned Stainless Steel Wire. This is given a coating of tin by passing single strands through a bath of molten tin. Tinned coatings are used to facilitate soldering. The temper of the finished wire is controlled by processing prior to the tinning operation.

Lead Coated Stainless Steel Wire. This is given a coating of lead either by passing single strands through a bath of molten lead or by

immersing bundles of wire in a bath of molten lead. The wire is drawn to finish size with the lead forming a thin coating over the entire surface. This coating is useful in the coiling of springs where it serves as a lubricant.

Finishes or Coatings on Cold Heading Wire. Refer to commodity classifications as follows.

Commodity Classifications

There are many stainless steel wires for specific applications that have been developed for definite components of machines and equipment or for some particular applications. The unique properties of each of these individual wire items are developed by employing a combination of steel composition, steel quality, process heat treatments and cold drawing practices. The details of manufacture may vary slightly with different wire manufacturers, but the finished wire will be produced to fulfill the specification requirements. These several wires have, by long established custom, become known by product or commodity names generally connected with the purpose for which the wire has been designed.

Free Machining Stock. This is produced for machining in automatic screw machines or other types of machining equipment. The principal types used are 303, 303Se, 416, 420F and 430F. Some machining equipment operates using feed stock in wire form. Where straightened and cut feed stock is required, see Section 6.

Cold Heading Wire. This is produced in as many of the various types as the application requires. In all instances, the product is subjected to special tests and inspection to assure satisfactory performance in cold heading and cold forging operations.

For best results in upsetting or cold forging operations in the chromium-nickel group, Type 305 is commonly used as an all-purpose type and is generally necessary for severe upsetting. Other grades cold formed include 303Se, 304, 316, 321, 347 and 384.

In the 4xx series, Types 410, 420, 430 and 431 are used for a variety of cold headed products. Types 430 and 410 are commonly used for severe upsetting and for recessed head screws and bolts. Types 416 and 430F are designed primarily for free cutting and are not recommended for cold heading.

Cold heading wire is manufactured using a closely controlled annealing treatment at a predetermined size which produces optimum softness in the steel and still permits a very light finishing draft after pickling. The object of the finishing draft is to provide a coating that will aid the cold heading operation, and produce a coil of more uniform dimensions free from kinks.

Finishes or Coatings on Stainless Steel Cold Heading Wire. Cold heading wire is produced with a variety of finishes, all of which have the function of providing proper lubrication in the header dies. The finish or coating should have lubricating properties and be suitably adherent to prevent galling and undesirable die wear.

A copper finish, which is applied after the annealing treatment just prior to the finishing draft, is available; the copper finished wire is then lime coated and drawn in soap. Other coatings of lime and soap or oxide and soap are also employed.

Spring Wire. This is drawn from annealed rods and is subjected to mill tests and inspection designed to produce wire for extension and compression springs. The types commonly produced include 302, 304 and for additional corrosion resistance, 316.

Coarse sizes of spring wire can be furnished in a variety of finishes such as dry drawn lead finish, copper, lime and soap or oxide and soap drawn. Fine sizes are usually wet drawn, although they can be dry drawn.

Tensile strength ranges or minimums for the various sizes of Types 302, 304, 305 and 316 spring wire are given in Tables 10-2 and 10-3. The torsional modulus for wire produced in these types may vary from 8,500,000 to 11,000,000 psi (58.6 to 75.8 GPa). The magnetic permeability is low as compared to carbon steel wire. Springs made from this corrosion resisting wire retain their physical and mechanical properties at elevated temperatures up to approximately 600°F (315°C).

Rope Wire. This is a product intended for use in the construction of various ropes, cables and cord for a variety of uses, such as aircraft control cables, marine ropes, elevator supporter conductors, slings and anchor cables. Because of special requirements for fatigue strength, rope wire is produced from selected steel and is specially processed.

Rope wire is generally furnished as Type 302 or 304, unless a higher level of corrosion resistance is required, in which case Type 316 is furnished. Special nonmagnetic characteristics may be required which necessitate the selection of heats and special drawing.

Tensile properties of the regular rope wire are slightly lower than those of stainless steel spring wire shown in Tables 10-2 and 10-3.

Finishes for rope wire vary from a gray matte finish to a bright finish and a series of bright soap finishes to dark soap finishes. Those latter finishes afford some degree of lubrication in laying up the rope and also lubricate the strands of the rope to some extent when it is in use.

Weaving Wire. This is used in the weaving of screens for applications in coal mines, sand and gravel pits, paper mills, chemical and dairy plants, oil refineries, food products and others. It is necessary in the manufacture of this wire to control carefully the annealing and final drawing to maintain a uniform temper and finish through the entire coil or spool. This application requires ductility in the wire. It is usually furnished either in the annealed temper with a bright annealed finish, or in the soft temper with a lime soap finish or oil or grease drawn finish.

Most types of stainless steel are available in weaving wire, although the types most generally used are 302, 304, 309, 310, 316, 410 and 430. Annealed temper wire of the 3xx series commonly has 95,000 to 125,000 psi (655 to 862 MPa) tensile strength and 35 to 60 percent elongation in 2 in. (50.8 mm). Soft temper, commonly used in sizes over 0.030 in. (0.76 mm), averages 125,000 to 150,000 psi (862 to 1,034 MPa) tensile strength with 15 to 40 percent elongation in 2 in. (50.8 mm). Annealed temper wire of Types 410 and 430 averages 72,000 to 85,000 psi (496 to 586 MPa) in tensile strength and 17 to 23 percent elongation in 2 in. (50.8 mm).

Armature Binding Wire. This is produced in Types 302 and 304 and is made from a selected chemical composition balanced to produce the high tensile and yield strength properties required, and at the same time to meet maximum magnetic permeability requirements. The wire can be produced with a minimum tensile strength of 220,000 psi (1,517 MPa) and a minimum yield strength (offset: 0.2 percent) of 170,000 psi (1,172 MPa). Maximum permeability of 4.0 at 200 oersteds is the usual specification. The wire must be strong enough to withstand the centrifugal forces encountered in its use, yet be ductile enough to withstand being bent sharply back on itself without cracking when a hook is formed to hold the armature wire during the binding operation.

This wire is furnished on spools with a smooth, tightly adherent, tinned coating to facilitate soldering the closely wound wire when the armature is banded.

Slide Forming Wire. This is produced in all standard types and particularly 302, 304, 316, 410 and 430, and can be produced in tempers suitable for forming into the numerous shapes made on slide forming machines.

Wool Wire. This is designed for the production of wool by shredding. It is commonly furnished in an intermediate temper and produced to rigid standards in order that it will perform satisfactorily in the wool cutting operation. Usually, this wire is made from Type 430 and has a lime soap finish.

Reed Wire. This is a high quality special wire that is produced for the manufacture of dents for reeds which, after assembly, are used in the weaving of textiles and other products. Accuracy in size and shape is necessary because of the various processes the loom manufacturer puts the wire through and because of its end use. The dents are made by rolling the round reed wire into a flat section, the edges of which are finely machined and polished to a very smooth and accurate contour before cutting into the individual dent lengths.

Reed wire is usually made from Type 430 in an intermediate temper which must be uniform throughout the coil as well as the shipment. The finish must also be uniform and bright.

Lashing Wire. This is commonly made from Type 430 and has closely controlled properties. It is designed to lash aerial conductor cables to supporting strands. This wire is furnished in the annealed temper with a bright finish,

and has a maximum tensile strength of 95,000 psi (655 MPa) and 17 percent elongation minimum in 10 in. (254.0 mm). It is coiled on a coreless spool of specific dimensions and type of binding.

Cotter Pin Wire. This is an approximately half round wire intended to be used for fabrication into cotter pins. It is generally produced by rolling the stainless steel round wire through power-driven rolls, or by drawing it through a die or turkshead. For ease of spreading the ends of the cotter pins, it is desirable that the flat side of the wire have some small degree of radius at the edges, rather than sharp corners. Cotter pin wire is commonly furnished in vibrated or hank wound coils, with the flat side of the wire inward.

It is commonly made in soft temper to prevent undesirable springback in the legs. The wire is usually furnished bright, but can be metallic coated for lubrication where necessary.

Table 10-2

TENSILE STRENGTH REQUIREMENTS FOR TYPES 302 CLASS 1 AND 304^A

(ASTM A313/A313M)

Diameter, in. [mm]	Bend Test Minimum Number of Bends	ksi [MPa]	
		min	max
Up to 0.009 [0.23], incl	...	325 [2240]	355 [2450]
Over 0.009 [0.23] to 0.010 [0.25], incl	...	320 [2205]	350 [2415]
Over 0.010 [0.25] to 0.011 [0.28], incl	...	318 [2190]	348 [2400]
Over 0.011 [0.28] to 0.012 [0.30], incl	...	316 [2180]	346 [2385]
Over 0.012 [0.30] to 0.013 [0.33], incl	...	314 [2165]	344 [2370]
Over 0.013 [0.33] to 0.014 [0.36], incl	...	312 [2150]	342 [2360]
Over 0.014 [0.36] to 0.015 [0.38], incl	...	310 [2135]	340 [2345]
Over 0.015 [0.38] to 0.016 [0.41], incl	...	308 [2125]	338 [2330]
Over 0.016 [0.41] to 0.017 [0.43], incl	...	306 [2110]	336 [2315]
Over 0.017 [0.43] to 0.018 [0.46], incl	...	304 [2095]	334 [2300]
Over 0.018 [0.46] to 0.020 [0.51], incl	...	300 [2070]	330 [2275]
Over 0.020 [0.51] to 0.022 [0.56], incl	...	296 [2040]	326 [2250]
Over 0.022 [0.56] to 0.024 [0.61], incl	...	292 [2015]	322 [2220]
Over 0.024 [0.61] to 0.026 [0.66], incl	8	291 [2005]	320 [2205]
Over 0.026 [0.66] to 0.028 [0.71], incl	8	289 [1995]	318 [2190]
Over 0.028 [0.71] to 0.031 [0.79], incl	8	285 [1965]	315 [2170]
Over 0.031 [0.79] to 0.034 [0.86], incl	8	282 [1945]	310 [2135]
Over 0.034 [0.86] to 0.037 [0.94], incl	8	280 [1930]	308 [2125]
Over 0.037 [0.94] to 0.041 [1.04], incl	8	275 [1895]	304 [2095]
Over 0.041 [1.04] to 0.045 [1.14], incl	8	272 [1875]	300 [2070]
Over 0.045 [1.14] to 0.050 [1.27], incl	8	267 [1840]	295 [2035]
Over 0.050 [1.27] to 0.054 [1.37], incl	8	265 [1825]	293 [2020]
Over 0.054 [1.37] to 0.058 [1.47], incl	7	261 [1800]	289 [1990]
Over 0.058 [1.47] to 0.063 [1.60], incl	7	258 [1780]	285 [1965]
Over 0.063 [1.60] to 0.070 [1.78], incl	7	252 [1735]	281 [1935]
Over 0.070 [1.78] to 0.075 [1.90], incl	7	250 [1725]	278 [1915]
Over 0.075 [1.90] to 0.080 [2.03], incl	7	246 [1695]	275 [1895]
Over 0.080 [2.03] to 0.087 [2.21], incl	7	242 [1670]	271 [1870]
Over 0.087 [2.21] to 0.095 [2.41], incl	7	238 [1640]	268 [1850]
Over 0.095 [2.41] to 0.105 [2.67], incl	5	232 [1600]	262 [1805]
Over 0.105 [2.67] to 0.115 [2.92], incl	5	227 [1565]	257 [1770]
Over 0.115 [2.92] to 0.125 [3.17], incl	5	222 [1530]	253 [1745]
Over 0.125 [3.17] to 0.135 [3.43], incl	3	217 [1495]	248 [1710]
Over 0.135 [3.43] to 0.148 [3.76], incl	3	210 [1450]	241 [1660]
Over 0.148 [3.76] to 0.162 [4.11], incl	3	205 [1415]	235 [1620]
Over 0.162 [4.11] to 0.177 [4.50], incl	3	198 [1365]	228 [1570]
Over 0.177 [4.50] to 0.192 [4.88], incl	1	194 [1335]	225 [1550]
Over 0.192 [4.88] to 0.207 [5.26], incl	1	188 [1295]	220 [1515]
Over 0.207 [5.26] to 0.225 [5.72], incl	1	182 [1255]	214 [1475]
Over 0.225 [5.72] to 0.250 [6.35], incl	1	175 [1205]	205 [1415]
Over 0.250 [6.35] to 0.278 [7.06], incl	1	168 [1160]	198 [1365]
Over 0.278 [7.06] to 0.306 [7.77], incl	1	161 [1110]	192 [1325]
Over 0.306 [7.77] to 0.331 [8.41], incl	1	155 [1070]	186 [1280]
Over 0.331 [8.41] to 0.362 [9.19], incl	1	150 [1035]	180 [1240]
Over 0.362 [9.19] to 0.394 [10.00], incl	1	145 [1000]	175 [1205]
Over 0.394 [10.00] to 0.438 [11.12], incl	1	140 [965]	170 [1170]
Over 0.438 [11.12] to 0.500 [12.70], incl	1	135 [930]	165 [1140]
Over 0.500 [12.70]	1	130 [895]	160 [1105]

^A When wire is specified in straightened and cut lengths, the minimum tensile strength shall be 90 % of the values listed in the table.

Table 10-3

TENSILE STRENGTH REQUIREMENTS FOR TYPES 305, 316, 321, AND 347^A

(ASTM A313/A313M)

Diameter, in. [mm]	Bend Test Minimum Number of Bends	ksi [MPa]	
		min	max
Up to 0.010 [0.25], incl	...	245 [1690]	275 [1895]
Over 0.010 [0.25] to 0.015 [0.38], incl	...	240 [1655]	270 [1860]
Over 0.015 [0.38] to 0.024 [0.61], incl	...	235 [1620]	265 [1825]
Over 0.024 [0.61] to 0.041 [1.04], incl	8	235 [1620]	265 [1825]
Over 0.041 [1.04] to 0.047 [1.19], incl	8	230 [1585]	260 [1790]
Over 0.047 [1.19] to 0.054 [1.37], incl	8	225 [1550]	255 [1760]
Over 0.054 [1.37] to 0.062 [1.57], incl	7	220 [1515]	250 [1725]
Over 0.062 [1.57] to 0.072 [1.83], incl	7	215 [1480]	245 [1690]
Over 0.072 [1.82] to 0.080 [2.03], incl	7	210 [1450]	240 [1655]
Over 0.080 [2.03] to 0.092 [2.34], incl	7	205 [1415]	235 [1620]
Over 0.092 [2.34] to 0.105 [2.67], incl	5	200 [1380]	230 [1585]
Over 0.105 [2.67] to 0.120 [3.05], incl	5	195 [1345]	225 [1550]
Over 0.120 [3.05] to 0.148 [3.76], incl	3	185 [1275]	215 [1480]
Over 0.148 [3.76] to 0.166 [4.22], incl	3	180 [1240]	210 [1450]
Over 0.166 [4.22] to 0.177 [4.50], incl	3	170 [1170]	200 [1380]
Over 0.177 [4.50] to 0.207 [5.26], incl	1	160 [1105]	190 [1310]
Over 0.207 [5.26] to 0.225 [5.72], incl	1	155 [1070]	185 [1275]
Over 0.225 [5.72] to 0.250 [6.35], incl	1	150 [1035]	180 [1240]
Over 0.250 [6.35] to 0.312 [7.92], incl	1	140 [965]	170 [1170]
Over 0.312 [7.92] to 0.375 [9.53], incl	1	135 [930]	165 [1140]
Over 0.375 [9.53] to 0.500 [12.70], incl		130 [895]	160 [1105]
Over 0.500 [12.70]		125 [860]	155 [1070]

^A When wire is specified in straightened and cut lengths, the minimum tensile strength shall be 90 % of the values listed in the table.

Table 10-4

TENSILE STRENGTH REQUIREMENTS FOR TYPE 631^A

(ASTM A313/A313M)

Diameter, in. [mm]	Cold Drawn Condition C, ksi [MPa] Nominal	Condition CH-900 ^B , ksi [MPa]	
		min	max
0.010 [0.25] to 0.015 [0.38], incl	295 [2035]	335 [2310]	365 [2515]
Over 0.015 [0.38] to 0.020 [0.51], incl	290 [2000]	330 [2275]	360 [2480]
Over 0.020 [0.51] to 0.029 [0.74], incl	285 [1965]	325 [2240]	355 [2450]
Over 0.029 [0.74] to 0.041 [1.04], incl	275 [1895]	320 [2205]	350 [2415]
Over 0.041 [1.04] to 0.051 [1.30], incl	270 [1860]	310 [2135]	340 [2345]
Over 0.051 [1.30] to 0.061 [1.55], incl	265 [1825]	305 [2100]	335 [2310]
Over 0.061 [1.55] to 0.071 [1.80], incl	257 [1770]	297 [2050]	327 [2255]
Over 0.071 [1.80] to 0.086 [2.18], incl	255 [1760]	292 [2015]	322 [2220]
Over 0.086 [2.18] to 0.090 [2.29], incl	245 [1690]	282 [1945]	312 [2150]
Over 0.090 [2.29] to 0.100 [2.54], incl	242 [1670]	279 [1925]	309 [2130]
Over 0.100 [2.54] to 0.106 [2.69], incl	238 [1640]	274 [1890]	304 [2095]
Over 0.106 [2.69] to 0.130 [3.30], incl	236 [1625]	272 [1875]	302 [2080]
Over 0.130 [3.30] to 0.138 [3.50], incl	230 [1585]	260 [1795]	290 [2000]
Over 0.138 [3.50] to 0.146 [3.71], incl	228 [1570]	258 [1780]	288 [1985]
Over 0.146 [3.71] to 0.162 [4.11], incl	226 [1560]	256 [1765]	286 [1970]
Over 0.162 [4.11] to 0.180 [4.57], incl	224 [1545]	254 [1750]	284 [1960]
Over 0.180 [4.57] to 0.207 [5.26], incl	222 [1530]	252 [1740]	282 [1945]
Over 0.207 [5.26] to 0.225 [5.72], incl	218 [1505]	248 [1710]	278 [1915]
Over 0.225 [5.72] to 0.306 [7.77], incl	213 [1470]	242 [1670]	272 [1875]
Over 0.306 [7.77] to 0.440 [11.2], incl	207 [1425]	235 [1620]	265 [1825]
Over 0.440 [11.2] to 0.625 [15.88], incl	203 [1400]	230 [1585]	260 [1795]

^A When wire is specified in straightened and cut lengths, the minimum tensile strength shall be 90 % of the values listed in the table.^B Aged at 900°F [482°C] for 1 h and air cooled.

Table 10-5

TENSILE STRENGTH REQUIREMENTS FOR GRADE XM-16^A

(ASTM A313/A313M)

Diameter, in. [mm]	Cold Drawn, ksi [MPa] Nominal	Age Hardened ^B , ksi [MPa]	
		min	max
0.010 [0.25] to 0.040 [1.02], incl	245 [1690]	320 [2205]	350 [2415]
Over 0.040 [1.02] to 0.050 [1.27], incl	235 [1620]	310 [2135]	340 [2345]
Over 0.050 [1.27] to 0.060 [1.52], incl	225 [1550]	305 [2100]	335 [2310]
Over 0.060 [1.52] to 0.075 [1.90], incl	220 [1515]	295 [2035]	325 [2240]
Over 0.075 [1.90] to 0.085 [2.16], incl	215 [1480]	290 [2000]	320 [2205]
Over 0.085 [2.16] to 0.095 [2.41], incl	210 [1450]	285 [1965]	315 [2170]
Over 0.095 [2.41] to 0.110 [2.79], incl	200 [1380]	278 [1915]	308 [2125]
Over 0.110 [2.79] to 0.125 [3.17], incl	195 [1345]	272 [1875]	302 [2080]
Over 0.125 [3.17] to 0.150 [3.81], incl	190 [1310]	265 [1825]	295 [2035]
Over 0.150 [3.81] to 0.500 [12.7], incl	180 [1240]	260 [1795]	290 [2000]

^A When wire is straightened and cut lengths, the minimum tensile strength shall be 90 % of the values listed in the table.^B Aged at 850°F [454°C] for ½ h and air cooled.

Table 10-6

TENSILE STRENGTH REQUIREMENTS FOR GRADE XM-28^A

(ASTM A313/A313M)

Diameter, in. [mm]	ksi [MPa]	
	min	max
Up to 0.009 [0.23], incl	325 [2240]	355 [2450]
Over 0.009 [0.23] to 0.010 [0.25], incl	320 [2205]	350 [2415]
Over 0.010 [0.25] to 0.011 [0.28], incl	318 [2195]	348 [2400]
Over 0.011 [0.28] to 0.012 [0.30], incl	316 [2180]	346 [2385]
Over 0.012 [0.30] to 0.013 [0.33], incl	314 [2165]	344 [2370]
Over 0.013 [0.33] to 0.014 [0.36], incl	312 [2150]	342 [2360]
Over 0.014 [0.36] to 0.015 [0.38], incl	310 [2135]	340 [2345]
Over 0.015 [0.38] to 0.016 [0.41], incl	308 [2125]	338 [2330]
Over 0.016 [0.41] to 0.017 [0.43], incl	306 [2110]	336 [2315]
Over 0.017 [0.43] to 0.018 [0.46], incl	304 [2095]	334 [2305]
Over 0.018 [0.46] to 0.020 [0.51], incl	300 [2070]	330 [2275]
Over 0.020 [0.51] to 0.022 [0.56], incl	296 [2040]	326 [2250]
Over 0.022 [0.56] to 0.024 [0.61], incl	292 [2015]	322 [2220]
Over 0.024 [0.61] to 0.026 [0.66], incl	289 [1995]	319 [2200]
Over 0.026 [0.66] to 0.028 [0.71], incl	286 [1970]	316 [2180]
Over 0.028 [0.71] to 0.032 [0.81], incl	282 [1945]	312 [2150]
Over 0.032 [0.81] to 0.037 [0.94], incl	277 [1910]	307 [2120]
Over 0.037 [0.94] to 0.041 [1.04], incl	273 [1880]	303 [2090]
Over 0.041 [1.04] to 0.047 [1.19], incl	270 [1860]	300 [2070]
Over 0.047 [1.19] to 0.054 [1.37], incl	265 [1825]	295 [2035]
Over 0.054 [1.37] to 0.087 [2.21], incl	260 [1795]	290 [2000]
Over 0.087 [2.21] to 0.120 [3.05], incl	255 [1760]	285 [1965]
Over 0.120 [3.05] to 0.166 [4.22], incl	250 [1725]	280 [1930]
Over 0.166 [4.22] to 0.192 [4.88], incl	240 [1655]	270 [1860]
Over 0.192 [4.88] to 0.225 [5.72], incl	230 [1585]	260 [1795]
Over 0.225 [5.72] to 0.278 [7.06], incl	215 [1480]	245 [1690]
Over 0.278 [7.06] to 0.331 [8.41], incl	200 [1380]	230 [1585]
Over 0.331 [8.41] to 0.394 [10.00], incl	185 [1275]	215 [1480]
Over 0.394 [10.00] to 0.500 [12.70], incl	160 [1105]	190 [1310]

^A When wire is specified in straightened and cut lengths, the minimum tensile strength shall be 85 % of the values listed in the table.

