

AEROSPACE MATERIAL SPECIFICATION



AMS 5662M

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Superseding AMS 5662L

Nickel Alloy, Corrosion and Heat-Resistant, Bars, Forgings, and Rings
52.5Ni - 19Cr - 3.0Mo - 5.1Cb (Nb) - 0.90Ti - 0.50Al - 18Fe
Consumable Electrode or Vacuum Induction Melted
1775 °F (968 °C) Solution Heat Treated, Precipitation-Hardenable
(Composition similar to UNS N07718)

1. SCOPE:

1.1 Form:

This specification covers a corrosion and heat-resistant nickel alloy in the form of bars, forgings, flash welded rings, and stock for forging, flash welded rings, or heading.

1.2 Application:

These products have been used typically for parts requiring high resistance to creep and stress-rupture up to 1300 °F (704 °C) and oxidation resistance up to 1800 °F (982 °C), particularly those parts which are formed or welded and then precipitation heat treated to develop required properties, but usage is not limited to such applications.

2. APPLICABLE DOCUMENTS:

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent supplied herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

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2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

AMS 2261	Tolerances, Nickel, Nickel Alloy, and Cobalt Alloy Bars, Rods, and Wire
AMS 2269	Chemical Check Analysis Limits, Nickel, Nickel Alloys, and Cobalt Alloys
AMS 2371	Quality Assurance Sampling and Testing, Corrosion and Heat-Resistant Steels and Alloys, Wrought Products and Forging Stock
AMS 2374	Quality Assurance Sampling and Testing, Corrosion and Heat-Resistant Steel and Alloy Forgings
AMS 2750	Pyrometry
AMS 2806	Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat-Resistant Steels and Alloys
AMS 2808	Identification, Forgings
AMS 7490	Rings, Flash Welded, Corrosion and Heat-Resistant Austenitic Steels, Austenitic-Type Iron, Nickel, or Cobalt Alloys, or Precipitation-Hardenable Alloys
ARP1313	Determination of Trace Elements in High-Temperature Alloys

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 or www.astm.org.

ASTM E 8	Tension Testing of Metallic Materials
ASTM E 8M	Tension Testing of Metallic Materials (Metric)
ASTM E 10	Brinell Hardness of Metallic Materials
ASTM E 21	Elevated Temperature Tension Tests of Metallic Materials
ASTM E 103	Rapid Indentation Hardness Testing of Metallic Materials
ASTM E 112	Determining Average Grain Size
ASTM E 139	Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
ASTM E 292	Conducting Time-for-Rupture Notch Tension Tests of Materials
ASTM E 354	Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

Shall conform to the percentages by weight shown in Table 1, determined by wet chemical methods in accordance with ASTM E 354, by spectrochemical methods, by the methods of ARP1313 for lead, bismuth, and selenium, or by other analytical methods acceptable to purchaser.

TABLE 1 - Composition

Element	min	max
Carbon	--	0.08
Manganese	--	0.35
Silicon	--	0.35
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	17.00	21.00
Nickel	50.00	55.00
Molybdenum	2.80	3.30
Columbium (Niobium)	4.75	5.50
Titanium	0.65	1.15
Aluminum	0.20	0.80
Cobalt	--	1.00
Tantalum (3.1.1)	--	0.05
Boron	--	0.006
Copper	--	0.30
Lead	--	0.0005 (5 ppm)
Bismuth	--	0.00003 (0.3 ppm)
Selenium	--	0.0003 (3 ppm)
Iron	remainder	

3.1.1 Determination not required for routine acceptance.

3.1.2 Check Analysis: Composition variations shall meet the applicable requirements of AMS 2269.

3.2 Melting Practice:

Alloy shall be multiple melted using consumable electrode practice in the remelt cycle or shall be induction melted under vacuum. If consumable electrode remelting is not performed in vacuum, electrodes which have been produced by vacuum induction melting shall be used for remelting.

3.3 Condition:

The product shall be supplied in the following condition:

3.3.1 Bars: Hot or cold finished, solution heat treated, and descaled except as specified in 3.3.1.1 and 3.3.1.2.

3.3.1.1 Hot finished round bars shall be ground or turned; all other hot finished bars shall be as hot finished.

3.3.1.2 Cold finished round bars shall be ground or as cold finished; all other cold finished bars shall be as cold finished.

3.3.2 Forgings and Flash Welded Rings: Solution heat treated and descaled.

3.3.2.1 Flash welded rings shall not be supplied unless specified or permitted on purchaser's part drawing. When supplied, rings shall be manufactured in accordance with AMS 7490.

3.3.3 Stock for Forging, Flash Welded Rings, or Heading: As ordered by the forging, flash welded ring, or heading manufacturer.