Table 10-7

TENSILE STRENGTH REQUIREMENTS FOR TYPE 302 CLASS 2

(ASTM A313/A313M)

Diameter, in. [mm]	ksi [MPa]		
	Cold Drawn Nominal	Stress Relieved ^A	
		min	max
0.050 [1.30] to 0.160 [4.00], incl	290 000 [2000]	290 000 [2000]	340 000 [2345]

^A Stress relieved at 800 to 850°F [430 to 455°C] for ½ h and air cooled.

Table 10-8

PERMISSIBLE VARIATIONS IN DIAMETER AND OUT-OF-ROUND FOR ROUND WIRE^{A,B,C,D}

(ASTM A555/A555M)

Specified Diameter, in. [mm]	Diameter Tolerances, in. [mm]	
	Over	Under
1.000 [25.00] and over	0.0025 [0.06]	0.0025 [0.06]
Under 1.000 [25.00] to 0.500 [13.00]	0.002 [0.05]	0.002 [0.05]
Under 0.5000 [13.00] to 0.3125 [8.00] incl	0.0015 [0.04]	0.0015 [0.04]
Under 0.3125 [8.00] to 0.0440 [1.00] incl	0.001 [0.03]	0.001 [0.03]
Under 0.0440 [1.00] to 0.0330 [0.80] incl	0.0008 [0.02]	0.0008 [0.02]
Under 0.0330 [0.80] to 0.0240 [0.60] incl	0.0005 [0.015]	0.0005 [0.015]
Under 0.0240 [0.60] to 0.0120 [0.30] incl	0.0004 [0.010]	0.0004 [0.010]
Under 0.0120 [0.30] to 0.0080 [0.20] incl	0.0003 [0.008]	0.0003 [0.008]
Under 0.0080 [0.20] to 0.0048 [0.12] incl	0.0002 [0.005]	0.0002 [0.005]
Under 0.0048 [0.12] to 0.0030 [0.08] incl	0.0001 [0.003]	0.0001 [0.003]

^A The maximum out-of-round for round wire is one half of the total size tolerance given in this table.^B When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown above for sizes 0.024 in. [0.60 mm] and over.^C Size tolerances have not been evolved for wire produced by cold rolling.^D These tolerances apply to small diameter straightened and cut wire (sizes below approximately ¼ in.). Refer to Table 5 in Specification A 484/A 484M for bars (greater than approximately ¼ in.).

Table 10-9

**PERMISSIBLE VARIATIONS IN SIZE FOR
DRAWN WIRE IN HEXAGONS, OCTAGONS,
AND SQUARES^A**

(ASTM A555/A555M)

Specified Size ^B in. [mm]	Size Tolerance, in. [mm]	
	Over	Under
1.000 [25.00] and over	0	0.005 [0.12]
Under 1.000 [25.00] to 0.500 [12.70] incl	0	0.004 [0.10]
Under 1/2 [12.70] to 3/16 [4.75] incl	0	0.003 [0.08]
Under 3/16 [4.75] to 1/8 [3.18] incl	0	0.002 [0.05]

^A When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown above.

^B Distance across flats.

Table 10-10

**PERMISSIBLE VARIATIONS IN THICK-
NESS AND WIDTH FOR FLAT WIRE**

(ASTM A555/A555M)

Width, in. [mm]	Permissible Variations in Width, Over and Under, in. [mm] ^A	
	For Thicknesses 1/4 in. [6.5 mm] and Under	For Thicknesses Over 1/4 in. [6.5 mm]
1/16 [1.50] to 3/16 [9.0]	0.005 [0.12]	0.005 [0.12]
over 3/16 [9.0] to 1.0 [25.00]	0.004 [0.10]	0.004 [0.10]
over 1.0 [25.00]	0.006 [0.15]	0.004 [0.10]
Thickness, in. [mm]	Permissible Variations in Thickness, Over and Under, in. [mm] ^A	
Up to 0.029 [0.70], incl	0.001 [0.03]	
Over 0.029 [1.70] to 0.035 [1.00], incl	0.0015 [0.04]	
Over 0.035 [1.00]	0.002 [0.05]	

^A When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

TUBULAR PRODUCTS

The specialty tubular products covered are those hollow forms, variously designated *pipe, tubes and tubing*, that are used for conveying gases, liquids and solids, and for a diversity of mechanical and structural purposes. Cylindrical forms intended as containers for storage and shipping purposes are not included. The products described do not include those cast to tubular shape.

The terms used in describing sizes and other characteristics of tubular products have grown with the industry and, in some cases, are hard to define. There is, for example, no easy rule for distinguishing between the terms pipe, tubes and tubing except by general usage.

Basically, the process or processes employed in the production of pipe are the same as those used in producing round tubes. Pipe, as distinguished from tubes, is commonly produced in relatively few standard sizes. Tubing is generally made in smaller quantities to more exacting specifications for dimensions, finish, chemical composition and mechanical properties as required by the specification.

There are two general methods of producing stainless steel tubular products: seamless and welded.

General Description

Chemical Requirements. Chemical composition ranges and limits are set forth in the applicable specifications for particular end use requirements.

Stainless steel mechanical tubing is produced to various compositions which were developed for particular production processes and to obtain optimum properties for the particular application.

Grain Size. Stainless steels are generally not manufactured to specific grain size requirements. Such requirements, if necessary, should be referred to the steel producer for consideration.

Hot Working. In hot bending, upsetting or other hot working operations on stainless and heat resisting steel tubing, experience indicates that as low a temperature as is consistent with good forging practice be used. The hardenable grades require retarded cooling or annealing after hot working.

Heat Treatment. Stainless steel is seldom placed in service in the hot worked condition. Annealing or other forms of heat treatment are desirable to improve the corrosion resisting and mechanical properties of these steels.

Some austenitic stainless steels precipitate carbides in the grain boundaries when heated to or cooled slowly through the temperature range of about 800 to 1650°F (426 to 882°C). Associated with this carbide precipitation is a loss of corrosion resistance at the grain boundaries, dependent upon time, temperature, composition of the alloy and type of corrodent involved. Susceptibility to intergranular corrosion may be avoided by using the proper grade or type of stainless steel, or by using suitable heat treatment.

In heat treating stainless steels, the general methods employed are similar to those used with other steels, and no special equipment is needed. Heat treatment may be performed in any conventional electric, gas fired, oil fired, salt bath or induction furnace in which the required temperatures can be obtained. Precautions should be taken to avoid exposure of the steel to the direct flame of the burners. Conditions which will result in carburization of the surface of the steel should be avoided. In general, oxidizing furnace atmospheres are preferred. Bright scale-free heat treatment is possible by the use of specially prepared and controlled atmospheres.

Weight. Reference should be made to the specific grade of stainless steel involved, since the density of the several types of grades varies from about 0.27 to 0.29 lb/in.³ (7,474 to 8,027 kg/m³). Also, see Table 11-2.

Dimensions. Unless otherwise specified, stainless steel pressure tubing, pipe and mechanical tubing are produced in mill lengths, 4 ft. (1,219 mm) and over. Dimensional tolerances for the various forms of stainless steel tubing are shown in Tables 11-4 through 11-9.

Coatings and Finishes

Coatings. Stainless steel tubular products are customarily shipped without any oil or other protective coatings. If a coating is desired, the producer should be consulted.

Finish. Slight blemishes and minor surface imperfections may be removed by grinding or polishing, provided wall thicknesses are not decreased to less than the minimum permitted by applicable specifications.

Polishing. For applications requiring special surface finish, tubing may be specified polished on the outside, inside or on both surfaces. Welded and cold finished seamless tubing is suitable for grinding or polishing and is produced in sizes up to 6 ⁵/₈ in. (168.3 mm.) OD with a polished outside surface. It is not practical to polish the interior surface of tubes with ID less than ³/₄ in. (19.05 mm). Such polishing, on either exterior or interior, or both surfaces, can be performed in the sizes listed below:

Exterior grinding or polishing:
sizes ¹/₈ in. (3.18 mm) OD to 6 ⁵/₈ in.
(168.3 mm) OD

Interior polishing:
sizes ³/₄ in. (19.05 mm) ID to 6 ⁵/₈ in.
(168.3 mm) OD

Such polishing, either exterior or interior, or both surfaces, can be obtained in the following finishes: 80 grit, 120 grit, 180 grit and 320 grit.

Descriptions of Stainless Steel Tubular Products

Stainless steel tubular products may be divided into the following seven groups according to their intended service.

Stainless Steel Tubing for General Corrosion Resisting Service. This category is divided into three groups, namely, the straight chromiums ("ferritic" and "martensitic") and the chromium-nickel ("austenitic"). The straight chromium types are produced in the annealed or heat treated condition and the chromium-nickel types are produced in the annealed condition or cold-worked condition.

The austenitic types are inherently tougher and more ductile than the ferritic types.

The following specifications are in common use:

ASTM A268
Seamless and Welded Ferritic Stainless Steel Tubing for General Service

ASTM A269
Seamless and Welded Austenitic Stainless Steel Tubing for General Service

Stainless Steel Pressure Piping. This is produced from chromium or chromium-nickel alloys commonly in the sizes and wall thicknesses shown in Table 12-8. The following specifications and standards are in common use:

ASTM A312
Seamless and Welded Austenitic Stainless Steel Pipe

ASTM A358
Electric-Fusion-Welded Austenitic Chromium-Nickel-Alloy Steel Pipe for High-Temperature Service

ASTM A376
Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service

ASTM A409
Welded Large Outside Diameter Light-Wall Austenitic Chromium-Nickel Alloy Steel Pipe for Corrosive or High-Temperature Service

Stainless Steel Pressure Tubes. These include boiler tubes, superheater, condenser and heat exchanger tubes commonly manufactured from chromium-nickel alloys, and the requirements are contained in the following ASTM specifications:

ASTM A213
Seamless Ferritic and Austenitic Alloy Steel Boiler, Superheater and Heat Exchanger Tubes

ASTM A249
Welded Austenitic Stainless Steel Boiler, Superheater, Heat Exchanger and Condenser Tubes

Oil still tubes are furnished to the following specification:

ASTM A271
Seamless, Austenitic, Chromium-Nickel Steel Still Tubes for Refinery Service

Stainless Steel Sanitary Tubing. This is used extensively in the dairy and food industries, where corrosion resistance and cleanliness are important factors. Sanitary tubing can be furnished polished on the outside, inside or both, in order to provide smooth, easily cleaned surfaces. Specification ASTM A270, Seamless and Welded Austenitic Stainless Steel Sanitary Tubing, is in common use for this tubing.

Special finishes and close dimensional tolerances for special fittings are sometimes required.

Stainless Steel Mechanical Tubing. This is used for a variety of mechanical purposes and is produced in round, square, rectangular or special shapes. Specifications ASTM A511, Seamless Stainless Steel Mechanical Tubing, and A554, Welded Stainless Steel Mechanical Tubing, are in common use for this tubing.

Stainless Steel Aircraft Tubing. Produced from the chromium-nickel alloys, this tubing has many applications in aircraft construction because of the heat resistant and corrosion resistant properties which characterize these grades when in the annealed or austenitic condition. Work hardened tubing can be produced where high strength is required, but is not recommended for parts that may be subject to certain corrodents or combinations of corrodents and repeated stressing. Compositions stabilized by titanium and columbium-tantalum are commonly used if welding is contemplated without a subsequent heat treatment.

Aircraft tubing can be made from a variety of stainless steel compositions, and the term is generally applied to structural, hydraulic, engine and accessory parts which are actually airborne. It is made to close tolerance, and with special surface finishes, special mechanical properties and stringent testing and inspection requirements.

Aircraft tubing is made by the seamless process or by the welded process. These products are available in the usual compositions. Aircraft tubing is used for such purposes as airplane fuselages, engine mounts, engine oil lines, landing gear, engine parts and, in increasing importance, for hydraulic systems, fuel injection, exhaust and heating systems. These uses are divided into two main groups: structural and hydraulic.

Aircraft Structural Tubing. Larger sizes of seamless and welded stainless steel tubing are commonly used in exhaust systems including stacks, cross-headers, collector rings, various engine parts, heaters and pressurizers. In some cases, aircraft stainless steel structural tubing is produced for parts that are to be machined. AMS and MIL specifications covering stabilized grades are intended for use when welding or brazing is contemplated.

Seamless and welded aircraft stainless steel structural tubing is usually made in sizes ranging from $\frac{1}{16}$ to 5 in. (1.59 to 127 mm) OD and wall thicknesses from 0.010 to 0.250 in. (0.25 to 6.35 mm). These sizes are usually produced to government and AMS specifications of which the following are examples.

Specifications	Composition and Condition	Process
MIL-T-5695	18-8 Hardened (by cold working)	Seamless and Welded
MIL-T-6737	18-8 Stabilized, Annealed	Welded
MIL-T-8506	18-8 Annealed	Seamless and Welded
MIL-T-8606	18-8 Stabilized, Annealed	Seamless and Welded
AMS 5560	19 Cr 9 Ni Annealed	Seamless
AMS 5565	19 Cr 9 Ni Annealed	Welded
AMS 5570	18 Cr 11 Ni (Ti) Annealed	Seamless
AMS 5571	18 Cr 11 Ni (Cb+Ta) Annealed	Seamless
AMS 5572	25 Cr 20 Ni Annealed	Seamless
AMS 5573	17 Cr 12.5 Ni 2.5 Mo Annealed	Seamless
AMS 5574	23 Cr 13.5 Ni Annealed	Seamless
AMS 5575	18 Cr 11 Ni (Cb+Ta) Annealed	Welded
AMS 5576	18 Cr 10 Ni (Ti) Annealed	Welded
AMS 5577	25 Cr 20 Ni Annealed	Welded
AMS 5578	12.5 Cr 8.5 Ni 0.030 (Cb+Ta) 1.1 Ti 2.0 Cu Annealed	Seamless

Aircraft Hydraulic Line Tubing. Stainless steel tubing of the 300 Series, as 304, 321 and 347, is used widely in aircraft and aerospace vehicles for fuel injection lines and for hydraulic systems. Most of the tubing used for this application is in the smaller size range.

These applications necessitate tubing with high strength, high ductility, high fatigue resistance, high corrosion resistance and good working qualities. The ability to flare for use with standard flare fittings, ability to bend without excessive distortion or fracture and cleanliness of the inside surface are important requirements.

Aircraft stainless steel hydraulic line tubing is produced either annealed or in the 1/8 hard condition. The 1/8 hard condition is obtained by cold drawing and this temper is used wherever possible to effect savings in weight. Some specifications for aircraft stainless steel hydraulic line tubing, seamless and welded, are listed below:

Specification	Type
MIL-T-6845	304 – 1/8 Hard
MIL-T-8504	304 – Annealed
MIL-T-8808	321 or 347 – Annealed
AMS 5556	347 – Annealed
AMS 5557	321 – Annealed
AMS 5560	304 – Annealed
AMS 5566	304 – 1/8 Hard

Mechanical and Manipulative Testing

The following specialized tests (which apply only to tubular products and when specified or required by applicable specifications) are commonly made in accordance with ASTM A370, Mechanical Testing of Steel Products, including Annex A2, Steel Tubular Products.

Reverse Flattening Test. This test is designed primarily for application to electric welded tubing for the detection of flash overlaps and lack of weld penetration.

In this test, the sample is opened and flattened with the inside surface of the weld at the point of maximum bend.

Crush Test. This test, sometimes referred to as an upsetting test, is performed by longitudinally compressing a sample of the tube to collapse.

Flange Test. This test is made on a sample cut from a tube, and consists of having a flange turned over at right angles to the body of the tube to the width required by the applicable specification.

Flaring Test. This test consists of expanding a sample from the tube, or the end of the tube, with a tapered mandrel until the diameter has been increased to the extent required.

Bend Test. The bend test is bent at room temperature to an inside diameter, as designated by the applicable product specification, to the extent specified without major cracking on the outside of the bent portion.

Reverse Bend Test. This test consists of a specimen split longitudinally 90° each side of the weld, opened and bent around a mandrel having a diameter four times the wall thickness, with the mandrel parallel to the tube and on the outside of the tube. The weld is held at the point of maximum deformation.

Nondestructive Testing

Hydrostatic Testing. The hydrostatic test consists of filling the tube with test fluid and applying hydrostatic pressure. This test is prima-

rily a leak test and is not intended to bear a direct relationship to bursting pressures, working pressures or design data.

Air Testing. When air testing is performed in the tubular industry, it consists of subjecting the pipe or tube to air pressure under water.

Ultrasonic, Eddy Current and Liquid Penetrant Testing. For details concerning these non-destructive various specifications and producers of stainless steel tubular products should be consulted.

Tolerances

Tolerances listed in Tables 11-4 through 11-7 for stainless steel pipe, pressure tubing and mechanical tubing are those shown in applicable specifications, such as shown as follows.

For square and rectangular tubing, the producer should be consulted for tolerances for outside dimensions, radii of corners, twist and squareness of sides.

<i>Product</i>	<i>ASTM</i>
Pressure Tubing	A213 (Seamless)
	A249 (Welded)
	A268 (Seamless and Welded)
	A269 (Seamless and Welded)
	A270 (Seamless and Welded)
	A271 (Seamless)
Pressure Pipe	A312 (Seamless and Welded)
	A358 (Welded)
	A376 (Seamless)
	A409 (Welded)
Mechanical Tubing	A511 (Seamless)
	A544 (Welded)
General Requirements	A450 (Tubes)
	A530 (Pipe)

Table 11-1

SPECIFICATIONS FOR STAINLESS STEEL TUBULAR PRODUCTS

Agency	Specification	Title
Boiler and Superheater Tubes		
ASTM	A213	Seamless Ferritic and Austenitic Alloy Steel Boiler, Superheater and Heat Exchanger Tubes
ASME	SA-213	
ASTM	A249	Welded Austenitic Steel Boiler, Superheater, Heat Exchanger and Condenser Tubes
ASME	SA-249	
Still Tubes (Refinery Service)		
ASTM	A271	Seamless Austenitic, Chromium-Nickel Steel Still Tubes for Refinery Service
Heat Exchanger and Condenser Tubes		
ASTM	A213	Seamless Ferritic and Austenitic Alloy Steel Boiler, Superheater and Heat Exchanger Tubes
ASME	SA-213	
ASTM	A249	Welded Austenitic Steel Boiler, Superheater, Heat Exchanger and Condenser Tubes
ASME	SA-249	
ASTM	A498	Seamless and Welded Carbon, Ferritic and Austenitic Alloy Steel Heat Exchanger Tubes with Integral Fins
Fuel and Hydraulic Line Tubing		
USA	MIL-T-6845	Tubing, Steel, Corrosion-Resistant (304) Aerospace Vehicle Hydraulic System, 1/8 Hard Condition
USA	MIL-T-8504	Tubing, Steel, Corrosion-Resistant (304) Aerospace Vehicle Hydraulic Systems, Annealed, Seamless and Welded
USA	MIL-T-8808	Tubing, Steel, Corrosion Resistant (18-8 Stabilized), Aircraft Hydraulic Quality (ASG)
AMS	AMS 5556	Steel Tubing, Corrosion and Heat Resistant 18Cr - 11Ni - (Cb + Ta), Hydraulic
AMS	AMS 5557	Steel Tubing, Corrosion and Heat Resistant, 18Cr - 11Ni - Ti (SAE 30321) Hydraulic
AMS	AMS 5560	Steel Tubing, Seamless, Corrosion Resistant, 19Cr - 10Ni (SAE 30304)
AMS	AMS 5566	Steel Tubing, Seamless or Welded, Corrosion Resistant, 19Cr - 10Ni (SAE 30304) High Pressure Hydraulic
Mechanical Tubing		
ASTM	A511	Seamless Stainless Steel Mechanical Tubing
ASTM	A554	Welded Stainless Steel Mechanical Tubing
General Service Tubing		
ASTM	A268	Seamless and Welded Ferritic Stainless Steel Tubing for General Service
ASME	SA-268	
ASTM	A269	Seamless and Welded Austenitic Stainless Steel Tubing for General Service
Pipe		
ASTM	A312	Seamless and Welded Austenitic Steel Pipe
ASME	SA-312	
ASTM	A358	Electric-Fusion-Welded Austenitic Chromium-Nickel-Alloy Steel Pipe for High-Temperature Service
ASME	SA-358	
ASTM	A376	Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service
ASME	SA-376	

Table 11-1 (Continued)

Organizations Represented

<i>Initials</i>	<i>Name and Address</i>	<i>Specification Symbol</i>
ASTM	ASTM 100 Barr Harbor Drive W. Conshohocken, PA 19428-2959	A
ASME	American Society of Mechanical Engineers Boiler and Pressure Vessel Code 345 East 4 th Street New York, NY 10017	SA
AAR	Association of American Railroads 59 East Van Buren Street Chicago, IL 60605	AAR
NFPA	National Fluid Power Association P.O. Box 49 Thiensville, WI 53093	T
SAE	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, PA 15096	J
AMS(SAE)	Aerospace Material Specifications Society of Automotive Engineers 400 Commonwealth Drive Warrendale, PA 15096	AMS
USA	United States Government Military MIL Federal Defense Printing Service Standardization Documents Ordering Desk 700 Robbins Avenue, Bldg. 4D Philadelphia, PA 19111	QQ and WW
ANSI	American National Standards Institute 1430 Broadway New York, NY 10018	ANS

Table 11-2

**NOMINAL WEIGHTS
SEAMLESS AND WELDED PIPE^a
STAINLESS AND HEAT RESISTING STEELS**

The weights given in this table are in pounds per linear foot (kilograms per meter) and are for carbon steel pipe with plain ends. The different grades of stainless steel permit considerable variations in weight. The ferritic stainless steels may be about 5 percent less and the austenitic stainless steels about 2 percent greater than the values shown in this table.

<i>Nominal Pipe Size, in. (mm)</i>		<i>Schedule 5S</i>	<i>Nominal Weights of Carbon Steel Pipe, Plain Ends</i>		
			<i>Schedule 10S</i>	<i>Schedule 40S</i>	<i>Schedule 80S</i>
1/8	(3.18)		0.19 (0.28)	0.24 (0.36)	0.31 (0.46)
1/4	(6.35)		0.33 (0.49)	0.42 (0.62)	0.54 (0.80)
3/8	(9.52)		0.42 (0.62)	0.57 (0.85)	0.74 (1.10)
1/2	(12.7)	0.54 (0.80)	0.67 (1.00)	0.85 (1.26)	1.09 (1.62)
3/4	(19.1)	0.69 (1.03)	0.86 (1.28)	1.13 (1.68)	1.47 (2.19)
1	(25.4)	0.87 (1.29)	1.40 (2.08)	1.68 (2.50)	2.17 (3.23)
1 1/4	(31.8)	1.11 (1.65)	1.81 (2.69)	2.27 (3.38)	3.00 (4.46)
1 1/2	(38.1)	1.28 (1.90)	2.09 (3.11)	2.72 (4.05)	3.63 (5.40)
2	(50.8)	1.61 (2.40)	2.64 (3.93)	3.65 (5.43)	5.02 (7.47)
2 1/2	(63.5)	2.48 (3.69)	3.53 (5.25)	5.79 (8.62)	7.66 (11.40)
3	(76.2)	3.03 (4.51)	4.33 (6.44)	7.58 (11.28)	10.25 (15.25)
3 1/2	(88.9)	3.48 (5.18)	4.97 (7.40)	9.11 (13.56)	12.51 (18.62)
4	(102)	3.92 (5.83)	5.61 (8.35)	10.79 (16.06)	14.98 (22.29)
5	(127)	6.36 (9.46)	7.77 (11.56)	14.62 (21.76)	20.78 (30.92)
6	(152)	7.60 (11.31)	9.29 (13.82)	18.97 (28.23)	28.57 (42.52)
8	(203)	9.93 (14.77)	13.40 (19.94)	28.55 (42.49)	43.39 (64.57)
10	(254)	15.19 (22.60)	18.65 (27.75)	40.48 (60.24)	54.74 (81.46)
12	(305)	20.98 (31.22)	24.17 (35.97)	49.56 (73.75)	65.42 (97.36)

^aANSI B36.19.

Table 11-3

DIMENSIONS OF WELDED AND SEAMLESS STAINLESS STEEL PIPE^A

ASTM A813/A813M

Note 1 — Table 1 is based on Table 1 of the American National Standard for Stainless Steel Pipe (ANSI B36.19-1965).

Note 2 — The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
	in.	mm	Schedule 5S ^B		Schedule 10SB		Schedule 40S		Schedule 80S	
			in.	mm	in.	mm	in.	mm	in.	mm
1/8	0.405	10.29	—	—	0.049 ^C	1.24	0.068	1.73	0.095	2.41
1/4	0.540	13.72	—	—	0.065 ^C	1.65	0.088	2.24	0.119	3.02
3/8	0.675	17.15	—	—	0.065 ^C	1.65	0.091	2.31	0.126	3.20
1/2	0.840	21.34	0.065 ^C	1.65	0.083 ^C	2.11	0.109	2.77	0.147	3.73
3/4	1.050	26.67	0.065 ^C	1.65	0.083 ^C	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065 ^C	1.65	0.109 ^C	2.77	0.133	3.38	0.179	4.55
1 1/4	1.660	42.16	0.065 ^C	1.65	0.109 ^C	2.77	0.140	3.56	0.191	4.85
1 1/2	1.900	48.26	0.065 ^C	1.65	0.109 ^C	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065 ^C	1.65	0.109 ^C	2.77	0.154	3.91	0.218	5.54
2 1/2	2.875	73.03	0.083	2.11	0.120 ^C	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120 ^C	3.05	0.216	5.49	0.300	7.62
3 1/2	4.000	101.60	0.083	2.11	0.120 ^C	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120 ^C	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109 ^C	2.77	0.134 ^C	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134 ^C	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109 ^C	2.77	0.148 ^C	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134 ^C	3.40	0.165 ^C	4.19	0.365	9.27	0.500 ^C	12.70 ^C
12	12.750	323.85	0.156 ^C	3.96	0.180 ^C	4.57	0.375 ^C	9.52 ^C	0.500 ^C	12.70 ^C
14	14.000	355.60	0.156 ^C	3.96	0.188	4.78	—	—	—	—
16	16.000	406.40	0.165 ^C	4.19	0.188	4.78	—	—	—	—
18	18.000	457.20	0.165 ^C	4.19	0.188	4.78	—	—	—	—
20	20.000	508.00	0.188 ^C	4.78	0.218 ^C	5.54	—	—	—	—
22	22.000	558.80	0.188 ^C	4.78	0.218 ^C	5.54	—	—	—	—
24	24.000	609.60	0.218 ^C	5.54	0.250	6.35	—	—	—	—
30	30.000	762.00	0.250	6.35	0.312	7.92	—	—	—	—

^AFor pipe sizes not listed, the dimensions and tolerances shall be by agreement between the purchaser and producer.

^BSchedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).

^CThese do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10-1979).

Table 11-4

PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETER^A
PRESSURE TUBING

ASTM A 450/A 450M

Outside Diameter, in. [mm]	Permissible Variations, in. [mm]	
	Over	Under
Hot-Finished Seamless Tubes		
4 [101.6] and under	1/64 [0.4]	1/32 [0.8]
Over 4 to 7 1/2 [101.6 to 190.5], incl.	1/64 [0.4]	3/64 [1.2]
Over 7 1/2 to 9 [190.5 to 228.6], incl.	1/64 [0.4]	1/16 [1.6]
Welded Tubes and Cold-Finished Seamless Tubes		
Under 1 [25.4]	0.004 [0.1]	0.004 [0.1]
1 to 1 1/2 [25.4 to 38.1], incl.	0.006 [0.15]	0.006 [0.15]
Over 1 1/2 to 2 [38.1 to 50.8], excl.	0.008 [0.2]	0.008 [0.2]
2 to 2 1/2 [50.8 to 63.5], excl.	0.010 [0.25]	0.010 [0.25]
2 1/2 to 3 [63.5 to 76.2], excl.	0.012 [0.3]	0.012 [0.3]
3 to 4 [76.2 to 101.6], incl.	0.015 [0.38]	0.015 [0.38]
Over 4 to 7 1/2 [101.6 to 190.5], incl.	0.015 [0.38]	0.025 [0.64]
Over 7 1/2 to 9 [190.5 to 228.6], incl.	0.015 [0.38]	0.045 [1.14]

^AThese permissible variations include out-of-roundness. These permissible variations in outside diameter apply to hot-finished seamless, welded and cold-finished seamless tubes before other fabricating operations such as upsetting, swaging, expanding, bending, or polishing.

Table 11-5

PERMISSIBLE VARIATIONS IN WALL THICKNESS^A
PRESSURE TUBING

ASTM A450/A450M

Outside Diameter, in. [mm]	Wall Thickness, %							
	0.095 [2.4] and Under		Over 0.095 to 0.150 [2.4 to 3.8], incl.		Over 0.150 to 0.180 [3.8 to 4.6], incl.		Over 0.180, [4.6]	
	Over	Under	Over	Under	Over	Under	Over	Under
Seamless, Hot-Finished Tubes								
4[101.6] and under Over 4 [101.6]	40	0	35	0	33	0	28	0
	—	—	35	0	33	0	28	0
Seamless, Cold-Finished Tubes								
	Over				Under			
1 1/2 [38.1] and under Over 1 1/2 [38.1]	20				0			
	22				0			
Welded Tubes								
All sizes	18				0			

^AThese permissible variations in wall thickness apply only to tubes, except internal-upset tubes, as rolled or cold-finished, and before swaging, expanding, bending, polishing, or other fabricating operations.

Table 11-6

PERMISSIBLE VARIATIONS IN LENGTH^A
PRESSURE TUBING

ASTM A450/A450M

Method of Manufacture	Outside Diameter, in. [mm]	Cut Length, in. [mm]	
		Over	Under
Seamless, hot-finished	All sizes	3/16 [5]	0 [0]
Seamless, cold-finished	Under 2 [50.8]	1/8 [3]	0 [0]
	2 [50.8] and over	3/16 [5]	0 [0]
Welded	Under 2 [50.8]	1/8 [3]	0 [0]
	2 [50.8] and over	3/16 [5]	0 [0]

^AThese permissible variations in length apply to tubes before bending. They apply to cut lengths up to and including 24 ft. [7.3 m]. For lengths greater than 24 ft. [7.3 m], the above over-tolerances shall be increased by 1/8 in. [3 mm] for each 10 ft. [3 m] or fraction thereof over 24 ft. or 1/2 in. [13 mm], whichever is the lesser.

Table 11-7

PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETER, OVALITY, WALL THICKNESS, AND CUT-LENGTH VARIATIONS (COLD-FINISHED ROUND TUBING)^A
MECHANICAL TUBING

ASTM A511

Outside Diameter, in.	Outside Diameter, Tolerance, ^B in. Over and Under	Ovality, ^B Double Outside Diameter Tolerance when wall is:	Wall Thickness in % ^{C,D}		Permissible Variations in Cut Length, in. ^E	
			Over	Under	Over	Under
Under ½	0.005	less than 0.015 in.	15	15	1/8	0
½ to 1 ½, excl..	0.005	less than 0.065 in.	10	10	1/8	0
1 ½ to 3 ½, excl..	0.010	less than 0.095 in.	10	10	3/16	0
3 ½ to 5 ½, excl.	0.015	less than 0.150 in.	10	10	3/16	0
5 ½ to 8, excl.	0.030	less than 0.240 in.	10	10	3/16	0
8 to 8 5/8, excl.	0.045	less than 0.300 in.	10	10	3/16	0
8 5/8 to 12 ¾ incl.	0.062	less than 0.350 in.	10	10	3/16	0

^ATolerances of tubes produced by the rod or bar mandrel process and which have an inside diameter under ½ in. (12.7 mm) (or an inside diameter under 5/8 in. (15.8mm) when the wall thickness is more than 20% of the outside diameter) are as shown in this table, except that wall thickness tolerances are 10% over and under the specified wall thickness.

^BFor ovality values, the tolerance for average outside diameter at any one cross section does not exceed the outside diameter tolerance value for the applicable outside diameter.

^CMany tubes with wall thicknesses more than 25% of outside diameter or with wall thicknesses over 1 ¼ in. (31.7 mm) or weighing more than 90 lb/ft, are difficult to draw over a mandrel. Therefore, the wall thickness can vary 12 ½ % over and under that specified. Also see Footnote (B).

^DFor those tubes with inside diameter under ½ in. (12.7 mm) (or under 5/8 in. (15.8 mm) when the wall thickness is more than 20% of the outside diameter) which are not commonly drawn over a mandrel, Footnote (A) is not applicable. Therefore, the wall thickness can vary 15% over and under that specified, and the inside diameter is governed by both the outside diameter and wall thickness tolerances.

^EThese tolerances apply to cut lengths up to and including 24 ft. (7.3 m). For lengths over 24 ft., an additional over tolerance of 1/8 in. (3.1 mm) for each 10 ft. (3 m) or fraction thereof shall be permissible, up to a maximum tolerance of ½ in. (12.7 mm).

Table 11-8

**PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETER, WALL THICKNESS, AND CUT-LENGTH VARIATIONS
(HOT-FINISHED ROUND TUBING)
MECHANICAL TUBING**

ASTM A511

Specified Size, Outside Diameter, in.	Ratio of Wall Thickness to Outside Diameter	Outside Diameter and Wall Thickness Tolerances										Permissible Variations in Cut Length, in. ^A	
		Outside Diameter, in.		Wall Thickness, %									
				0.109 in. and under		0.109 to 0.172 in., incl		Over 0.172 to 0.203 in., incl		Over 0.203 in.			
		over	under	over	under	over	under	over	under	over	under		
Under 3	all wall thicknesses	0.023	0.023	16.5	16.5	15	15	14	14	12.5	12.5	3/16	0
3 to 5 ½, excl.	all wall thicknesses	0.031	0.031	16.5	16.5	15	15	14	14	12.5	12.5	3/16	0
5 ½ to 8, excl.	all wall thicknesses	0.047	0.047	—	—	—	—	14	14	12.5	12.5	3/16	0
8 to 10 ¾, excl.	5% and over	0.047	0.047	—	—	—	—	—	—	12.5	12.5	3/16	0
10 ¾ to 12 ¾, incl.	under 5%	0.063	0.063	—	—	—	—	—	—	12.5	12.5	3/16	0

^AThese tolerances apply to cut lengths up to and including 24 ft. (7.3 m). For lengths over 24 ft., an additional over tolerance of 1/8 in. (3.1 mm) for each 10 ft. (3m) or fraction thereof shall be permissible, up to a maximum tolerance of 1/2 in. (12.7 mm).

Table 11-9

DIAMETER, WALL,^A AND OVALITY TOLERANCES FOR TUBING WITH BEAD REMOVED MECHANICAL TUBING

ASTM A554

Note 1 — Ovality is the difference between maximum and minimum outside diameters measured at any one cross section. There is no additional tolerance for ovality on tubes having a nominal wall thickness of more than 3% of the outside diameter.

Note 2 — An ovality allowance of twice the outside diameter tolerance, shown in this table, is applied one half plus and one half minus to the outside diameter, for tubes having a nominal wall thickness of 3% or less of the outside diameter. The average of the maximum and minimum outside diameter readings should fall within the outside diameter tolerances of this table.

Note 3 — Tubing may be specified to only two of the three following dimensions—outside diameter, inside diameter, or wall.

OD Size, in. (mm)	OD, $\pm$		ID, $\pm$	
	in.	mm	in.	mm
Up to 3/32 (2.4), excl.	0.001	0.03	0.001	0.03
3/32 to 3/16 (2.4 to 4.8), excl.	0.0015	0.038	0.0015	0.038
3/16 to 1/2 (4.8 to 12.7), excl.	0.003	0.08	0.005	0.13
1/2 to 1 (12.7 to 25.4), excl.	0.004	0.10	0.006	0.15
1 to 1 1/2 (25.4 to 38.1), excl.	0.005	0.13	0.007	0.18
1 1/2 to 2 (38.1 to 50.8), excl.	0.006	0.15	0.008	0.20
2 to 2 1/2 (50.8 to 63.5), excl.	0.007	0.18	0.010	0.25
2 1/2 to 3 1/2 (63.5 to 88.9), excl.	0.010	0.25	0.014	0.36
3 1/2 to 5 (88.9 to 127.0), incl.	0.015	0.38	0.020	0.51
Over 5 to 16 (127.0 to 406.4), incl.	0.00125 in./in. or mm/mm of circumference		0.0013 in./in. or mm/mm of circumference	

^AWall tolerance is $\pm 10\%$ of nominal wall thickness.

Table 11-10

LENGTH VARIATIONS—CUT LENGTH TUBES MECHANICAL TUBING

ASTM A554

Length, ft. (m)	Outside Diameter, in. (mm)	Permissible Variations in Length, in.		
		Over ^A		Under
		in.	mm	
4(1.2) and under	up to 2 (50.8), incl.	1/16	1.6	0
	over 2 to 4 (50.8 to 101.6), incl.	3/32	2.4	0
	over 4 (101.6)	1/8	3.2	0
Over 4 to 10 (1.2 to 3.0), incl.	up to 2 (50.8), incl.	3/32	2.4	0
	over 2 (50.8)	1/8	3.2	0
Over 10 to 24 (3.0 to 7.3), incl.	all sizes	3/16	4.8	0

^AFor all diameters in lengths over 24 ft. (7.3 m), an additional over tolerance of 1/8 in. (3.2 mm) for each 10 ft. (3.0 m) or fraction thereof shall be permissible, up to a tolerance of 1/2 in. (12.7 mm), max.

Table 11-11

PERMISSIBLE VARIATIONS IN OUTSIDE DIMENSIONS FOR SQUARE AND RECTANGULAR SEAMLESS MECHANICAL TUBING^{AB}

ASTM A511

Largest Outside Dimension Across Flats, in.	Tolerances, Outside Dimension Seamless Mechanical Tubing Plus and Minus, in.	
	For Wall Thickness, Given, in.	Tolerance for Outside Dimension (Including Convexity or Concavity Plus and Minus, in.
To 3/4, incl.	0.065 and lighter	0.015
To 3/4, incl.	over 0.65	0.010
Over 3/4 to 1 1/4, incl.	all thicknesses	0.015
Over 1 1/4 to 2 1/2, incl.	all thicknesses	0.020
Over 2 1/2 to 3 1/2, incl.	0.065 and lighter	0.030
Over 2 1/2 to 3 1/2, incl.	Over 0.065	0.025
Over 3 1/2 to 5 1/2, incl.	all thicknesses	0.030
Over 5 1/2 to 7 1/2, incl.	all thicknesses	1%

^AThe wall thickness tolerance is plus and minus 10% of nominal wall thickness.^BThe straightness tolerance is 0.075 in. 3 ft. using a 3-ft. straight edge and feeler gage.

Table 11-12

LENGTH TOLERANCES FOR SQUARE AND RECTANGULAR MECHANICAL TUBING

ASTM A511

Length tolerance on exact lengths of tubing (all types), in.	+ 3/8, - 0
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Appendix I

TYPICAL APPLICATIONS OF SELECTED STAINLESS STEELS

<u>Type</u>	<u>Application</u>	<u>Type</u>	<u>Application</u>
201	air bag containers		bulk milk coolers
201L	automobile wheel covers		candy making equipment
	automotive trim		cheese manufacturing equipment
	cookware bodies and lids		coal hoppers
	flatware		cooking utensils
	hose clamps		cosmetics processing
	piston rings		dairy equipment
	thermal window spacers		deep-drawn sugar bowls, creamers and shallow-drawn trays
	transit car roofing and siding		door plates
	transit car structural members		food processing and packing equipment
	truck trailer posts and door frames		food serving and handling equipment
	washing machine baskets		gasoline tanks
202	children's slide		hinges
	cooking utensils; pots and pans		hosiery forms
	electric range part stamping		hospital equipment
	hub cap		household appliances
	milk handling; storage and pasteurizing equipment		ice cream freezers
	rail car, truck trailer		institution equipment
	sink, counter top		jewelry
	window flashing		laundry and dry cleaning equipment
205	cryogenic applications		meat packing equipment
	non-magnetic applications		milk dispensers
301	automotive trim		oil refining equipment
	automotive wheel covers		packaging machinery
	button and snaps for work clothing		pharmaceutical equipment
	conveyor belts		plumbing fixtures and fittings
	door plates		press plates
	fasteners		racks to hold concrete building blocks during curing
	pole line hardware		refrigeration equipment
	roof drainage components		soda fountain equipment
	stressed sheet and strip applications		sheet metal products
	structural members where high strength is required; aircraft, rail cars, trucks and bodies		signs
302	animal cages		sports equipment
	architectural trim		switchboard panels
	architectural exteriors	302B	heat resisting parts such as heat treating fixtures, radiant tube heating elements, annealing boxes, tube supports, for resistance to oxidation at temperatures up to 1700°F (926°C), but not over 1600° (871°C) for intermittent service involving rapid cooling
	baby bottle warmers and sterilizers		For service at both intermittent and continuous temperatures up to about 1600°F (871°C); annealing covers, burner sections, furnace parts
	baking equipment		
	beverage equipment		
	bottling machinery		
	brewing equipment		
	basket assemblies for automatic washers		
	broilers		

<u>Type</u>	<u>Application</u>	<u>Type</u>	<u>Application</u>
303	bolts bushings nuts parts produced on automatic screw machines and other machine tool equipment shafts salt water spinning reels for surf casting	305	coffee urn tops cold drawing in two drawing stages expanded metal parts free spinning and cold heading operations mixing bowls reflectors
303Se	aircraft fittings bolts forged or swaged parts nuts parts produced on automatic screw machine and other machine tool equipment rivets screws studs (The machinability of Type 303Se is slightly lower than Type 303, but 303Se has better hot and cold forming capability)	308	furnaces, industrial sulfite liquor at high temperatures welding rod
304	appliances architectural trim beer barrels beer fermentation tanks beer storage tanks chemical processing equipment consumer products corn products refinery equipment dairy equipment, including heads and bottoms fasteners floor plates gutters, downspout and flashing hospital equipment kitchen equipment liquid oxygen, nitrogen and hydrogen tanks parts for dispensers of some carbonated beverages still tubes vessels and other equipment for nuclear power plants waste water treatment equipment wire cloth and screens (industrial)	309	air heaters annealing boxes baffle plates boiler baffles chemical equipment dryers dye house equipment fire box sheets furnace arch supports furnace skids heat exchangers heat treating trays kiln linings oil burner parts oil refining equipment oven linings paper mill equipment pump parts rolls for roller hearth furnaces still tube supports tube hangers wire cloth and screens (industrial)
304L	lining for coal hoppers liquid fertilizer spray tanks nitric acid processing equipment tomato paste storage tanks wire cloth and screens (industrial) (For use when lower carbon content than that of Type 304 is needed to restrict carbide precipitation resulting from welding, particularly when parts cannot be annealed after welding)	309S	When lower carbon content than that of Type 309 is needed to restrict carbide precipitation resulting from welding or other fabrication operations and when the completed structure is subjected to moist corrosive conditions
304H	power plant superheater boiler tubing	310	air heaters annealing boxes baking oven equipment boiler baffles carburizing boxes carburizing and reducing environments dye house equipment fire box sheets furnace arch supports furnace castings furnace conveyors and supports furnace linings furnace stacks and dampers gas turbine parts heat exchangers incinerators industrial oven linings kiln linings nitrate crystallizing pans