3.4 Heat Treatment:

Bars, forgings, and flash welded rings shall be solution heat treated by heating to a temperature within the range 1725 to 1850 °F (941 to 1010 °C), holding at the selected temperature within ± 25 °F (± 14 °C) for a time commensurate with cross-sectional thickness, and cooling at a rate equivalent to an air cool or faster. Pyrometry shall be in accordance with AMS 2750.

3.4.1 If forgings are not to be machined all over, heat treatment shall be performed in a suitable protective atmosphere or, when permitted by purchaser, a suitable protective coating may be applied to the forgings in lieu of using a protective atmosphere.

3.5 Properties:

The product shall conform to the following requirements:

3.5.1 Bars, Forgings, and Flash Welded Rings:

3.5.1.1 As Solution Heat Treated:

3.5.1.1.1 Hardness: Shall be not higher than 277 HB, or equivalent (See 8.2), determined in accordance with ASTM E 10 or ASTM E 103.

3.5.1.1.2 Average Grain Size: Shall be as follows, determined by the comparative method of ASTM E 112. In case of disagreement, the intercept (Heyn) procedure shall be used.

3.5.1.1.2.1 Bars and flash welded rings under 9 square inches (58 cm²) in cross-sectional area shall exhibit an average grain size of ASTM No. 5 or finer. Up to 20% of the cross section of the product may have an average grain size of ASTM No. 3 to 5, determined by the intercept method of ASTM E 112, due to the presence of nonrecrystallized grains.

3.5.1.1.2.2 Bars and flash welded rings 9 to 50 square inches (58 to 323 cm²), inclusive, in cross-sectional area and all forgings shall exhibit an average grain size of ASTM No. 4 or finer. Up to 20% of the product cross section may have an average grain size of ASTM No. 2 to 4, determined by the intercept method of ASTM E 112, due to the presence of nonrecrystallized grains.

3.5.1.1.3 Microstructure: Product shall be free of Laves phase. Banding of acicular phase and amount of acicular phase shall conform to standards acceptable to purchaser.

3.5.1.2 Response to Heat Treatment: Product, 5 inches (127 mm) and under in nominal diameter or least distance between parallel sides, shall meet the requirements of 3.5.1.2.1, 3.5.1.2.2, and 3.5.1.2.3 after being precipitation heat treated by heating to $1325^{\circ}\text{F} \pm 15$ ($718^{\circ}\text{C} \pm 8$), holding at heat for not less than eight hours, cooling at a rate of $100^{\circ}\text{F} \pm 15$ ($56^{\circ}\text{C} \pm 8$) degrees per hour to $1150^{\circ}\text{F} \pm 15$ ($621^{\circ}\text{C} \pm 8$), holding at $1150^{\circ}\text{F} \pm 15$ ($621^{\circ}\text{C} \pm 8$) for not less than eight hours, and cooling in air. Instead of the 100°F (56°C) degrees per hour cooling rate to $1150^{\circ}\text{F} \pm 15$ ($621^{\circ}\text{C} \pm 8$), product may be furnace cooled at any rate provided the time at $1150^{\circ}\text{F} \pm 15$ ($621^{\circ}\text{C} \pm 8$) is adjusted to give a total precipitation heat treatment time of not less than 18 hours.

3.5.1.2.1 Tensile Properties:

3.5.1.2.1.1 At Room Temperature: Shall be as shown in Table 2, determined in accordance with ASTM E 8 or ASTM E 8M.

TABLE 2A - Minimum Room Temperature Tensile Properties, Inch/Pound Units

Specimen Orientation	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 4D %	Reduction of Area %
Longitudinal	185	150	12	15
Long-Transverse (Forgings)	180	150	10	12
Transverse (Bars)	180	150	6	8

TABLE 2B - Minimum Room Temperature Tensile Properties, SI Units

Specimen Orientation	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 4D %	Reduction of Area %
Longitudinal	1276	1034	12	15
Long-Transverse (Forgings)	1241	1034	10	12
Transverse (Bars)	1241	1034	6	8

- 3.5.1.2.1.2 AT 1200 °F (649 °C): Shall be as specified in Table 3, determined in accordance with ASTM E 21 on specimens heated to 1200 °F $\pm$ 5 (649 °C $\pm$ 3), held at heat for not less than 20 minutes before testing, and tested at 1200 °F $\pm$ 5 (649 °C $\pm$ 3).