<u>Type</u>	<u>Application</u>	<u>Type</u>	<u>Application</u>
	nozzle diaphragm assemblies for turbojet engines		flexible couplings
	oil burner parts		furnace heating elements
	oil refinery equipment		jet engine parts
	paper mill equipment		large mufflers for stationery diesel engines
	recuperators		pressure vessels
	rolls for roller hearth furnaces		stack liners
	soot blower tubing	347	For welded construction and parts subjected to heating in the carbide precipitation range
	tube hangers		airplane exhaust stacks
	wire cloth and screens (industrial)		all-welded tank car for carrying chemicals
310S	When lower carbon content than that of Type 310 is needed to restrict carbide precipitation resulting from welding jet engine rings		annealing box inner covers
			collector rings
			expansion joints
			fasteners
314	annealing boxes		heat resistors
	carburizing boxes		heavy wall welded equipment
	heat treating fixtures		jet engine parts
	radiant tubes		welded tanks for storing organic chemicals
			wire cloth and screens (industrial)
316	acetic acid compounds	348	Welded and seamless tubes and welded and seamless pipe for radioactive system service
	brandy vats		
	corn products refining equipment	384	cold headed bolts, rivets, screws, upset and punched nuts
	fasteners		instrument parts
	kettles for cooking ketchup		parts involving coining, extrusion and swaging
	pharmaceutical processing equipment	403	highly stressed sections in gas turbines
	phosphate industry parts		jet engine rings
	photographic film processing equipment		turbine blades subjected to corrosion, abrasive wear and wet erosion
	pitting-corrosion resistance		
	pulp and paper processing equipment	405	annealing boxes
	smokestacks		oxidation-resistant partitions
	textile finishing equipment		quenching racks
	textile mill kiers		
	water softener tanks	409	automotive exhaust systems, including mufflers, resonators, silencers, pipes and emission control units
	wire cloth and screens (industrial)		dry fertilizer spreaders
	yeast tubes		fins for heater tubes
316L	When lower carbon content than that of Type 316 is needed to restrict carbide precipitation resulting from welding, particularly when part cannot be annealed after welding		fuel filters
			gas turbine exhaust silencers
317	dyeing equipment		heat exchangers
	flue gas desulfurization units		high pressure agricultural spray tanks
	ink manufacturing equipment		smoke control duct work
	pitting-corrosion resistance		transformer and capacitor cases
	pulp and paper processing equipment	410	applications requiring good resistance to scaling at elevated temperatures, such as furnace parts and burners operating below 1200°F (648 °C)
321	For welded construction and parts subjected to heating in the carbide precipitation range		beater bars for paper mills
	aircraft collector rings		bolts
	aircraft exhaust stacks		bushings
	boiler casings		coal bunker linings
	cabin heaters		coal chutes
	carburetor air intensifier tubes		coal screens
	exhaust manifolds		cutlery
	fasteners		
	fire walls		
	flash boilers		

<u>Type</u>	<u>Application</u>	<u>Type</u>	<u>Application</u>
	dam gate rollers and tracks	416Se	Free machining, for cuts lighter than those used on Type 416, and when hot working or cold heading may be performed
	fasteners		
	fishing tackle		
	gage parts		
	gun cleaners		
	hand tools		
	hardware		
	jet engine rings		
	keys		
	lamp brackets		
	lining for reaction chamber		
	locomotive safety valve seats		
	low temperature annealing furnace parts		
	micrometer parts		
	mining machinery		
	nuts		
	oil burner parts		
	parts for valves for oil field use		
	press plates		
	pump shafting		
	railroad equipment		
	rifle barrels		
	roofing materials		
	scissors		
	screens		
	shutter screens in water wells		
	spindles		
	steam turbine parts		
	trays, supports, caps and vapor risers in petroleum fractionating towers		
	valve parts		
	valve stems		
	valves		
	wire cloth and screens (industrial)		
414	beater bars		
	bells for ships		
	bolts		
	gage parts		
	hardware		
	mining equipment		
	scissors		
	spindles		
	valve seats		
416	aircraft fittings		
	bolts		
	fire extinguisher inserts		
	forged and swaged parts		
	free machining, for cuts heavier than those used on Type 410		
	machined parts		
	non-seizing and non-galling applications		
	nuts		
	products machined on automatic screw machines		
	rivets		
	screws		
	studs		
		420	applications involving high spring tempers cutlery flatware knife blades glass molds hand tools magnets shafts surgical instruments valves vegetable choppers
		420F	Similar to those of Type 420 when somewhat better machinability is necessary
		429	nitric acid equipment nitrogen fixation equipment
		430	architectural decorative applications (interior) for bank vaults, safety deposit box doors, stair and cafeteria railings, moldings, screens automotive trim or molding builder's hardware combustion chamber liners for diesel engines combustion chambers decorative trim dishwashers fasteners gas burners on domestic heating units gasoline powered automobile engines gutters and downspouts heaters hinges ice cream cabinet tops kitchen equipment kitchen trim mufflers nitric acid plant equipment nitrogen fixation apparatus oil burner parts oil refinery equipment press plates pyrometer protection tubes range hoods recuperators roofing and siding panels restaurant equipment rubber plant machinery rubbish burners scientific apparatus soot blowers stove tops tanks tobacco machinery tubing wire cloth and screens (industrial)

<u>Type</u>	<u>Application</u>	<u>Type</u>	<u>Application</u>
430F	Similar to those for Type 430, when somewhat better machinability is necessary	442	combustion chambers furnace parts nozzles
431	aircraft stressed members having high yield strength and shock resistance structural components exposed to marine environments	446	annealing boxes baffle plates burning points combustion chambers on oil-fired domestic heating units furnace parts glass molds heaters
434	automotive trim and fasteners to resist atmospheric corrosion in the presence of winter road conditioning and dust-laying compounds		High temperature applications when resistance to oxidation is required and strength at temperature is not important; when strength at temperature is important, Type 310 may be considered
436	automotive trim to resist atmospheric corrosion in the presence of winter road conditioning and dust-laying compounds		kiln linings oil burner parts pyrometer tubes recuperators stirring rods valves and fittings wire cloth and screens (industrial)
440A	cutlery dental and surgical instruments permanent magnets pivot pins valve parts		
440B	cutlery hardened balls instrument bearings permanent magnets valve parts wear resisting parts		
440C	ball check valves ball studs balls and seats for oil well pumps bearing balls bearing races bushings cutlery instrument bearings needle valves nozzles pump parts valve seats wear-resistant textile components		

Appendix II

ASTM STAINLESS STEEL STANDARDS

Specifications

A167	Plate, sheet and strip, chromium-nickel	A453	Bolting materials, high temperature, 50 to 120 ksi yield strength with expansion coefficients comparable to austenitic steels
A176	Plate, sheet and strip, chromium	A473	Forgings
A182	Forged flanges, fittings and valves	A478	Weaving wire, chromium-nickel
A193	Bolts	A479	Bars and shapes for use in boilers and other pressure vessels
A194	Nuts	A480	General requirements for plate, sheet and strip
A213	Seamless ferritic and austenitic alloy boiler, superheater and heat exchanger tubes	A484	General requirements for bars, billets and forgings
A217	Castings, martensitic stainless and alloy	A487	Castings suitable for pressure service, martensitic
A240	Plate, sheet and strip for pressure vessels	A492	Rope wire
A249	Tubes, welded boiler, superheater, heat-exchanger and condenser, austenitic	A493	Cold heading and cold forging bar and wire
A263	Clad plate, sheet and strip, chromium	A498	Seamless and welded carbon, ferritic and austenitic alloy heat exchanger tubes with integral fins
A264	Clad plate, sheet and strip, chromium-nickel	A511	Seamless mechanical tubing
A268	Tubing, seamless and welded, ferritic	A530	Specialized carbon and alloy steel pipe, general requirements
A269	Tubing, seamless and welded, austenitic	A554	Welded mechanical tubing
A270	Sanitary tubing, austenitic	A555	General requirements for wire and wire rods
A271	Still tubes for refinery service, seamless, austenitic	A564	Bars and shapes, hot-rolled and cold-finished, age hardening
A276	Bars and shapes	A565	Bars, forgings and forging stock for high temperature service, martensitic
A297	Castings, iron-chromium, iron-chromium-nickel, heat resistant, for general application	A579	Superstrength alloy forgings
A312	Pipe, austenitic	A580	Wire
A313	Spring wire, chromium-nickel	A581	Wire, free-machining
A314	Bars and billets for forging	A582	Bars, hot-rolled or cold-finished, free-machining
A320	Bolting for low temperature service	A608	Centrifugally cast iron-chromium nickel high alloy tubing for pressure application at high temperatures
A336	Forgings for pressure and high temperature parts	A632	Seamless and welded tubing, small diameter, for general service, austenitic
A351	Castings for pressure-containing parts, austenitic, austenitic-ferritic (duplex)	A638	Iron-base superalloy bars, forgings and forging stock for high temperature service, precipitation hardening
A352	Castings for pressure-containing parts suitable for low temperature service, ferritic and martensitic	A666	Sheet, strip, plate and flat bar, for structural and architectural applications, austenitic
A356	Heavy-walled castings for steam turbines	A688	Welded feedwater heater tubes, austenitic
A358	Electric fusion welded pipe, austenitic	A693	Plate, sheet and strip, precipitation hardening
A368	Wire strand	A705	Forgings, age hardening
A376	Pipe for high-temperature central station service, austenitic	A733	Welded and seamless carbon steel and austenitic stainless steel pipe nipples
A403	Pipe fittings	A743	Castings, iron-chromium, iron-chromium-nickel and nickel-base, corrosion resistant, for general service
A409	Welded large diameter pipe, austenitic	A744	Castings, iron-chromium-nickel, for severe service
A426	Centrifugally-cast pipe, ferritic	A747	Castings, precipitation hardening
A430	Forged and bored pipe, austenitic		
A437	Alloy steel turbine-type bolting material specially heat treated for high temperature service		
A447	Castings for high temperature service, chromium-nickel-iron		
A450	General requirements for tubes, austenitic and ferritic		
A451	Centrifugally cast austenitic steel pipe for high temperature service		

- A756 Anti-friction bearing steel
- A757 Castings, ferritic and martensitic for pressure-containing and other applications for low temperature service
- A771 Tubing for breeder reactor core components, austenitic
- A774 As-welded fittings for general corrosive service at low and moderate temperatures, austenitic
- A778 Welded tubular products, unannealed austenitic
- A781 Castings, common requirements for general industrial use
- A789 Seamless and welded tubing for general service, ferritic/austenitic
- A790 Seamless and welded pipe, ferritic/austenitic
- A791 Welded tubing, unannealed ferritic
- A793 Rolled floor plate, austenitic
- A803 Welded feedwater heater tubes, ferritic
- A813 Single-or double-welded pipe, austenitic
- A814 Cold-worked welded pipe, austenitic
- A815 Pipe fittings, ferritic, ferritic/austenitic and martensitic
- A826 Duct tubes for breeder reactor core components, austenitic and ferritic
- A831 Bars, billets and forgings for use in core components
- A851 High-frequency, induction-welded condenser tubes, austenitic
- A872 Centrifugally cast pipe for corrosive environments, ferritic/austenitic
- A887 Borated stainless steel plate, sheet and strip for nuclear applications
- A890 Castings, iron-chromium-nickel-molybdenum, for general application, duplex (austenitic/ferritic)
- A891 Iron-base superalloy forgings for turbine rotor disks and wheels, precipitation hardening
- A895 Plate, sheet and strip, free machining
- A908 Needle tubing
- A928 Pipe, electric fusion welded with addition of filler metal, ferritic/austenitic (duplex)
- A943 Spray-formed seamless pipes, austenitic
- A946 Plate, sheet and strip, chromium-nickel-silicon alloy
- A947M Textured sheet
- A949 Spray-formed seamless pipe, ferritic/austenitic
- A953 Seamless and welded tubing, austenitic chromium-nickel-silicon alloy
- A954 Seamless and welded pipe, austenitic chromium-nickel-silicon alloy
- A955 Deformed and plain bars for concrete reinforcement
- A957 Investment castings, steel and alloy, common requirements for general industrial use
- A959 Guide for specifying harmonized standard grade compositions for wrought stainless steels
- A960 Common requirements for wrought steel pipe fittings
- A968 Bars and shapes, chromium-nickel-silicon alloy
- B163 Seamless nickel and nickel alloy condenser and heat exchanger tubes
- B366 Factory-made wrought nickel and nickel alloy fittings
- B407 Nickel-iron-chromium seamless pipe and tube
- B409 Nickel-iron-chromium plate, sheet and strip
- B462 Forged or rolled UNS N08020, N08024, N08026 and N08367 alloy pipe flanges, forged fittings, and valves and parts for corrosive high-temperature service
- B463 UNS N08020, N08024 and N08026 alloy plate, sheet and strip
- B464 Welded UNS N08020, N08024, and N08026 alloy pipe
- B468 Welded UNS N08020, N08024 and N08026 alloy tubes
- B471 UNS N08020, N08024 and N08026 alloy spring wire
- B472 UNS N08020, N08024, N08026, N08367, N08926 and R20033 nickel alloy billets and bars for reforging
- B473 UNS N08020, N08024 and N08026 nickel alloy bar and wire
- B474 Electric fusion welded UNS N08020, N08024 and N08026 nickel alloy pipe
- B475 UNS N08020, N08024 and N08026 nickel alloy round weaving wire
- B511 Nickel-iron-chromium-silicon alloy bars and shapes
- B512 Nickel-chromium-silicon alloy (N08330) billets and bars
- B514 Welded nickel-iron-chromium alloy pipe
- B515 Welded UNS N08800, N08810 and N08811 alloy tubes
- B535 Nickel-iron-chromium-silicon alloys (N08330 and N08332) seamless pipe and tube
- B546 Electric fusion welded Ni-Cr-Co-Mo alloy (N06617), Ni-Fe-Cr-Si alloys (N08330 and N08332), Ni-Cr-Fe alloy (N06025), and Ni-Cr-Fe-Si alloy (N06045) pipe
- B564 Nickel alloy forgings
- B599 Nickel-iron-chromium-molybdenum-columbium stabilized alloy (N08700) plate, sheet and strip
- B625 UNS N08904, N08925, N08031, N08932, N09926 and R20033 plate, sheet and strip
- B649 Ni-Fe-Cr-Mo-Cu low carbon alloy (N08904), Ni-Fe-Cr-Mo-Cu-N low carbon alloys (N08925, N08031 and N089260) and Cr-Ni-Fe-N low carbon alloy (R20033) bar and wire
- B672 Nickel-iron-chromium-molybdenum-columbium stabilized (N08700) bar and wire
- B673 UNS N08904, N08925, and N08926 welded pipe
- B674 UNS N08904, N08925 and N08926 welded tube
- B675 UNS N08366 and N08367 welded pipe
- B676 UNS N08366 and N08367 welded tube
- B677 UNS N08904, N08925 and N08926 seamless pipe and tube
- B688 Chromium-nickel-molybdenum-iron (N08366 and N08367) plate, sheet and strip
- B690 Iron-nickel-chromium-molybdenum alloys (N08366 and N08367) seamless pipe and tube
- B691 Iron-nickel-chromium-molybdenum alloys (N08366 and N08367) rod, bar and wire
- B710 Nickel-iron-chromium-silicon alloy welded pipe
- B729 Seamless UNS N08020, N08026 and N08024, nickel alloy pipe and tube

- B739 Nickel-iron-chromium-silicon alloy welded tube
- C795 Thermal insulation for use in contact with austenitic stainless steel
- E437 Industrial wire cloth and screens (square opening series)
- E454 Industrial perforated plate and screens (square opening series)
- E674 Industrial perforated plate and screens (round opening series)
- F55 Surgical implants, bar and wire
- F56 Surgical implants, sheet and strip
- F138 Surgical implants, bar and wire, special quality
- F139 Surgical implants, sheet and strip, special quality
- F352 Lock washers (surgical implants)
- F593 Bolts, hex cap screws and studs
- F594 Nuts
- F621 Forgings for surgical implants
- F642 Flexible wire for surgical fixations for soft tissue
- F738M Metric bolts, screws and studs
- F745 Shot/bar/ingot for cast/solution treated implants
- F836M Metric nuts
- F837 Socket head cap screws
- F879M Metric socket button and flat countersunk cap screws
- F880 Socket set screws
- F899 Billet, bar and wire for surgical instruments
- F1079 Inserted and noninserted surgical scissors
- F1314 Bar and wire for surgical implants, nitrogen-strengthened high manganese high chromium
- F1350 Surgical fixation wire

Practices

(ASTM Volume No. follows each entry)

- A262 Detecting susceptibility to attack in austenitic stainless steels **01.03, 01.05, 03.02**
- A380 Cleaning and descaling stainless steel parts, equipment and systems **01.03, 02.05**
- A609 Castings, carbon, low-alloy, and martensitic stainless steel, ultrasonic examination thereof **01.02**
- A700 Packaging, marking and loading methods for steel products for domestic shipment **01.01, 01.03, 01.04, 01.05**
- A745 Ultrasonic examination of austenitic steel forgings **01.05**
- A763 Detecting susceptibility to intergranular attack in ferritic stainless steels **01.03**
- A799 Instrument calibration for estimating ferrite content of stainless steel castings **01.02**
- A800 Estimating ferrite content of austenitic alloy steel castings **01.02**
- A880 Criteria for use in evaluation of testing laboratories and organizations for examination of steel, stainless steel and related alloys **01.03**
- A967 Chemical passivation treatments for stainless steel parts **01.03**
- B254 Preparation of and electroplating on stainless steel **02.05**

- D2651 Preparation of metal surfaces for adhesive bonding **15.06**
- E426 Practice for electromagnetic (eddy-current) testing of seamless and welded tubular products, austenitic stainless steels and similar alloys **03.03**
- E527 Practice for numbering metals and alloys (UNS)
- G35 Determining the susceptibility of stainless steels and related nickel-chromium-iron alloys to stress corrosion cracking in polythionic acids **03.02**
- G46 Examination and evaluation of pitting corrosion **03.02**
- G58 Preparation of stress-corrosion test specimens for weldments **03.02**
- G78 Guide for crevice corrosion testing of iron base and nickel base stainless alloys in seawater and other chloride-containing environments **03.02**

Test Methods

- A370 Mechanical testing of steel products **01.01, 01.02, 01.03, 01.04, 01.05**
- A604 Macroetch testing bars, billets and blooms **01.03, 01.05**
- A751 Test methods, practices and terminology for chemical analysis of steel products **01.01, 01.02, 01.03, 01.04, 01.05, 03.05**
- A923 Detecting detrimental intermetallic phase in wrought ferritic-austenitic (duplex) stainless steels **01.03**
- E112 Determining average grain size **03.01**
- E327 Optical emission spectrometric analysis of stainless type 18-8 steels by the point-to-plane technique **03.05**
- E572 X-ray emission spectrometric analysis of stainless steel **03.06**
- E1086 Optical emission vacuum spectrometric analysis of stainless steel by the point-to-plane excitation technique **03.06**
- G36 Practice for performing stress-corrosion cracking tests in a boiling ferric chloride solution **03.02**
- G48 Pitting and crevice corrosion resistance of stainless steels and related alloys by the use of ferric chloride solution **03.02**
- G98 Galling resistance of materials **03.02**
- G108 Electrochemical reactivation (EPR) for detecting sensitization of AISI Type 304 and 304L stainless steels **03.02**

Hardness Conversion Tables

- E140 Standard hardness conversion tables for metals (includes tables for austenitic stainless steel plate and sheet) **03.01**

Specifications by Mill Shape

Bar (ASTM Volume 01.03)

- A276 Bars and shapes
- A479 Bars and shapes for use in boilers and other pressure vessels

- A484 General requirements for bars, billets and forgings
- A564 Bars and shapes, hot-rolled and cold-finished, age hardening
- A565 Bars, forgings and forging stock for high temperature service, martensitic
- A582 Bars, hot-rolled or cold-finished, free-machining
- A831 Bars, billets and forgings for use in core components
- A955 Deformed and plain bars for concrete reinforcement
- 01.04**
- A968 Bars and shapes, chromium-nickel-silicon alloy

Bar (ASTM Volume 02.04)

- B472 UNS N08020, N08024, N08026, N08367, N08926 and R20033 nickel alloy billets and bars for reforging
- B473 UNS N08020, N08024 and N08026 nickel alloy bar and wire
- B511 Nickel-iron-chromium-silicon alloy bars and shapes
- B512 Nickel-chromium-silicon alloy (N08330) billets and bars
- B649 Ni-Fe-Cr-Mo-Cu low carbon alloy (N08904), Ni-Fe-Cr-Mo-Cu-N low carbon alloys (N08925, N08031 and N089260) and Cr-Ni-Fe-N low carbon alloy (R20033) bar and wire
- B672 Nickel-iron-chromium-molybdenum-columbium stabilized (N08700) bar and wire
- B691 Iron-nickel-chromium-molybdenum alloys (N08366 and N08367) rod, bar and wire

Castings (ASTM Volume 01.02)

- A217 Castings, martensitic stainless and alloy
- A297 Castings, iron-chromium, iron-chromium-nickel, heat resistant, for general application
- A351 Castings for pressure-containing parts, austenitic, austenitic-ferritic (duplex)
- A352 Castings for pressure-containing parts suitable for low temperature service, ferritic and martensitic
- A356 Heavy-walled castings for steam turbines
- A447 Castings for high temperature service, chromium-nickel-iron
- A487 Castings suitable for pressure service, martensitic
- A608 Centrifugally cast iron-chromium nickel high alloy tubing for pressure application at high temperatures
- A743 Castings, iron-chromium, iron-chromium-nickel and nickel-base, corrosion resistant, for general service
- A744 Castings, iron-chromium-nickel, for severe service
- A747 Castings, precipitation hardening
- A757 Castings, ferritic and martensitic for pressure-containing and other applications for low temperature service
- A781 Castings, common requirements for general industrial use
- A890 Castings, iron-chromium-nickel-molybdenum, for general application, duplex (austenitic/ferritic)
- A957 Investment castings, steel and alloy, common requirements for general industrial use

Forgings (ASTM Volume 01.05)

- A314 Bars and billets for forging
- A336 Forgings for pressure and high temperature parts
- A473 Forgings
- A484 General requirements for bars, billets and forgings
- A705 Forgings, age hardening

Forgings (ASTM Volume 02.04)

- B462 Forged or rolled UNS N08020, N08024, N08026 and N08367 alloy pipe flanges, forged fittings, and valves and parts for corrosive high-temperature service
- B472 UNS N08020, N08024, N08026, N08367, N08926 and R20033 nickel alloy billets and bars for reforging
- B564 Nickel alloy forgings

Pipe (ASTM Volume 01.01)

- A312 Pipe, austenitic
- A358 Electric fusion welded pipe, austenitic
- A376 Pipe for high-temperature central station service, austenitic
- A409 Welded large diameter pipe, austenitic
- A426 Centrifugally-cast pipe, ferritic
- A430 Forged and bored pipe, austenitic
- A530 Specialized carbon and alloy steel pipe, general requirements
- A733 Welded and seamless carbon steel and austenitic stainless steel pipe nipples
- A790 Seamless and welded pipe, ferritic/austenitic
- A813 Single- or double-welded pipe, austenitic
- A814 Cold-worked welded pipe, austenitic
- A815 Pipe fittings, ferritic, ferritic/austenitic and martensitic
- A872 Centrifugally cast pipe for corrosive environments, ferritic/austenitic
- A928 Pipe, electric fusion welded with addition of filler metal, ferritic/austenitic (duplex)
- A943 Spray-formed seamless pipe, austenitic
- A949 Spray-formed seamless pipe, ferritic/austenitic
- A954 Seamless and welded pipe, austenitic chromium-nickel-silicon alloy
- A960 Common requirements for wrought steel pipe fittings

Pipe (ASTM Volume 02.04)

- B407 Nickel-iron-chromium seamless pipe and tube
- B462 Forged or rolled UNS N08020, N08024, N08026 and N08367 alloy pipe flanges, forged fittings, and valves and parts for corrosive high-temperature service
- B464 Welded UNS N08020, N08024, and N08026 alloy pipe
- B474 Electric fusion welded UNS N08020, N08024 and N08026 nickel alloy pipe
- B514 Welded nickel-iron-chromium alloy pipe (N08330 and N08332) seamless pipe and tube
- B546 Electric fusion welded Ni-Cr-Co-Mo alloy (N06617), Ni-Fe-Cr-Si alloys (N08330 and N08332), Ni-Cr-Fe alloy (N06025), and Ni-Cr-Fe-Si alloy (N06045) pipe

- B673 UNS N08904, N08925, and N08926 welded pipe
- B675 UNS N08366 and N08367 welded pipe
- B677 UNS N08904, N08925 and N08926 seamless pipe and tube
- B690 Iron-nickel-chromium-molybdenum alloys (N08366 and N08367) seamless pipe and tube
- B710 Nickel-iron-chromium-silicon alloy welded pipe
- B729 Seamless UNS N08020, N08026 and N08024, nickel alloy pipe and tube

Plate, Sheet and Strip (ASTM Vol. 01.03)

- A167 Plate, sheet and strip, chromium-nickel
- A176 Plate, sheet and strip, chromium
- A240 Plate, sheet and strip for pressure vessels
- A263 Clad plate, sheet and strip, chromium
- A264 Clad plate, sheet and strip, chromium-nickel
- A666 Sheet, strip, plate and flat bar, for structural and architectural applications, austenitic
- A693 Plate, sheet and strip, precipitation hardening
- A793 Rolled floor plate, austenitic
- A887 Borated stainless steel plate, sheet and strip for nuclear applications
- A895 Plate, sheet and strip, free machining
- A946 Plate, sheet and strip, chromium-nickel-silicon alloy
- A947M Textured sheet

Plate, Sheet and Strip (ASTM Vol. 02.04)

- B409 Nickel-iron-chromium plate, sheet and strip
- B599 Nickel-iron-chromium-molybdenum-columbium stabilized alloy (N08700) plate, sheet and strip
- B625 UNS N08904, N08925, N08031, N08932, N09926 and R20033 plate, sheet and strip
- B688 Chromium-nickel-molybdenum-iron (N08366 and N08367) plate, sheet and strip

Tube (ASTM Volume 01.01)

- A213 Seamless ferritic and austenitic alloy boiler, superheater and heat exchanger tubes
- A249 Tubes, welded boiler, superheater, heat-exchanger and condenser, austenitic
- A268 Tubing, seamless and welded, ferritic
- A269 Tubing, seamless and welded, austenitic
- A270 Sanitary tubing, austenitic
- A271 Still tubes for refinery service, seamless, austenitic
- A450 General requirements for tubes, austenitic and ferritic
- A498 Seamless and welded carbon, ferritic and austenitic alloy heat exchanger tubes with integral fins
- A511 Seamless mechanical tubing
- A554 Welded mechanical tubing
- A608 Centrifugally cast iron-chromium nickel high alloy tubing for pressure application at high temperatures
- A632 Seamless and welded tubing, small diameter, for general service, austenitic
- A688 Welded feedwater heater tubes, austenitic
- A771 Tubing for breeder reactor core components, austenitic

- A778 Welded tubular products, unannealed austenitic
- A789 Seamless and welded tubing for general service, ferritic/austenitic
- A791 Welded tubing, unannealed ferritic
- A803 Welded feedwater heater tubes, ferritic
- A803 Welded feedwater heater tubes, ferritic
- A826 Duct tubes for breeder reactor core components, austenitic and ferritic
- A851 High-frequency, induction-welded condenser tubes, austenitic
- A908 Needle tubing
- A953 Seamless and welded tubing, austenitic chromium-nickel-silicon alloy

Tube (ASTM Volume 02.04)

- B163 Seamless nickel and nickel alloy condenser and heat exchanger tubes
- B407 Nickel-iron-chromium seamless pipe and tube
- B468 Welded UNS N08020, N08024 and N08026 alloy tubes
- B515 Welded UNS N08800, N08810 and N08811 alloy tubes
- B535 Nickel-iron-chromium-silicon alloys (N08330 and N08332) seamless pipe and tube
- B674 UNS N08904, N08925 and N08926 welded tube
- B676 UNS N08366 and N08367 welded tube
- B677 UNS N08904, N08925 and N08926 seamless pipe and tube
- B690 Iron-nickel-chromium-molybdenum alloys (N08366 and N08367) seamless pipe and
- B729 Seamless UNS N08020, N08026 and N08024, nickel alloy pipe and tube
- B739 Nickel-iron-chromium-silicon alloy welded tube

Wire and Wire Rod (ASTM Volume 01.03)

- A313 Spring wire, chromium-nickel
- A368 Wire strand
- A478 Weaving wire, chromium-nickel
- A492 Rope wire
- A493 Cold heading and cold forging bar and wire
- A555 General requirements for wire and wire rods
- A580 Wire
- A581 Wire, free-machining

Wire and Wire Rod (ASTM Volume 02.04)

- B471 UNS N08020, N08024 and N08026 alloy spring wire
- B473 UNS N08020, N08024 and N08026 nickel alloy bar and wire
- B475 UNS N08020, N08024 and N08026 nickel alloy round weaving wire
- B649 Ni-Fe-Cr-Mo-Cu low carbon alloy (N08904), Ni-Fe-Cr-Mo-Cu-N low carbon alloys (N08925, N08031 and N089260) and Cr-Ni-Fe-N low carbon alloy (R20033) bar and wire
- B672 Nickel-iron-chromium-molybdenum-columbium stabilized (N08700) bar and wire
- B691 Iron-nickel-chromium-molybdenum alloys (N08366 and N08367) rod, bar and wire

Stainless Steel Specifications According to Product Type

Architectural Applications

- A666 Sheet, strip, plate and flat bar, for structural and architectural applications, austenitic (ASTM Volume 01.03)
- A947M Textured sheet (ASTM Vol. 01.03)

Bearings (ASTM Volume 01.05)

- A756 Anti-friction bearing steel

Bolts and Nuts (ASTM Volume 01.01)

- A193 Bolts
- A194 Nuts
- A320 Bolting for low temperature service
- A437 Alloy steel turbine-type bolting material specially heat treated for high temperature service
- A453 Bolting materials, high temperature, 50 to 120 ksi yield strength with expansion coefficients comparable to austenitic steels

Fasteners (ASTM Volume 15.08)

- F593 Bolts, hex cap screws and studs
- F594 Nuts
- F738M Metric bolts, screws and studs
- F836M Metric nuts
- F837 Socket head cap screws
- F879M Metric socket button and flat countersunk cap screws
- F880 Socket set screws

Fittings, Flanges & Valves (ASTM Volume 01.01)

- A182 Forged flanges, fittings and valves
- A403 Pipe fittings
- A774 As-welded fittings for general corrosive service at low and moderate temperatures, austenitic
- A815 Pipe fittings, ferritic, ferritic/austenitic and martensitic

Fittings, Flanges & Valves (ASTM Volume 02.04)

- B366 Factory-made wrought nickel and nickel alloy fittings
- B462 Forged or rolled UNS N08020, N08024, N08026 and N08367 alloy pipe flanges, forged fittings, and valves and parts for corrosive high-temperature service

Floor Plate (ASTM Volume 01.03)

- A793 Rolled floor plate, austenitic

Industrial Wire Cloth, Screens & Perforated Plate (ASTM Vol. 14.02)

- E437 Industrial wire cloth and screens (square opening series)
- E454 Industrial perforated plate and screens (square opening series)
- E674 Industrial perforated plate and screens (round opening series)

Needle Tubing (ASTM Volume 01.01)

- A908 Needle tubing

Nuclear Applications

- A771 Tubing for breeder reactor core components, austenitic **(01.01)**
- A826 Duct tubes for breeder reactor core components, austenitic and ferritic **(01.01)**
- A831 Bars, billets and forgings for use in core components **(01.03)**
- A887 Borated stainless steel plate, sheet and strip for nuclear applications **(01.03)**

Sanitary Tubing (ASTM Volume 01.01)

- A270 Sanitary tubing, austenitic

Surgical Implant Materials (ASTM Volume 13.01)

- F55 Surgical implants, bar and wire
- F56 Surgical implants, sheet and strip
- F138 Surgical implants, bar and wire, special quality
- F139 Surgical implants, sheet and strip, special quality
- F352 Lock washers (surgical implants)
- F621 Forgings for surgical implants
- F642 Flexible wire for surgical fixations for soft tissue
- F745 Shot/bar/ingot for cast/solution treated implants
- F899 Billet, bar and wire for surgical instruments
- F1079 Inserted and noninserted surgical scissors
- F1314 Bar and wire for surgical implants, nitrogen-strengthened high manganese high chromium
- F1350 Surgical fixation wire

Appendix III

STAINLESS STEEL TRADE NAMES AND THEIR ORIGINS

<u>Designation</u>	<u>UNS</u>	<u>Designation</u>	<u>UNS</u>	<u>Designation</u>	<u>UNS</u>
2RE69 ^b	S31050	303 Super-X ^r	S30310	AL 219 ^d	S21904
2RK65 ^b	N08904	317LX ^d	S31725	AL 255 ^d	S32550
3CR12 ^a	S41003	317LXN ^d	S31726	AL 433 ^d	S44500
3R12 ^b	S30403	330 ^u	N08330	AL 468 ^d	S46800
3RE60 ^b	S31500	353MA ^c	S35315	AL 904L ^d	N08904
5R10 ^b	S30400	416 Plus-X ^r	S41610	AL 2205 ^d	S31803
5R60 ^b	S31600	439LT ^f	S43932	ALMAR 362 ^d	S36200
6R35 ^b	S32100	654 SMO ^c	S32654	ALTEMP A286 ^d	S66286
7Mo ^c	S32900	800 ^s	N08800	AM 350 ^d	S35000
7Mo Plus ^c	S32950	800H ^s	N08810	AM 355 ^d	S35500
8R40 ^b	S34709	800HT ^s	N08811	Armco 15-5PH ^f	S15500
8RE10 ^b	S31008	904L ^c	N08904	Armco 17-4PH ^f	S17400
13Cr-4Ni ^c	S41500	1713LCN ^g	S31726	Armco 17-7PH ^f	S17700
15-5PH ^f	S15500	1812LCN ^g	S31653	Armco 19D ^f	S32001
15Cr-5Ni ^c	S15500	1815LCSi ^g	S30600	Armco 439LT ^f	S43932
15-7Mo ^f	S15700	1925LC ^g	N08904	ArmcoPH15-7Mo ^f	S15700
15-15LC ^c	S21300	2205 ^c	S31803	Carpenter 7Mo Plus ^c	S32950
17-4PH ^f	S17400	2205 Code Plus Two ^k	S32205	Carpenter 15-15LC ^c	S21300
17Cr-4Ni ^r	S17400	2304 ^c	S32304	Carpenter 20Cb3 ^c	N08020
17Cr-7Ni ^r	S17700	2507 ^c	S32750	Carpenter 20 Mo4 ^c	N08024
17-5Mn ^c	S20100	2520nv ^g	S31008	Carpenter 20 Mo6 ^c	N08026
17-7PH ^f	S17700	2803Mo ^g	S32803	Carpenter 303 Al-Modified ^c	S30345
17-14-4LN ^c	S31726	3228NbCe ^g	S33228	Carpenter Alloy 255 ^c	S32550
18-9LW ^f	S30430	3620Nb ^g	N08020	Croloy 16-6PH ^j	S16600
18-15LCSi ^g	S30600	3718 ^g	N08330	Cromweld 3CR12 ^a	S41003
18-18PLUS ^c	S28200	4565S ⁱ	S34565	Cronifer 1713LCN ^g	S31726
19D ^f	S32001	A903 ⁱ	S31803	Cronifer 1812LCN ^g	S31653
19-9DL ^{aa}	S63198	AF22 ^{ab}	S31803	Cronifer 1925LC ^g	N08904
19-9DX ^c	S63199	AL-4X ^d	N08904	Cronifer 2520nv ^g	S31008
20Cb3 ^c	N08020	AL-6XN ^d	N08367	Cronifer 2803Mo ^g	S32803
20Mo4 ^c	N08024	AL 20 ^d	N08020	Cronifer 3620Nb ^g	N08020
20Mo6 ^c	N08026	AL 29-4 ^d	S44700	Cronifer3718 ^g	N08330
25-6Mo ^s	N08926	AL 29-4C ^d	S44735	Cryogenic Tenelon ^x	S21460
44LN ^h	S31200	AL 29-4-2 ^d	S44800	Custom 450 ^c	S45000
153 MA ^c	S30415	AL 30 ^d	S20400	Custom 455 ^c	S45500
203EZ ^d	S20300	AL 33 ^d	S24000	Custom 630 ^c	S17400
253 MA ^c	S30815	AL 40 ^d	S21904	Discaloy ^w	S66220
254 SMO ^c	S31254	AL 50 ^d	S20910	DP1 ^m	S31500
303Al-Modified ^c	S30345	AL 201L ^d	S20103	DP3 ^m	S31260
303 Plus X ^r	S30310	AL 201LN ^d	S20153	DP3W ^m	S39274

Trade Names of the Following Companies:

a Cromweld Steel, Ltd.	g Krupp-VDM AG	m Sumitomo Metal Ind.	s Inco Alloys International	y Korean
b AB Sandvik Steel	h Nyby-Uddeholm AB	n Lukens Steel Co.	t Krupp Thyssen Nirosta	z Weir Materials, Ltd.
c Avesta Sheffield AB	i Bohler, Ltd.	o Trent Tube	u Rolled Alloys, Inc.	aa Universal Cyclops
d Allegheny Ludlum	j Babcock & Wilcox	p Samuel Fox & Co., Ltd.	v Thyssen	ab Mannesmann
e Carpenter Technology	k Avesta Sheffield, Inc.	q Langley Alloy	w Westinghouse Elec.	ac Nippon Kokan
f Armco, Inc.	l Firth Sterling	r Crucible Steel Co.	x U.S. Steel Co.	ad Valourec

<u>Designation</u>	<u>UNS</u>	<u>Designation</u>	<u>UNS</u>	<u>Designation</u>	<u>UNS</u>
DP6 ^m	S32900	Nirosta 4521 ⁱ	S44400	W545 ^w	S66545
DP8 ^m	S31803	Nirosta 4539 ⁱ	N08904	X15 ^e	S65150
DP11 ^m	S32304	Nirosta 4541 ⁱ	S32100	Zeron 100 ^z	S32760
DP12 ^m	S31260	Nirosta 4550 ⁱ	S34700		
Duracorr ⁿ	S41003	Nirosta 4565S ⁱ	S34565		
E4 ^r	S41050	Nirosta 4571 ⁱ	S31635		
EB26-1 ^d	S44627	Nitronic 30 ^f	S20400		
E-Brite ^d	S44627	Nitronic 32 ^f	S24100		
Esshete 1250 ^p	S21500	Nitronic 33 ^f	S24000		
Falc 100 ^g	S32760	Nitronic 40 ^f	S21900/S21904		
Falc 223 ^g	S31803	Nitronic 50 ^f	S20910		
Ferallium 255 ^q	S32550	Nitronic 60 ^f	S21800		
FS 10 ^m	S44800	NKCr22 ^{ac}	S31803		
Gall-Tough ^e	S20161	Nu Monit ^h	S44635		
Greek Ascoloy ⁱ	S41800	PH13-8Mo ^f	S13800		
HR3C ^m	S31042	PH14-8Mo ^f	S14800		
HR3ELM ^m	S31050	PH15-7Mo ^f	S15700		
HR8C ^m	N08904	Project 70 Stainless 182-FM ^e	S18200		
HR254	S31254	Pyromet 350 ^e	S35000		
HWT ^d	S43035	Pyromet 355 ^e	S35500		
HyResist 22/5 ^c	S31803	Pyromet 538 ^e	S21900		
INCO 020 ^s	N08020	Promet X-15 ^e	S65150		
INCO 25-6Mo ^s	N08926	Pyrowear 675 ^e	S42670		
Incoloy 800 ^s	N08800	RA 85H ^u	S30615		
Incoloy 801 ^s	N08801	RA 330 ^u	N08330		
Incoloy 802 ^s	N08802	Remanit 4462 ^v	S31803		
Incoloy 800H ^s	N08810	Remanit 4522 ^v	S44400		
Incoloy 800HT ^s	N08811	SAF 2205 ^b	S31803		
Incoloy 825 ^s	N08825	SAF 2304 ^b	S32304		
Jethete M152 ^p	S64152	SAF 2507 ^b	S32750		
JS700 ^d	N08700	Safurex ^b	S32906		
MA956 ^g	S67956	Sanicro 28 ^b	N08028		
Moly Ascoloy ^d	S41500	SC-1 ^r	S44660		
MONIT ^h	S44635	Sea-Cure ^o	S44660		
Nicrofer 3228NbCe ^g	S33228	SM13CRS ^m	S41426		
Nicrofer 3620Nb ^g	N08020	SM22Cr ^m	S31803		
Nicrofer 3718 ^g	N08330	SR50A ^y	S32050		
Nirosta 4000 ⁱ	S41008	Stainless W ^x	S17600		
Nirosta 4002 ⁱ	S40500	SX ^b	S32615		
Nirosta 4006 ⁱ	S41000	Tenelon ^x	S21400		
Nirosta 4016 ⁱ	S43000	TrimRite ^e	S42010		
Nirosta 4113 ⁱ	S43400	UR 35N ^y	S32304		
Nirosta 4301 ⁱ	S30400	UR45N ^y	S31803		
Nirosta 4306 ⁱ	S30403	UR47N ^y	S31260		
Nirosta 4401 ⁱ	S31600	Uranus 50 ^y	S32404		
Nirosta 4439 ⁱ	S31726	Uranus 52N+ ^y	S32520		
Nirosta 4462 ⁱ	S31803	Uranus B66 ^y	S31266		
Nirosta 4509 ⁱ	S44100	UR B6 ^y	N08904		
Nirosta 4510 ⁱ	S43035	USS 18-8-2 ^x	S38100		
Nirosta 4512 ⁱ	S40900	VS 22 ^{ad}	S31803		

Trade Names of the Following Companies:

a Cromwell Steel, Ltd.	g Krupp-VDM AG	m Sumitomo Metal Ind.	s Inco Alloys International	y Korean
b AB Sandvik Steel	h Nyby-Uddeholm AB	n Lukens Steel Co.	t Krupp Thyssen Nirosta	z Weir Materials, Ltd.
c Avesta Sheffield AB	i Bohler, Ltd.	o Trent Tube	u Rolled Alloys, Inc.	
d Allegheny Ludlum	j Babcock & Wilcox	p Samuel Fox & Co., Ltd.	v Thyssen	ab Mannesmann
e Carpenter Technology	k Avesta Sheffield, Inc.	q Langley Alloy	w Westinghouse Elec.	ac Nippon Kokan
f Armco, Inc.	l Firth Sterling	r Crucible Steel Co.	x U.S. Steel Co.	ad Valourec

Appendix IV

NATIONAL DESIGNATIONS FOR SIMILAR STAINLESS STEELS

A Guide to Steels with Similar Chemical Compositions

USA UNS	USA ASTM	France AFNOR	Germany—DIN W.-Nr. Material Code	Japan JIS	Sweden SS	UK BS	Euronorm EN
N08028		Z2NCU 31-27	X1NiCrMoCu 31 27		2584		
N08330	330	Z12NC 37-18	X12NiCrSi 36 16	SUH330		NA17	
N08700	JS700		X7NiCrMoCuNb 25 20				
N08810	800H		X10NiCrAlTi 32 20				
N08904	904L	Z3NCU 25-20M	X1NiCrMoCuN 25-20-5		2562	904S13	1.4539
S13800	XM-13	Z4CN DAT 13-09	X3CrNiMoAl 13 8 2				
S15700	632	Z8CND A15-07	X7CrNiMoAL 15 7				
S17400	630	Z5CNU 17-4	X5CrNiCuNb 17 4	SUS630			
S17700	631	Z8CNA 17-07	X7CrNiAl 17 7	SUS631	2388	460S52	
S20100	201	Z12CMNI 7-07AZ		SUS201			1.4372
S20200	202		X12CrMnNi 18 8 5	SUS202	2357	284S16	
S30100	301	Z10CN 18-08	X12CrNi 17 7	SUS301	2331	301S21	1.4310
S30200	302	Z10CN 18-09	X12CrNi 18 8	SUS302	2332	304S31	1.4310
S30300	303	Z8CNF 18-09	X10CrNiS 18 9	SUS303	2346	303S31	1.4305
S30323	303Se			SUS303Se		303S41	
S30400	304	Z7CN 18-09	X5CrNi 18 10	SUS304	2332	304S18	1.4301
S30403	304L	Z3CN 18-10	X2CrNi 18 9	SUS304L	2352	304S11	1.4307
S30409	304H	Z6 18-09	X6CrNi 18 11	SUS304H	2333	304S51	1.4948
S30415					2372		1.4818
S30430	304Cu/XM-7	Z6CNU 18-10	X3CrNiCu 18 9	SUSXM7		304S49	1.4576
S30451	304N	Z5CN 18-10AZ	X2CrNiN 18 10	SUS304N1		304S71	
S30453	304LN	Z3CN 18-10AZ	X2CrNiN 18 10	SUS304LN	2371	304S61	1.4311
S30500	305	ZCN 18-12	X5CrNi 18 12	SUS305		305S19	1.4303
S30600		Z1CNS 18-15	X1CrNiSi 18 15				
S30800	308			SUSY308			
S30815			X8CrNiSiN 21 11		2368		1.4835

USA UNS	USA ASTM	France AFNOR	Germany—DIN		Japan JIS	Sweden SS	UK BS	Euronorm EN
			W.-Nr.	Material Code				
S30900	309	Z15CN 25-13	1.4828	X15CrNi 20 12	SUH309		309S24	
S30908	309S	Z10CN 25-13	1.4833	X7CrNi 23 14	SUS309S		309S16	1.4833
S31000	310	Z12CN 25-20	1.4841	X15CrNiSi 25 20	SUSY310	2361	310S24	
S31008	310S	Z8CN 25-20	1.4845	X12CrNi 25 21	SUS310S	2361	310S61	1.4845
S31050		Z2NCDDU 31-27	1.4466	X1CrNiMoN 25 22 2				
S31254						2378		1.4547
S31260		Z5CND 27-05AZ	1.4460	X8CrNiMo 27 5	SUS329J2L			
S31400	314	Z12CN 25-20	1.4841	X15CrNiSi 25 20	SCS18			
S31500			1.4417	X2CrNiMoSi 19 5		2372		
S31600	316	Z7CND 18-12-03	1.4401	X5CrNiMo 17 12 2	SUS316	2343	316S53	1.4401
S31603	316L	Z7CND 19-15-04	1.4404	X2CrNiMo 17 13 2	SUS316L	2348	316C12	1.4404
S31609	316H	Z7CND 17-12-02	1.4401	X5CrNiMo 17 12 2	SUS316H			
S31635	316Ti	Z6CNDT 17-12	1.4571	X10CrNiMoTi 18 10	SUS316Ti	2350	320S31	1.4571
S31640	316Cb	Z6CNDNb 17-12	1.4580	X6CrNiMoNb 17 12	SCS22		316S17	
S31653	316LN	Z3CND 17-12AZ	1.4406	X2CrNiMoN 18 12		2375	316S63	1.4406
S31700	317	Z4CND 19-13M	1.4449	X5CrNiMo 17 13	SUS317	2366	317S16	
S31703	317L	Z3CND 19-15-04	1.4438	X2CrNiMo 18 16	SUS317L	2367	317S12	1.4438
S31725	317LM				SUS317J1			
S31726		Z3CND 18-14-05AZ	1.4439	X3CrNiMoN 17 13 5				1.4438
S31753	317LN	Z3CND 19-14AZ	1.4442	X2CrNiMoN 18 15 4	SUS317LN	2373		1.4434
S31800	318		1.4583	X10CrNiMoNb 18 12				
S31803		Z3CND 22-05AZ	1.4462	X2CrNiMoNb 22 5		2377	318S13	1.4462

USA UNS	USA ASTM	France AFNOR	Germany—DIN W.-Nr. Material Code	Japan JIS	Sweden SS	UK BS	Euronorm EN
S32100	321	Z6CNT 18-10	1.4541 X10CrNiTi 18 9	SUS321	2337	321S12	1.4541
S32109	321H	Z6CNT 18-10	1.4878 X12CrNiTi 18 8	SUS321H	2327	321S51	1.4878
S32304		Z3CN 23-04AZ	1.4362 X2CrNiN 23 4		2327		1.4362
S32550		Z3CNDU 25-07AZ	1.4507 X2CrNiMoCuN 25 6 3				1.4507
S32654							1.4562
S32750		Z3CND 25-06AZ			2328		1.4410
S32760			1.4501 X2CrNiMoCuWN 25 7 4				
S32900	329	Z5CND 27-05AZ	1.4460 X8CrNiMo 27 5	SUS329J1	2324		1.4460
S33228			1.4877 X5NiCrNbCe 32 27				
S34700	347	Z6CNNb 18-10	1.4550 X6CrNiNb 18 10	SUS347	2338	347S17	
S34709	347H	Z6CNNb18-10M	1.4961 X8CrNiNb 16 13			347S49	
S34800	348		1.4546 X5CrNiNb 18 10			347S31	
S35315							1.4854
S35500	634	Z12CND 16-04					
S38100	XM-15			SUSXM15J1			
S38400	384	Z6NC 18-16		SUS384			
S40300	403	Z6C13	1.4000 X7Cr13	SUS403	2301	403S17	
S40500	405	Z6CA 13	1.4002 X7CrAl 13	SUS405		405S17	
S40900	409	Z6CT 12	1.4512 X5CrTi 12	SUS409		409S19	1.4512
S41000	410	Z6C 13	1.4006 G-X10Cr 13	SUS410	2302	410S21	
S41008	410S	Z6C 13	1.4000 X7Cr13	SUS410S	2301	410S21	1.4000
S41025			1.4106 X10CrMo13	SUS410J1			

USA UNS	USA ASTM	France AFNOR	Germany—DIN		Japan JIS	Sweden SS	UK BS	Euronorm EN
			W.-Nr.	Material Code				
S41050		Z8CNT 12	1.4003	X2CrNi 12				1.4003
S41400	414	Z12CN 13-02M	1.4008	X8CrNi 13	SCS3			
S41500		Z6CN 13-04	1.4313	X5CrNi 13 4		2385	425C11	
S41600	416	Z12CF 13	1.4005	X12CrS 13	SUS416	2380	416S21	
S41623	416Se						416S41	
S42000	420	Z20C 13N	1.4028	X30Cr 13	SUS420J2	2304	420S45	1.4028
S42010		Z30CF 13	1.4021	X20Cr 13	SUS420J1	2303	420S29	1.4021
S42020	420F	Z30CF 13			SUS420F		416S29	
S42200	422/616		1.4935	X20CrMoWV 12 1	SUH616			
S42900	429	Z8C13FF	1.4000/1.4001	X6Cr 13/G-X7Cr 13	SUS429			
S43000	430	Z8C 17	1.4016	X6Cr 17	SUS430	2320	430S15	1.4016
S43020	430F	Z10CF 17	1.4104	X12CrMoS 17	SUS430F	2383		
S43035	439	X8CT 17	1.4510	X6CrTi 17				
S43036	430Ti/XM-8	Z4CT 17	1.4510	X6CrTi 17	SUS430LX			
S43100	431	Z15CN 16-02	1.4057	X20CrNi 17 2	SUS431	2321	431S29	
S43400	434	Z8CD 17-01	1.4113	X6CrMo 17 1	SUS434	2325	434S17	
S43600	436				SUS436L			
S44002	440A	Z70CD 14	1.4109	X65CrMo 14	SUS440A			
S44003	440B		1.4112	X90CrMoV 18	SUS440B			
S44004	440C	Z100CD 17	1.4125	X105CrMo 17	SUS440C			
S44020	440F				SUS440F			
S42200	442						442S19	
S44400	444		1.4521	X1CrMoTi 18 2	SUS444	2326		

USA UNS	USA ASTM	France AFNOR	W.-Nr.	Germany—DIN Material Code	Japan JIS	Sweden SS	UK BS	Euronorm EN
S44600	446	Z10C 24	1.4762	X10CrAl 24	SUH446	2322		
S44627	XM-27	Z1CDNb 26-01	1.4131	X1CrMo 26 1	SUSXM27			
S66286	660	Z6NCTDU 25-15B	1.4980	X5NiCrTi 26 15	SUH660	2570	HR650	

Appendix V

STAINLESS STEEL BUYER'S GUIDE— PART 1

Producers and Suppliers of Stainless Steels and Superalloys

	Sheet/Strip	Plate	Bar	Rod	Wire	Pipe/Tube	Semi-Finished
Allegheny Ludlum Corp. Pittsburgh, PA 412-394-2800	SS/SA	SS/SA	SS/SA			SS/SA	SS/SA
Allvac Monroe, NC 800-841-5491			SS/SA	SS/SA		SA	SS/SA
AL Tech Specialty Steel Corp. Dunkirk, NY 800-828-8600			SS/SA	SS/SA		SA	SS/SA
Armco, Inc. Pittsburgh, PA 800-231-1054	SS	SS					SS
Atchison Casting Corp. Atchison, KS 913-367-2121							SS Castings
Atlas Stainless Steels Tracy, PQ 514-746-5000	SS	SS					
Atlas Specialty Steels Welland, ON 905-735-5661			SS/SA				SS/SA
Avesta Sheffield, Inc. Schaumburg, IL 800-833-8703	SS	SS	SS	SS		SS	SS
Carpenter Technology Corp. Reading, PA 800-654-6543	SS/SA/strip		SS/SA	SS/SA	SS/SA		SS/SA
Corralloy, Inc. Lancaster, PA 800-346-8167	SS/SA	SS/SA	SS/SA		SS/SA		
Creusot-Marrel, Inc. Wayne, PA 610-254-9900	SS	SS					Forgings
Ellwood Quality Steels Co. New Castle, PA 412-658-6508							SS Ingot
Cromweld Steel U.S. Cornelius, NC 704-896-8114	SS	SS					
Erie Forge and Steel, Inc. Erie, PA 814-452-2300							SS Forgings
ESCO, Ltd. Port Hope, ON 905-885-6301							SS Castings
FirstMiss Steel Inc. Hollsopple, PA 814-479-2551			SS				SS

SS=Stainless Steel

SA=Superalloys

	Sheet/Strip	Plate	Bar	Rod	Wire	Pipe/Tube	Semi-Finished
G. O Carlson Inc. Steel Division Thorndale, PA 610-384-2800		SS/SA					
Electralloy Division Oil City, PA 800-458-7273			SS/SA				SS/SA
Hamilton Precision Metals Lancaster, PA 717-569-7061	SS/SA Strip/Foil						
Harrison Alloys Inc. Harrison, NJ 201-483-4800	SA			SA	SA		
C.I. Hayes Cranston, RI 401-467-5200	SS/SA Strip/Foil						
Haynes International Inc. Kokomo, IN 765-456-6412	SA	SA	SA	SA	SA	SA	SA
Inco Alloys International Inc. Huntington, WV 800-334-INCO	SA	SA	SA	SA	SA	SA	SA
J & L Specialty Steel Inc. Pittsburgh, PA 412-338-1600	SS	SS				SS	
Krupp Hoesch Steel Products Inc. Parsippany, NJ 201-829-1900	SS	SS					
Krupp VDM Parsippany, NJ 201-267-8545	SS/SA	SS/SA	SS/SA	SS/SA	SS/SA		SS/SA
Markham Markham, ON 905-477-2064	SS/SA	SS/SA	SS/SA	SS/SA	SS/SA		SS/SA
Latrobe Steel Co. Latrobe, PA 412-537-7711			SS				
Lukens Inc. Coatesville, PA 610-383-2000	SS	SS				SS	
Mexinox SA de CV San Angel, Mex. 525-593-4164	SS	SS					
North American Stainless Ghent, KY 502-347-6000	SS						
Precision Rolled Products Reno, NV 702-972-0272	SS						
Republic Engineered Steels Massillon, OH 330-837-6000			SS	SS			SS
Rodney Metals New Bedford, MA 508-996-5691	SS						
Rolled Alloys Temperance, MI 800-521-0332	SS/SA	SS/SA	SS/SA			SS/SA	
Sandusky International Sandusky, OH 419-626-5340							Centrifugal castings
Sandvik Steel Co. Scranton, PA 717-587-5191			SS	SS	SS	SS	

SS=Stainless Steel

SA=Superalloys

	Sheet/Strip	Plate	Bar	Rod	Wire	Pipe/Tube	Semi-Finished
Slater Steels Corp. Fort Wayne, IN 219-434-2800			SS/SA				
Special Metals Corp. New Hartford, NY 315-798-2900			SA	SA			
Sumitomo Metal USA Corp. Chicago, IL 312-326-4377		SS				SS	
Talley Metals Technology Inc. Hartsville, SC 803-335-7540			SS	SS			

SS=Stainless Steel SA=Superalloys

Appendix V

STAINLESS STEEL BUYER'S GUIDE— PART 2

Tube and Pipe Producers (USA and Canada)

COMPANY	OD, inch	Wall, inch
A. T. Wall Co., Warwick, RI 401-739-0740	0.050–4.00	0.005–0.250
Accu-Tube, Englewood, CO 303-761-2258	0.3750	0.035
Accumetrics Ltd., Royersford, PA 610-948-0181	0.005–0.250	0.001–0.035
Acme Tube, Somerset, NJ 908-560-8111	14.0	$\frac{1}{2}$
Al Tech Specialty Steel Corp., Watervliet, NY 518-273-4110	1.050–5.500	0.065–1.250
American Tube Co., Inc., Nazareth, PA 610-759-8700	$\frac{1}{4}$ – $\frac{3}{4}$	0.010–0.065
American Tube Technology Inc., Lakewood, CO 800-595-8823	0.010–0.250	0.002–0.033
Associated Tube Industries, Markham, ON 800-387-4217	$\frac{3}{16}$ – $6\frac{5}{8}$	0.010–0.265
ASTI-American Stainless Tubing, Statesville, NC 800-908-TUBE	$\frac{1}{2}$ – $2\frac{1}{2}$	0.028–0.120
Avesta Sheffield, Inc., Schaumburg, IL 800-731-7473	$\frac{1}{2}$ –80	up to 2 (in some sizes)
Bristol Metals, L.P., Bristol, TN 423-968-2151	$\frac{1}{2}$ –96	0.049–1
Bundy Corp., Warren, MI 810-755-8418	0.125–0.875	0.010–0.080
CE Pipe, Kingston, ON 613-545-3246	$\frac{3}{4}$ –6	Sch 10S, 40S, 80S
Carpenter Special Products, El Cajon, CA 619-596-4340	0.250–36	0.015–0.125
Century Tube Corp., Pine Bluff, AR 800-643-1523	0.706–5.000	0.035–0.180
Century Tubes, Inc., San Diego, CA 619-586-0550	0.008–3.500	0.0015–0.500
Consolidated Stainless, Inc., Auburndale, FL 941-967-6506	$\frac{1}{2}$ – $10\frac{3}{4}$	0.049–0.237
Damascus-Bishop Tube Co., Greenville, PA 412-646-1500	$8\frac{5}{8}$	0.350
Davis Pipe, Blountville, TN 423-323-2171	$\frac{1}{2}$ –48	0.083–0.375
DMV Stainless USA, Inc., Houston, TX 800-848-0867	$\frac{1}{4}$ –24	0.035–2
Douglas Brothers, Portland, ME 207-797-6771	$3\frac{1}{2}$ –72	0.078–0.375
Eckstrom Industries, Arlington, WA 360-435-8521	3–60	0.078–0.312

Felker Brothers Corp., Marshfield, WI 715-384-3121	3-96	16 ga. -0.500
Fischer CANADA Stainless Steel Tubing, Inc., Waterloo, ON 519-746-0088	$\frac{1}{2}$ - 3.150	0.020-0.188
G & L Manufacturing, Inc., Cookeville, TN 615-528-1732	0.1875 - $2\frac{1}{4}$	0.010-0.078
Gibson Tube, Inc., Cranbury, NJ 908-218-1400	$\frac{1}{16}$ - 2	0.008-0.083
Greenville Tube Corp., Downers Grove, IL 630-985-5600	0.125-1.375	0.015-0.157
H.B. Evans Co., Inc., Huntington Beach, CA 714-373-2515	1 to over 90	0.002-0.375
Handy & Harman Tube Co., Inc., Norristown, PA 610-539-3900	0.062-1.000	0.010-0.200
Henderson, Barwick, Inc., Brockville, ON 613-342-8471	$\frac{3}{4}$ - 96	0.062-0.375
High-Tek Tube Corp., Littleton, CO 303-979-3399	0.028-0.375	0.004-0.045
International Extruded Products, Buffalo, NY 716-894-7770	6.625-20.0	0.35-5.5
International Specialty Tube, Detroit, MI 313-841-6900	0.500-3.00	0.028-0.120
International Tubular Products, Inc., Claremore, OK 800-TPD-TUBE	$\frac{5}{8}$ - 2	0.025-0.109
Johnson Bros. Metal Forming, Berkeley, IL 708-449-7050	0.226-1.500	0.010-0.125
K-Tube Corp., San Diego, CA 800-394-0058	0.004-0.250	0.001-0.020
Kaiser Electroprecision-Rollmet Products, Irvine, CA 714-250-1015	6-24	0.048-0.375
LTV Steel Tubular Products, Youngstown, OH 800-445-7473	0.840- $6\frac{5}{8}$	0.065-0.375
Mascotech Industrial Components, Northville, MI 810-344-4700	0.125-3	0.008-0.085
Microgroup, Inc., Medway, MA 800-255-8823	0.006-1.500	0.0006-0.125
North Star Co., Inc., Gardena, CA 310-515-2200	$\frac{3}{8}$ - 2	0.015-0.060
Ocean Metal Corp., City of Industry, CA 818-333-0160	$\frac{7}{8}$ - 3	0.035-0.060
Perforated Tubes, Inc., Ada, MI 616-942-4550	0.250- $11\frac{5}{8}$	0.024-0.187
Phoenix Tube Co., Bethlehem, PA 610-865-5337	$\frac{1}{2}$ - 10	0.035-0.500
Plymouth Tube Co., Warrenville, IL 800-323-9506	0.125-2.00	0.012-0.188
Rath Manufacturing Co., Janesville, WI 800-367-7284	$\frac{1}{2}$ - 4	0.028-0.350
Romac Metals, Troutman, NC 800-438-6628	$\frac{1}{2}$ - 5	0.018-0.188
Rota Corp., Phillipsburg, NJ 908-213-1777	$\frac{1}{16}$ - $\frac{3}{4}$	0.010-0.049
Salem Tube, Inc., Greenville, PA 412-646-4301	$\frac{1}{8}$ - $1\frac{1}{2}$ 3.17-38.1 HM	0.020-0.156 0.50-3.96 HM
Sandvik Steel, Scranton, PA 717-587-5191	$\frac{1}{8}$ - 10	0.007-1
Sandvik Steel Canada, Arnprior, ON 613-623-6501	$\frac{1}{4}$ - $1\frac{1}{2}$	0.028-0.250

Scientific Tube, Inc., Addison, IL 630-543-0858	$\frac{3}{8} - 1\frac{3}{4}$	0.010-0.055
Small Diameter Stainless, W. Bloomfield, MI 800-232-1420	$\frac{1}{4} - 2\frac{1}{2}$	0.028-0.083
Southern Tube Co., Inc. Tuscaloosa, AL 205-345-1880	$\frac{3}{4} - 1$	0.049-0.083
Standard Tube of Canada, Woodstock, ON 519-537-6671	0.750-7.500 1×1-6×6 Square; $\frac{1}{2} \times 1\frac{1}{2}$ - 8×4 Rectangular	0.035-0.460
Superior Tube Co., Collegeville, PA 610-489-5365	0.010-1.125	0.003-0.218
Swepeco Tube Corp., Clifton, NJ 201-778-3000	3.5-72	0.062-3
Tectron Tube, DePere, WI 800-999-TUBE	0.500-2.500	0.062-3
Teledyne Rodney Metals, Koppel, PA 412-847-6300	$2\frac{5}{8}$ max	$1\frac{1}{2}$ max
The Timken Co., Canton, OH 330-471-3267	1-13	0.100-3.00
Trent Tube, East Troy, WI 414-642-5658	$\frac{1}{2} - 48$	0.016- $1\frac{1}{2}$
Truform Machine & Mfg. Co., Somerville NJ 908-725-4525	0.187-0.750	0.018-0.049
Uniform Tubes, Inc., Collegeville, PA 800-321-6285	0.003-0.625	0.001-0.049
United Industries, Inc., Beloit, WI 608-365-8891	$\frac{1}{2} - 6$	0.020-0.200
Valmont Industries, Valley, NE 800-825-6825	1-16	0.049-0.280
Vita Needle Co., Needham, MA 617-444-1780	0.004-0.375	0.001-0.038
Webco Industries, Inc., Sand Springs, OK 800-331-4096	0.250-5.000	0.015-0.500
Western Pneumatic Tube Co., Kirkland, WA 206-822-8271	0.500-10.0	0.004-0.150
Woverine Tube, Inc., Decatur, AL 205-353-1310	0.017-4.500	0.005-0.410

Appendix V

STAINLESS STEEL BUYER'S GUIDE— PART 3

Steel Service Centers which Supply Stainless Steel Products (USA and Canada)

	Plate	Hot rolled bar	Cold rolled sheet/strip	Hot rolled sheet/strip	Tubing	Wire	Pipe		Plate	Hot rolled bar	Cold rolled sheet/strip	Hot rolled sheet/strip	Tubing	Wire	Pipe
Acier Vaudreuil Steel Inc. St. Pierre, PQ (514-363-5212)	•	•	•	•	•	•	•	Indianapolis, IN (317-781-3800)							
Admiral Metals Servicerter Woburn, MA (781-933-8300)	•	•	•	•	•	•	•	Muncie, IN (317-282-5335)							
Aerospace Alloys, Inc. Cincinnati, OH (513-874-6802)	•	•	•	•	•	•	•	South Bend, IN (219-288-9181)							
BRANCH: Bethel, CT (203-790-6306)	•	•	•	•	•	•	•	Louisville, KY (502-635-7481)							
AFCO Metals, Inc. Little Rock, AR (501-490-2255)	•	•	•	•	•	•	•	Dayton, OH (513-253-6121)							
BRANCHES: Ft. Smith, AR (501-646-7331)	•	•	•	•	•	•	•	Perrysburg, OH (419-666-4899)							
West Memphis, AR (501-732-3700)	•	•	•	•	•	•	•	Alpena, MI (517-354-4188)							
Wichita, KS (316-524-2909)	•	•	•	•	•	•	•	Battle Creek, MI (616-968-0234)							
Shreveport, LA (318-869-3161)	•	•	•	•	•	•	•	Benton Harbor, MI (616-925-2117)							
Jackson, MS (601-373-5995)	•	•	•	•	•	•	•	Cadillac, MI (616-775-9336)							
Oklahoma City, OK (405-745-2992)	•	•	•	•	•	•	•	Detroit, MI (313-366-8000)							
Allied Metals, Inc. Houston, TX (713-923-9491)	•	•	•	•	•	•	•	Grand Blanc, MI (810-736-1234)							
BRANCH: Tulsa, OK (918-832-1900)	•	•	•	•	•	•	•	Grand Rapids, MI (616-452-5111)							
Allied Steel Corp. N. Charleston, SC (803-552-6300)	•	•	•	•	•	•	•	Jackson, MI (517-787-5500)							
Alloy Tool Steel, Inc. Santa Fe Springs, CA (800-288-9800)	•	•	•	•	•	•	•	Lansing, MI (517-371-9600)							
Alro Metals Service Center Corp. Boca Raton, FL (561-997-6766)	•	•	•	•	•	•	•	Alstrip, Inc. Skokie, IL (800-323-1240)				•			
BRANCHES: Orlando, FL (407-678-2576)	•	•	•	•	•	•	•	BRANCHES: Exton, PA (800-323-1240)							
Tampa, FL (813-661-1646)	•	•	•	•	•	•	•	Springfield, TN (800-323-1240)							
Pensacola, FL (904-434-0851)	•	•	•	•	•	•	•	Alvin Metals Co. Culver City, CA (213-870-1780)					•		•
Alro Steel Corp. Jackson, MI (517-787-5500)	•	•	•	•	•	•	•	Amcan Specialty Steels, Inc. Hartsville, SC (803-335-5005)			•			•	
BRANCHES: Fort Wayne, IN (219-432-3524)	•	•	•	•	•	•	•	Amstek Metal Joliet, IL (815-725-2520)				•		•	
								Anderson Metals Inc. Columbia, PA (717-684-9194)			•	•	•	•	
								Arco Steel, Inc. Houston, TX (713-928-6000)			•				
								BRANCHES: Rancho Cucamonga, CA (909-941-2998)							
								Mooreville, IN (800-999-2726)							

Data taken, with permission, from information provided by the Steel Service Center Institute,
Key Center, Suite 2400, 127 Public Square, Cleveland, OH 44114-1216. Tel. 216-694-3630; Fax 216-694-3940.

	Plate	Hot rolled bar	Cold finished bar	Hot rolled sheet/strip	Cold rolled sheet/strip	Tubing	Wire	Pipe
Art Iron, Inc. Toledo, OH (419-241-1261) BRANCHES: Fort Wayne, IN (219-749-9661) South Bend, IN (219-288-9080) Cincinnati, OH (513-771-4450) Columbus, OH (614-878-7271)	•	•	•	•	•	•	•	•
Ashley Metals Bensenville, IL (630-766-5410)			•	•				
Atlas Alloys Etobicoke, ON (416-622-3100)	•	•	•	•	•	•	•	•
Atlas Steel Products Co. Twinsburg, OH (216-425-1600)				•				
Avesta Sheffield Inc. Mississauga, ON (905-567-9900) BRANCHES: Edmonton, AB (403-436-2030) Burnaby, BC (604-420-9222) Thunder Bay, ON (807-623-2155) Montreal, PQ (514-735-1511)	•	•	•	•	•	•	•	•
Banner Service Corp. Des Plaines, IL (847-298-2300)				•				
Bassett Industries, Inc. King of Prussia, PA (610-277-6500)	•					•		
Benedict-Miller, Inc. Lyndhurst, NJ (201-438-3000)				•				
Benjamin Steel Co., Inc. Springfield, OH (513-322-8600) BRANCHES: Columbus, OH (614-253-5555) Dayton, OH (513-233-1212) Lima, OH (419-229-8045) Mansfield, OH (419-522-5500)	•	•			•			
Bergsen Inc. South Gate, CA (562-861-8272)				•				
Berwick Steel Co. Columbus, OH (614-866-1338) BRANCH: Piqua, OH (513-778-8884)				•				
The Bissett Steel Co. Valleyview, OH (216-447-4000)				•				
Boutette & Barnett Inc. London, ON (519-679-1770)				•				
Bridgeport Steel Co. Milford, CT (203-874-2591)				•				

	Plate	Hot rolled bar	Cold finished bar	Hot rolled sheet/strip	Cold rolled sheet/strip	Tubing	Wire	Pipe
British Steel Alloys Inc. Delta, BC (604-940-0439)	•	•	•	•	•	•	•	•
Burgon Tool Steel Co. Inc. Portsmouth, NH (800-258-7106)	•	•	•	•	•			
Capitol Metals Co. Phoenix, AZ (602-275-4131)			•	•	•	•		
Cardinal Metals, Inc. Pounding Mill, VA (540-964-2583)			•			•		
Cardinal Steel Supply, Inc. St. Louis, MO (314-382-6500)			•			•		
Carolina Steel Corp. Greensboro, NC (910-275-9711) BRANCHES: Lexington, KY (606-253-2415) Wilson, NC (919-291-4111) Greenville, SC (803-244-3510) Knoxville, TN (615-524-5798) Lynchburg, VA (804-846-5221) Roanoke, VA (540-992-5252)			•			•		
A.M. Castle & Co. Franklin Park, IL (708-455-7111) BRANCHES: Phoenix, AZ (602-275-7861) Los Angeles (Paramount), CA (310-630-1400) San Diego, CA (800-287-7053) Stockton, CA (800-289-2785) Atlanta (Kennesaw), GA (800-289-2785) Wichita, KS (316-522-5900) Worcester, MA (508-798-2592) Detroit (Farmington Hills), MI (810-553-3322) Kansas City, MO (816-231-6100) Minneapolis (Roseville), MN (612-635-9088) Buffalo (Clarence), NY (800-333-0490) Charlotte, NC (800-395-4000) Chicago, IL (312-582-3200) Hammond, IN (312-582-0088) Cincinnati, OH (800-456-4140) Cleveland (Bedford Heights), OH (216-292-7600) Tulsa, OK (918-437-3460) Philadelphia (Fairless Hills), PA (215-736-8600) Pittsburgh (Cheswick), PA (412-274-1000) Dallas (Grand Prairie), TX (800-289-2785) Houston, TX (713-462-7100) Salt Lake City, UT (800-453-8019)	•	•	•					

	Plate	Hot rolled bar	Cold rolled sheet/strip	Hot rolled sheet/strip	Tubing	Wire	Pipe
Milwaukee (Wauwatosa), WI (414-771-6800)							
Edmonton, AB (403-461-5757)							
Montreal (Pointe Claire), PQ (514-694-9575)							
Toronto (Mississauga), ON (905-858-3888)							
Winnipeg, MB (204-233-8558)							
Central Steel & Wire Co. Chicago, IL (773-471-3800)	•	•	•	•	•	•	•
BRANCHES:							
Cincinnati, OH (513-242-2233)							
Detroit, MI (313-368-5000)							
Milwaukee, WI (414-481-5000)							
Certified Metals, Inc. Springfield, MO (800-222-5990)	•	•	•	•	•	•	•
Chatham Steel Corp. Savannah, GA (912-233-4182)	•	•	•	•	•		
BRANCHES:							
Birmingham, AL (205-791-2261)							
Orlando, FL (407-859-0310)							
Durham, NC (919-682-3388)							
Columbia, SC (803-799-8888)							
Chicago Tube & Iron Co. Chicago, IL (773-523-1441)			•		•		•
BRANCHES:							
Indianapolis, IN (317-872-9999)							
Milan, IL (309-787-4947)							
Duluth, MN (218-723-8111)							
St. Paul, MN (612-454-6800)							
Milwaukee, WI (414-535-1331)							
Copper & Brass Sales, Inc. Eastpointe, MI (810-771-6400)	•		•	•			
BRANCHES:							
Fresno, CA (209-252-1645)							
Los Angeles, CA (213-726-3131)							
Oakland, CA (510-437-8888)							
Wallingford, CT (203-265-1567)							
Miami (Pompano Beach), FL (305-975-4778)							
Orlando, FL (407-648-8748)							
Atlanta (Marietta), GA (404-424-9550)							
Chicago (Schaumburg), IL (708-490-9870)							
Indianapolis, IN (317-872-5450)							
Terre Haute, IN (812-877-9879)							
Louisville, KY (502-245-6864)							
North Attleboro, MA (508-695-7141)							
Big Rapids, MI (616-796-2691)							
Detroit, MI (313-891-4800)							
Detroit, MI (313-365-7700)							
Grand Rapids, MI (616-459-8201)							
St. Louis, MO (314-298-0044)							
Winston-Salem, NC (910-773-1305)							

	Plate	Hot rolled bar	Cold rolled sheet/strip	Hot rolled sheet/strip	Tubing	Wire	Pipe
Buffalo (West Seneca), NY (716-675-0600)							
Cleveland, OH (216-883-8100)							
Dayton, OH (513-898-7400)							
Dayton, OH (513-435-7600)							
Mansfield, OH (419-524-9445)							
Toledo (Maumee), OH (419-893-8220)							
Portland, OR (503-254-2600)							
Philadelphia (Collingdale), PA (215-586-1800)							
Pittsburgh (Cranberry Twp.), PA (724-776-9602)							
Nashville, TN (615-831-9350)							
Toronto (Mississauga), ON (905-238-6699)							
Crest Steel Corp. Carson, CA (310-830-2651)						•	
BRANCHES:							
Phoenix, AZ (602-968-6156)							
Cyclone Steel Services, Inc. Houston, TX (713-635-5555)	•						
Damstahl Stainless Inc. Janesville, WI (800-828-8765)	•	•	•	•	•	•	•
Denman & Davis Clifton, NJ (201-684-3900)	•	•	•	•	•		•
BRANCHES:							
Albany, NY (518-465-3306)							
Slatersville, RI (401-767-0111)							
Dietrich Industries, Inc. Pittsburgh, PA (412-281-2805)				•			
EMJ (Earle M. Jorgensen Co.) Brea, CA (800-336-5365)	•	•	•	•	•	•	•
BRANCHES:							
Bessemer, AL (205-426-6061)							
Little Rock, AR (501-568-4371)							
Phoenix, AZ (602-272-0461)							
Hayward, CA (510-487-2700)							
City of Industry, CA (310-699-9961)							
Denver, CO (303-287-0381)							
Wethersfield, CT (860-529-6861)							
Kapolei, HI (808-682-2020)							
Davenport, IA (319-386-3200)							
Schaumburg, IL (847-301-6100)							
Plainfield, IN (317-838-8899)							
Hopkinton, MA (508-435-6854)							
Oak Park, MI (810-547-9000)							
Blaine, MN (612-784-5000)							
Earth City, MO (314-291-6080)							
Kansas City, MO (816-483-4140)							
Tonawanda, NY (716-876-4700)							
Cincinnati, OH (513-771-3223)							
Twinsburg, OH (216-425-4911)							
Tulsa, OK (918-835-1511)							

	Plate	Hot rolled bar	Cold rolled sheet/strip	Hot rolled sheet/strip	Tubing	Wire	Pipe
Portland, OR (503-283-2251)							
Langhorne, PA (215-949-2850)							
Memphis, TN (901-377-8309)							
Dallas, TX (214-741-1761)							
Houston, TX (713-672-1621)							
Kent, WA (206-872-0100)							
Mississauga, ON (905-564-0866)							
Ville de Laval, PQ (514-661-5181)							
ESCO Corp.	•	•	•	•	•	•	•
Portland, OR (503-226-7341)							
BRANCHES:							
Hayward, CA (510-429-0100)							
Los Angeles, CA (213-722-0300)							
Denver, CO (303-422-8282)							
Seattle, WA (206-623-4160)							
Spokane, WA (509-535-4668)							
Eagle Stainless Tube Corp.			•		•		•
Franklin, MA (508-528-8650)							
Eagle Steel Products, Inc.			•		•		
Jeffersonville, IN (812-282-4770)							
East Tennessee Steel Supply, Inc.	•	•	•	•	•		•
Morristown, TN (423-587-3500)							
Edgcomb Metals Co.	•	•	•	•	•		
Bensalem, PA (215-245-3300)							
BRANCHES:							
Indianapolis, IN (317-823-1004)							
Minneapolis, MN (612-331-4000)							
Charlotte, NC (704-394-7341)							
Cincinnati, OH (513-769-4000)							
Greensboro, NC (910-275-8421)							
Nashua, NH (603-883-7731)							
Syracuse (Liverpool), NY							
(315-451-1551)							
Schenectady, NY (518-356-0511)							
Cleveland (Maple Heights), OH							
(216-587-7000)							
Philadelphia (Bensalem), PA							
(215-639-4000)							
York, PA (717-755-1923)							
Providence (Slatersville), RI							
(401-767-0011)							
Greenville, SC (803-277-6011)							
Murfreesboro, TN (615-849-8800)							
Nashville, TN (615-244-2801)							
Charlottesville (Troy), VA							
(804-589-8285)							
Edmonton Tube & Alloys Ltd.			•		•	•	•
Edmonton, AB (403-468-5656)							
Joseph P. Fazzio, Inc.	•		•		•		•
Glassboro, NJ (609-881-3185)							
Ferguson Metals	•	•	•	•	•	•	•
Bethel, CT (203-790-6306)							

	Plate	Hot rolled bar	Cold rolled sheet/strip	Hot rolled sheet/strip	Tubing	Wire	Pipe
Ferro Union, Inc.	•	•	•	•	•		
Torrence, CA (310-538-9900)							
BRANCHES:							
Phoenix, AZ (602-247-6440)							
City of Industry, CA (800-338-8823)							
Fontana, CA (909-350-4477)							
Fremont, CA (510-791-1352)							
San Diego, CA (619-449-8550)							
Stockton, CA (800-544-8806)							
Alpharetta, GA (770-751-1172)							
Ewa Beach, HI (808-682-3000)							
Vicksburg, MS (800-662-9227)							
Catoosa, OK (800-221-1869)							
Houston, TX (800-231-6375)							
Fidelity Stainless Ltd.		•	•			•	
Mississauga, ON (905-405-9186)							
First Metals Inc.	•	•	•		•		•
Houston, TX (713-676-1700)							
BRANCH:							
Tucker, GA 770-414-9011							
Fox Metals & Alloys, Inc.		•	•				
Houston, TX (713-890-6666)							
Friendswood Metals & Specialty Steel Corp.			•				
Friendswood, TX (713-482-1968)							
Fry Steel Co.		•	•				
Santa Fe Springs, CA (301-802-2721)							
Fullerton Metals Co.				•	•		
Northbrook, IL (847-291-2400)							
Future Metals, Inc.	•	•	•	•	•	•	•
Ft. Lauderdale, FL (954-739-5350)							
BRANCHES:							
Cerritos, CA (310-926-0401)							
Ft. Lauderdale, FL (954-739-5350)							
Commack, NY (516-543-3070)							
Arlington, TX (817-561-4094)							
Pacific, WA (206-735-9000)							
Galvmet, Inc.				•			
Kansas, City, MO (816-453-8500)							
Genzink Steel	•	•	•	•	•	•	•
Holland, MI (616-392-1437)							
Glazer Steel & Aluminum	•	•	•		•		•
New Orleans, LA (504-529-2761)							
BRANCH:							
Knoxville, TN (423-687-1251)							
Goldin Industries, Inc.	•	•	•	•	•	•	•
Gulfport, MS (601-896-6216)							

	Plate	Hot rolled bar	Cold rolled sheet/strip	Hot rolled sheet/strip	Tubing	Wire	Pipe
Grammer, Dempsey & Hudson, Inc. Newark, NJ (201-589-8000)	•			•	•		
Great Western Metals Warehouse Houston, TX (713-484-1150) BRANCHES: Corpus Christi, TX (512-289-8888) San Antonio, TX (512-822-6707)	•	•	•	•	•		•
Habco Steel Service, Inc. Memphis, TN (901-775-1060)	•			•	•		
Hanna Steel Co. Fairfield, AL (205-780-1111)				•	•	•	
Hunter Steel & Supply Ltd. Stratford, ON (519-273-3151)	•	•	•	•	•	•	•
Huntington Steel & Supply Co., Inc. Huntington, WV (304-522-8218) BRANCHES: Pikeville, KY (606-432-0354) Charleston, WV (304-766-6601) Logan, WV (304-239-2318) Morgantown, WV (304-296-2112)	•						
Ideal Roofing Co. Ltd. Ottawa, ON (613-746-3206)				•			
Independent Metals Germantown, WI (414-255-4444) BRANCHES: Orlando, FL (407-855-0060) Broadview, IL (414-255-4444) New Hope, MN (612-537-2110)	•	•	•	•	•	•	•
Industrial Metals International Ltd. Ronkonkoma, NY (516-981-1300)	•	•	•	•	•	•	•
Interstate Steel Supply Co., Inc. Philadelphia, PA (215-673-0300) BRANCHES: Baltimore, MD (410-752-6900) Ambridge, PA (412-266-7708) Philadelphia, PA (215-673-0300)	•			•			
KG Specialty Steel, Inc. North Brunswick, NJ (732-422-3505)	•	•	•	•	•	•	•
KG Specialty Steel Div. of Kanematsu (Canada) Inc. Mississauga, ON (905-670-1977)	•	•	•	•	•	•	•
Keystone Tube Sales, Inc. Titusville, PA (814-827-9641)					•		
Klein Steel Service, Inc. Rochester, NY (716-328-4000)	•	•	•	•	•		•

	Plate	Hot rolled bar	Cold rolled sheet/strip	Hot rolled sheet/strip	Tubing	Wire	Pipe
Klockner-Namasco Corp. Garden City, NY (516-237-6900) BRANCHES: Bessemer, AL (205-426-1701) Irvine, CA (714-833-8970) Tampa, FL (813-247-4511) Jacksonville, FL (904-764-7724) Ocoee, FL (305-785-2850) Pompano Beach, FL (305-785-2850) Tampa, FL (813-225-1350) Norcross, GA (404-242-8600) Suwanee, GA (404-271-9948) Hoffman Estates, IL (708-843-3000) Libertyville, IL (708-367-3348) New Orleans, LA (504-947-4215) Detroit, MI (810-779-7950) Charlotte, NC (704-394-5999) Middletown, OH (513-422-4586) Hendersonville, TN (615-264-2448) Memphis, TN (404-242-8600) Corpus Christi, TX (512-882-7793) Dallas, TX (214-630-6959) Houston, TX (713-433-7211) Houston, TX (713-627-7310) Winnipeg, MB (204-661-8050) Brantford, ON (519-758-2710) Burlington, ON (416-335-5522) Willowdale, ON (416-491-5441) Windsor, ON (519-969-1160) Boucherville, PQ (514-449-2660)					•	•	
Kurtz Steel Company Detroit, MI (313-892-1212) BRANCHES: Indianapolis, IN (800-521-1407) Cleveland, OH (800-821-1993) Dayton, OH (800-837-8412) Grand Rapids, MI (800-248-0813)	•		•				
KWG Industries Bound Brook, NJ (908-356-4163)	•	•	•		•	•	•
Lapham-Hickey Steel Corp. Chicago, IL (708-496-6111) BRANCHES: Columbus, OH (614-443-4881) St. Louis, MO (314-535-8200) Providence, RI (401-861-4100) Oshkosh, WI (414-233-8502)				•			
Lafayette Steel Sales Lafayette, IN (317-423-5371)	•	•	•		•		
Liebovich Steel & Aluminum Co. Rockford, IL (800-892-2981)	•	•	•	•		•	•

	Plate	Hot rolled bar	Cold rolled sheet/strip	Hot rolled sheet/strip	Tubing	Wire	Pipe
Marmon/Keystone Corp. Butler, PA (724-283-3000) BRANCHES: Birmingham (Tarrant), AL (205-520-1000) Fresno, CA (800-372-6304) Los Angeles (Pomona), CA (909-620-7500) Denver, CO (303-296-7473) New Castle, DE (302-328-8000) Orlando, FL (800-241-8600) Atlanta (Norcross), GA (770-476-4111) Chicago (Bolingbrook), IL (708-739-4525) Southampton, MA (413-527-2000) Kansas City, MO (816-241-8222) Charlotte, NC (704-588-2192) Butler, PA (724-283-4500) Richmond (Sandston) VA (804-737-2851) Salt Lake City, UT (801-973-2700) Houston, TX (713-460-5400) Seattle (Auburn), WA (206-941-1151)				•		•	•
Marmon/Keystone Canada Inc. Mississauga, ON (905-567-9640) BRANCHES: Edmonton, AB (403-436-3856) Langley, BC ((604-847-9844) Winnipeg, MB (204-694-6008) Dartmouth, NS (902-468-8530) Burlington, ON (905-335-8827) Laval, PQ (514-335-3013) Boucherville, PQ (514-527-9153)						•	•
McCarty & Sons, Inc. Westbrook, CT (860-399-7946)	•	•	•	•	•	•	•
McNeilus Steel, Inc. Dodge Center, MN (507-374-6336)	•	•	•	•		•	•
Mead Metals, Inc. St. Paul, MN (612-484-1400)				•			
Meier Metal Servicenters, Inc. Hazel Park, MI (810-398-1900) BRANCH: Dayton, OH (513-294-0361)			•	•			
MetalCenter, Inc. Santa Fe Springs, CA (310-944-3322)				•			
Metal Services, Inc. Dallas, TX (214-348-7140) BRANCH: San Marcos, TX (512-353-5000)	•	•	•	•	•	•	•
Metal Supermarkets International Brampton, ON (905-459-0466)	•	•	•	•		•	•

	Plate	Hot rolled bar	Cold rolled sheet/strip	Hot rolled sheet/strip	Tubing	Wire	Pipe
Mi-Tech Steel, Inc. Louisville, KY (502-245-2110)						•	
Mill Steel Co. Grand Rapids, MI (616-949-6700)				•	•		
Millard Metal Service Center, Inc. Braintree, MA (617-848-1400) BRANCHES: Southington, CT (203-621-0171) Waterbury, CT (203-757-9277) Tampa, FL (813-247-4591) Carlstadt, NJ (201-935-0708) Rochester, NY (716-328-3240)			•	•	•	•	•
Murphy & Nolan, Inc. Syracuse, NY (315-474-8203) BRANCH: Rochester, NY (716-426-1420)	•	•	•	•	•	•	•
Napco Steel Inc. West Chicago, IL (630-293-1900)	•	•	•		•		
Nivert Metal Supply, Inc. Throop, PA (717-344-7141)	•	•	•	•	•		•
Olbert Metal Sales Ltd. Mississauga, ON (905-795-1180)	•	•	•	•		•	
Olympic Steel, Inc. Bedford Heights, OH (216-292-3800) BRANCHES: Birmingham, AL (205-923-8444) Milford, CT (203-878-9381) Elk Grove, IL (708-582-4000) Plymouth, MN (612-544-7100) Philadelphia, PA (215-521-6800) Pittsburgh, PA (412-391-4777) Greenville, SC (803-370-9400)	•	•	•	•	•	•	•
O'Neal Steel, Inc. Birmingham, AL (205-599-8000) BRANCHES: Birmingham, AL (205-599-8000) Chickasaw Station, AL (334-457-4361) Little Rock, AR (501-490-0040) Atlanta, GA (770-497-8040) Garden City, GA (912-964-2030) Waterloo, IA (319-235-6521) Peru, IL (317-398-9766) Evansville, IN (812-867-4280) New Haven, IN (219-493-1506) Shelbyville, IN (317-398-9766) Jacksonville, FL (904-781-4220) Tampa, FL (800-342-5237) Louisville, KY (502-363-1861) Breaux Bridge, LA (318-232-2612) Jackson, MS (601-939-4132) Greensboro, NC (910-668-1100) Toledo, OH (419-729-0621)	•	•	•	•	•	•	•

	Plate	Hot rolled bar	Cold rolled sheet	Hot rolled sheet	Tubing	Wire	Pipe
Ambridge, PA (800-338-6549)							
Chattanooga, TN (423-867-4820)							
Knoxville, TN (423-588-5365)							
Memphis, TN (901-774-6650)							
Nashville, TN (615-256-2900)							
Dallas, TX (214-556-2323)							
Houston, TX (713-675-1900)							
Lubbock, TX (806-747-4694)							
Pacific Machinery & Tool Steel Co. Portland, OR (503-228-1637)			•				
Pacific Metal Co. Portland, OR (503-227-0691)				•	•		
BRANCHES:							
Galt, CA (209-745-5200)							
Boise, ID (208-323-8045)							
Billings, MT (406-245-2210)							
Eugene, OR (541-485-1876)							
Medford, OR (541-779-7271)							
Seattle, WA (206-251-6100)							
Spokane, WA (509-535-0326)							
Patton Sales Corp. Ontario, CA (909-988-6461)	•	•	•			•	•
BRANCHES:							
Burbank, CA (818-846-3446)							
Irwindale, CA (818-338-8110)							
San Bernardino, CA (909-884-8771)							
Peachtree Metals Co. Duluth, GA (770-476-7000)			•				
Penn Stainless Products, Inc. Quakertown, PA (800-222-6144)	•	•	•	•	•	•	•
Pennsylvania Steel Co., Inc. Bensalem, PA (215-633-9600)			•	•			
Plus Ten Stainless, Inc. Benicia, CA (707-745-4625)	•	•					
Pyndus Steel & Aluminum Co., Inc. San Antonio, TX (210-735-9266)				•			
Quality Metals, Inc. St. Paul, MN (612-645-5875)				•	•		
Reynolds Aluminum Supply Co. Richmond, VA (804-281-2000)	•	•	•	•	•	•	•
BRANCHES:							
Birmingham, AL (205-853-7100)							
Phoenix, AZ (602-258-7121)							
City of Commerce, CA (213-726-7111)							
Livermore, CA (510-449-3498)							
Los Angeles, CA (213-726-2290)							
San Diego, CA (619-336-2100)							
Wallingford, CT (203-294-1241)							
Newark, DE (302-366-0555)							
Jacksonville, FL (904-695-7460)							

	Plate	Hot rolled bar	Cold rolled sheet	Hot rolled sheet	Tubing	Wire	Pipe
Orlando, FL (407-293-6430)							
Atlanta, GA (404-355-0310)							
Atlanta, GA (404-699-0726)							
Barbourville, KY (606-523-5076)							
Louisville, KY (502-266-5007)							
Shelbyville, KY (502-633-7770)							
Chesterfield, MI (810-598-7900)							
Grand Rapids, MI (616-241-3451)							
Kansas City, MO (816-842-2200)							
St. Louis, MO (314-344-0123)							
Charlotte, NC (704-552-2568)							
Cincinnati, OH (513-874-7744)							
Cleveland, OH (216-526-5969)							
Streetsboro, OH (216-562-4661)							
Portland, OR (503-283-4705)							
Memphis, TN (901-541-6540)							
Nashville, TN (615-242-3405)							
Dallas, TX (972-623-4000)							
Richmond, VA (804-222-7589)							
Kent, WA (206-872-7060)							
Seattle, WA (206-872-7060)							
Rio Algom, Ltd. Toronto, ON (416-365-6870)	•	•	•	•	•	•	•
Riverfront Steel, Inc. Cincinnati, OH (513-651-3333)			•				
Rosselle's Metals Inc. Miami, FL (305-696-7950)	•	•		•			
J. Rubin & Co. Rockford, IL (815-964-9471)	•	•	•	•	•	•	
BRANCH:							
Plymouth, MN (612-553-1550)							
Russel Metals Inc. Mississauga, ON (905-819-7777)	•	•	•	•	•	•	•
BRANCHES:							
Calgary, AB (403-279-6600)							
Grande Prairie, AB (403-539-3193)							
Edmonton, AB (403-439-2051)							
Red Deer, AB (403-346-2096)							
Campbell River, BC (604-287-8533)							
Fort St. John, BC (604-785-5641)							
Kitimat, BC (604-632-4702)							
Nanaimo, BC (604-758-2454)							
Prince George, BC (604-561-2988)							
Vancouver, BC (604-520-6111)							
Vernon, BC (604-542-8366)							
Winnipeg, MB (204-475-8584)							
Winnipeg, MB (204-772-0321)							
Edmundston, NB (506-739-9561)							
Saint John, NB (506-635-0005)							
St. John's NF (709-782-2000)							
Halifax, NS (902-876-7861)							
Burlington, ON (905-332-2288)							
Hamilton, ON (905-522-1347)							
Hamilton, ON (905-544-6866)							
Hamilton, ON (905-529-9660)							

	Plate	Hot rolled bar	Cold finished bar	Hot rolled sheet/strip	Cold rolled sheet/strip	Tubing	Wire	Pipe
Kingston, ON (613-546-1281)								
London, ON (519-451-1140)								
Milton, ON (905-875-3600)								
Mississauga, ON (905-567-8500)								
Ottawa, ON (613-247-7700)								
Sarnia, ON (519-332-6666)								
Sault Ste. Marie, ON (705-945-9802)								
Stoney Creek, ON (905-643-2001)								
Stoney Creek, ON (905-643-0326)								
Windsor, ON (519-737-1247)								
Arvida, PQ (418-548-3103)								
Lachine, PQ (514-631-4861)								
Saskatoon, SA (306-931-3338)								
Regina, SA (306-721-6411)								
Joseph T. Ryerson & Son, Inc.-Central Chicago, IL (773-762-2121)	•	•	•	•	•	•	•	•
BRANCHES:								
Indianapolis, IN (317-359-8282)								
Detroit, MI (313-874-3311)								
Minneapolis, MN (612-544-4401)								
Kansas City, MO (816-471-3500)								
St. Louis, MO (314-231-1020)								
Cincinnati, OH (513-542-5800)								
Tulsa, OK (404-368-4311)								
Dallas, TX (214-637-4710)								
Houston, TX (713-675-6111)								
Milwaukee, WI (414-453-8000)								
Joseph T. Ryerson & Son, Inc.-East West Chester, PA (610-429-0800)	•	•	•	•	•	•	•	•
BRANCHES:								
Wallingford, CT (203-269-8744)								
Buffalo, NY (716-894-3311)								
Charlotte, NC (704-392-1321)								
Cleveland, OH (216-432-1411)								
Philadelphia, PA (215-724-0700)								
Pittsburgh (Carnegie), PA (412-276-5400)								
Chattanooga, TN (615-499-3500)								
Joseph T. Ryerson & Son, Inc.-West Seattle, WA (206-242-3400)	•	•	•	•	•	•	•	•
BRANCHES:								
Phoenix, AZ (602-233-6100)								
Emeryville, CA (510-653-2933)								
Los Angeles, CA (213-268-7100)								
Denver, CO (303-287-0101)								
Portland, OR (503-285-4611)								
Clearfield, UT (801-773-0421)								
Seattle, WA (206-624-2300)								
Spokane, WA (509-535-1581)								
Ryerson Tull, Inc. Chicago, IL (773-762-2121)	•	•	•	•	•	•	•	•
Sampson Steel Corp. Beaumont, TX (409-838-1611)	•	•	•	•	•			

	Plate	Hot rolled bar	Cold finished bar	Hot rolled sheet/strip	Cold rolled sheet/strip	Tubing	Wire	Pipe
Samson Metal Supply Dayton, NJ (609-655-0777)	•	•	•	•	•	•	•	•
Samuel, Son & Co. Ltd. Mississauga, ON (905-279-5460)				•	•			
BRANCHES:								
Norcross, GA (770-279-0505)								
Baton Rouge, LA (504-927-0146)								
West Chicago, IL (708-231-6800)								
Baltimore, MD (410-234-2828)								
Detroit, MI (313-893-5000)								
Belmont, NH (800-489-9614)								
Parsippany, NJ (201-884-2222)								
Binghamton, NY (607-775-2000)								
Buffalo, NY (716-681-4200)								
Rochester, NY (716-426-8050)								
Syracuse, NY (315-457-5441)								
Cincinnati, OH (513-793-8500)								
Tulsa, OK (918-266-3113)								
Concordville, PA (610-558-5950)								
Erie, PA (814-838-5000)								
Hermitage, PA (724-983-1900)								
Pittsburgh, PA (412-323-1280)								
Houston, TX (713-462-5000)								
Irving, TX (214-438-3949)								
Leduc, AB (403-986-7141)								
Langley, BC (604-882-0429)								
Vancouver, BC (604-254-7765)								
Winnipeg, MB (204-985-6600)								
Cambridge, ON (519-658-4693)								
Hamilton, ON (905-547-1931)								
Hamilton, ON (905-573-9100)								
Scarborough, ON (905-724-6061)								
Stoney Creek, ON (905-561-7811)								
Sudbury, ON (705-560-0832)								
Chomedey, PQ (514-384-5220)								
Dorval, PQ (514-636-7610)								
Schultz Metal Service, Inc. Bridgewater, NJ (908-356-9500)		•	•			•	•	•
Schwartz Steel Service Inc. Gastonia, NC (704-865-0614)				•				
Service Steel, Div. of Van Pelt Corp. Detroit, MI (313-365-3600)						•		•
BRANCHES:								
East Moline, IL (309-755-2151)								
Wichita, KS (316-522-1541)								
Tonawanda, NY (716-694-5200)								
Cincinnati, OH (513-242-6000)								
Siskin Steel & Supply Co., Inc. Chattanooga, TN (423-266-3671)	•	•	•	•	•	•	•	•
BRANCHES:								
Birmingham, AL (205-326-6826)								
Nashville, TN (615-242-4444)								
Spartanburg, SC (864-599-9988)								

	Plate	Hot rolled bar	Cold rolled sheet/bar	Hot rolled sheet/strip	Cold rolled sheet/strip	Tubing	Wire	Pipe
Skorr Steel Co., Inc. Brooklyn, NY (718-386-9577)	•							
Southern Alloy of America Salisbury, NC (704-637-1906)				•				
South St. Paul Steel Supply Co., Inc. South St. Paul, MN (612-451-6666)	•	•	•	•	•	•		•
Southstar Steel Corp. Charlotte, NC (704-342-4247) BRANCHES: La Habra Heights, CA (310-947-1100) Fairless Hills, PA (215-736-8610) Milwaukee, WI (414-931-0900)			•	•			•	•
Stainless Stock Exchange Inc. Ridgefield Park, NJ (201-641-5100)	•			•	•			
Standard Tube Sales Corp. Marlborough, MA (800-225-9420) BRANCH: Woodbridge, NJ (800-526-4306)						•		•
State Steel Supply Co. Sioux City, IA (800-831-0862) BRANCHES: Grand Island, NE (308-381-2040) Sioux Falls, SD (605-338-9303)	•	•	•	•	•	•		•
Steel Services, Inc. Richmond, VA (804-673-3810) BRANCHES: Berlin, MD (410-632-0052) Norfolk, VA (804-855-0111) Richmond (Ashland), VA (804-798-3333) Roanoke, VA (540-774-4461)	•		•	•	•			
Summerville Steel Co. Kent, WA (206-251-5280)				•				
TBI Steel, Inc. Paducah, KY (502-442-4337)	•	•	•	•	•			
TCT Stainless Steel, Inc. Sterling Heights, MI (810-254-5333) BRANCHES: Cleveland, OH (216-892-3364) Lebanon, IN (615-443-4657)				•				
Tampa Bay Steel Corp. Tampa, FL (813-621-4738)	•		•	•	•	•		•
Tell Steel, Inc. Long Beach, CA (310-435-4826)	•	•	•	•	•	•		•
Thompson Metals & Tubing Fairfield, OH (513-874-1400)	•				•	•		•

	Plate	Hot rolled bar	Cold rolled sheet/bar	Hot rolled sheet/strip	Cold rolled sheet/strip	Tubing	Wire	Pipe
Thypin Steel Co., Inc. Long Island City, NY (718-937-2700) BRANCHES: Alabaster, AL (800-332-6631) Cambridge, MA (617-864-7700) Blasdell, NY (800-553-7700) Charlotte, NC (800-438-3455) Easton, PA (610-252-3440) Morrisville, PA (215-736-8970)	•	•	•	•	•	•		
Thyssen Marathon Canada Mississauga, ON (416-675-5941)	•	•	•	•	•	•	•	
Tioga Pipe Supply Co., Inc. Philadelphia, PA (215-831-0700) BRANCHES: Chicago, IL (708-371-3131) Houston, TX (713-433-2111)						•		•
Tool King, Inc. Wheeling, IL (847-537-2881)					•			
Torrington Brass & Steel Div. of TBS Industries, Inc. Torrington, CT (860-482-6581)				•				
Tremblay Tool Steels, Inc. Macedonia, OH (216-467-4725)	•		•					
Tubesales Glen Ellyn, IL (800-545-5000) BRANCHES: Mobile, AL (205-660-9931) Hayward, CA (510-475-5700) Los Angeles, CA (213-728-5310) Orlando, FL (407-648-1550) Forest Park, GA (404-361-5050) Garden City, GA (912-964-9673) Carol Stream, IL (708-690-0110) Bloomington, IN (800-545-5000) Wichita, KS (316-522-5400) Baton Rouge, LA (504-293-8699) Agawam, MA (413-786-1531) Rogers, MN (612-428-7663) Charlotte, NC (704-588-4111) Cranbury, NJ (609-655-4120) Rochester, NY (716-352-3880) Springfield, OH (513-390-0793) Grand Prairie, TX (214-988-8823) Houston, TX (713-462-5585) Woodinville, WA (206-488-5656) Brookfield, WI (414-783-7241) Horicon, WI (414-485-3133) Mequon, WI (414-241-3600)			•			•		•

	Plate	Hot rolled bar	Cold rolled sheet/bar	Hot rolled sheet/strip	Cold rolled sheet/strip	Tubing	Wire	Pipe
Tubular Steel, Inc. St. Louis, MO (314-851-9200) BRANCHES: Los Angeles, CA (909-427-1260) Chicago, IL (630-515-5000) Philadelphia, PA (215-741-2500) Houston, TX (281-579-4200)			•	•			•	•
J.M. Tull Metals Co., Inc. Norcross, GA (770-368-4311) BRANCHES: Birmingham, AL (205-854-8855) Jacksonville, FL (904-783-8855) Miami, FL (305-693-8855) Tampa, FL (813-237-8855) Baton Rouge, LA (504-926-8855) St. Rose, LA (504-466-8855) Charlotte, NC (704-588-3380) Greensboro, NC (919-668-0031) Columbia, SC (803-252-8855) Greenville, SC (803-235-8855) Richmond, VA (804-222-8855)	•	•	•	•	•	•		•
Turret Steel Corp. Leetsdale, PA (412-266-9200)		•	•					
U.S. Alloys, Inc. Houston, TX (713-644-1983)		•						
Ugine Stainless & Alloys Colmar, PA (800-523-3321) BRANCHES: Brea, CA (714-529-9774) Kennesaw, GA (770-499-1040) Batavia, IL (708-879-0400) Mahwah, NJ (201-529-5800) Houston, TX (713-649-4420)		•	•				•	
Ulbrich Stainless Steel & Special Metals, Inc. North Haven, CT (800-243-1676) BRANCHES: Fresno, CA (209-456-1532) Norcross, GA (770-921-3100) Chicago (Alsip), IL (708-489-9500) Indianapolis, IN (317-879-1000) Houston, TX (713-675-4154)				•			•	
United Steel & Aluminum Corp. Norwood, MA (617-762-0123) BRANCHES: American Steel & Aluminum Corp. Hartford, CT (203-527-2681) Auburn, MA (508-832-9681) Norwood, MA (617-762-8014)	•	•	•	•	•	•		•
Universal Metals & Machinery, Inc. Houston, TX (713-675-2729)	•		•			•		•

	Plate	Hot rolled bar	Cold rolled sheet/bar	Hot rolled sheet/strip	Cold rolled sheet/strip	Tubing	Wire	Pipe
Upstate Steel, Inc. Buffalo, NY (716-892-8434)	•	•						
Victory Tube Co. Cleveland, OH (216-641-9339) BRANCH: Hebron, KY (606-586-4000)							•	
The Warren Co. Erie, PA (814-838-8621) BRANCHES: Falconer, NY (716-665-3716) Oil City, PA (814-676-2311)	•		•	•				
Washington Specialty Metals Corp. Buffalo Grove, IL (800-672-2677) BRANCHES: Tampa, FL (813-247-6822) Lawrenceville, GA (770-995-1212) Youngsville, NC (919-554-4287) Carrollton, TX (214-380-8950) Brampton, ON (905-792-1414) Vandreuil, PQ (514-424-0153)				•				
West Coast Wire & Steel, LLC Riverside, CA (909-683-7252)						•		•
Wilkinson Steel & Metal Vancouver, BC (604-324-6611) BRANCHES: Calgary, AB (403-236-0300) Edmonton, AB (403-434-8441) Fort McMurray, AB (403-791-6860) Cranbrook, BC (604-489-3333) Kamloops, BC (604-374-7122) Lantzville, BC (604-390-1939) Prince George, BC (604-561-1950) Victoria, BC (604-361-4800) Saskatoon, SA (306-652-7151)	•		•	•				
Wolverine Metal Co., Inc. Warren, MI (810-758-6100)	•			•	•			
Yarde Metals, Inc. Bristol, CT (860-589-2386) BRANCHES: Deer Park, NY (516-595-2095) Tewksbury, MA (508-640-1500)	•		•	•		•	•	•

Appendix VI

DIRECTORY OF SPECIFICATION SOURCES

AMS

Society of Automotive Engineers, Inc.
400 Commonwealth Drive
Warrendale, PA 15086
(724) 776-4841
Fax (724) 776-0790

ASTM

100 Barr Harbor Drive
West Conshohocken, PA 19428
(610) 832-9585
Fax (610) 832-9555

Military

Defense Automated Printing Service
Standardization Documents Order Desk
700 Robbins Avenue, Building 4D
Philadelphia, PA 19111
(215) 697-2179
Fax (215) 697-1462

NACE

NACE International
P.O. Box 218340
Houston, TX 77218-8340
(281) 492-0535
Fax (281) 228-6300

SAE

Society of Automotive Engineers, Inc.
400 Commonwealth Drive
Warrendale, PA 15086
(724) 776-4841
Fax (724) 776-0790

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