TABLE 3A - Minimum Tensile Properties at 1200 °F, Inch/Pound Units

Specimen Orientation	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 4D %	Reduction of Area %
Longitudinal	145	125	12	15
Long-Transverse (Forgings)	140	125	10	12
Transverse (Bars)	140	125	6	8

TABLE 3B - Minimum Tensile Properties at 649 °C, SI Units

Specimen Orientation	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 4D %	Reduction of Area %
Longitudinal	1000	862	12	15
Long-Transverse (Forgings)	965	862	10	12
Transverse (Bars)	965	862	6	8

- 3.5.1.2.1.3 Longitudinal requirements of 3.5.1.2.1.1 and 3.5.1.2.1.2 apply to specimens taken with the axis approximately parallel to the grain flow, to specimens taken in the radial direction and in the tangential direction at the rim of disc forgings, and to specimens taken in the circumferential direction from flash welded rings. All other specimens shall be considered to be in the transverse direction.
- 3.5.1.2.1.4 Transverse tensile properties apply only to product from which a tensile specimen not less than 2.50 inches (63.5 mm) long can be obtained.
- 3.5.1.2.1.5 Specific locations of specimens from forgings and flash welded rings shall be as agreed upon by purchaser and vendor.

- 3.5.1.2.2 Hardness: Shall be not lower than 331 HB, or equivalent (See 8.2), determined in accordance with ASTM E 10 or ASTM E 103. Product shall not be rejected on the basis of hardness if the tensile property requirements of 3.5.1.2.1.1, determined on specimens taken from the same sample as that with nonconforming hardness or from another sample with similar nonconforming hardness, are acceptable.
- 3.5.1.2.3 Stress-Rupture Properties at 1200 °F (649 °C): Shall be as follows; testing of notched specimens and of combination smooth-and-notched specimens shall be performed in accordance with ASTM E 292 and testing of smooth specimens shall be performed in accordance with ASTM E 139:
- 3.5.1.2.3.1 A standard cylindrical combination smooth-and-notched specimen conforming to ASTM E 292, maintained at 1200 °F $\pm$ 3 (649 °C $\pm$ 2) while a load sufficient to produce an initial axial stress of 100 ksi (689 MPa) or higher is applied continuously, shall not rupture in less than 23 hours. The test shall be continued to rupture without change of load. Rupture shall occur in the smooth section and elongation of this section after rupture, measured at room temperature, shall be not less than 4% in 4D for product 5.0 inches (127 mm) and under in nominal diameter or distance between parallel sides.
- 3.5.1.2.3.2 As an alternate procedure, separate smooth and notched specimens, machined from adjacent sections of the same piece, with gage sections conforming to the respective dimensions shown in ASTM E 292 may be tested individually under the conditions of 3.5.1.2.3.1. The smooth specimen shall not rupture in less than 23 hours and elongation after rupture, measured at room temperature, shall be as specified in 3.5.1.2.3.1. The notched specimen shall not rupture in less time than the companion smooth specimen but need not be tested to rupture.
- 3.5.1.2.3.3 The tests of 3.5.1.2.3.1 and 3.5.1.2.3.2 may be conducted using incremental loading. In such case, the load required to produce an initial axial stress of 100 ksi (689 MPa) or higher shall be used to rupture or for 23 hours, whichever occurs first. After the 23 hours and at intervals of 8 hours minimum, thereafter, the stress shall be increased in increments of 5.0 ksi (34.5 MPa). Time to rupture, rupture location, and elongation requirements shall be as specified in 3.5.1.2.3.1.
- 3.5.1.3 After Re-solution and Precipitation Heat Treatment: The product shall meet the requirements of 3.5.1.2.1, 3.5.2.1.2.2, and 3.5.1.2.3 after being re-solution heat treated by heating to 1750 °F $\pm$ 25 (954 °C $\pm$ 14), holding at heat for not less than 60 minutes, and cooling at a rate equivalent to an air cool or faster and precipitation heat treated as in 3.5.1.2.
- 3.5.2 Forging Stock: When a sample of stock is forged to a test coupon, heat treated as in 3.4 and 3.5.1.2, specimens taken from the heat treated coupon shall conform to the requirements of 3.5.1.2.1, 3.5.1.2.2, and 3.5.1.2.3. If specimens taken from the stock after heat treatment as in 3.4 and 3.5.1.2 conform to the requirements of 3.5.1.2.1, 3.5.1.2.2, and 3.5.1.2.3, the tests shall be accepted as equivalent to tests of a forged coupon. Stock shall also meet these requirements after solution heat treatment and re-solution and precipitation heat treatment as in 3.5.1.3.

3.5.3 Stock for Flash Welded Rings or Heading: Specimens taken from the stock after heat treatment as in 3.4 and 3.5.1.2 shall conform to the requirements of 3.5.1.2.1, 3.5.1.2.2, and 3.5.1.2.3.

3.6 Quality:

The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the product.

3.6.1 Grain flow of die forgings, except in areas which contain flash-line end grain, shall follow the general contour of the forgings showing no evidence of reentrant grain flow.

3.7 Tolerances:

Bars shall conform to all applicable requirements of AMS 2261.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The vendor of the product shall supply all samples for vendor's tests and shall be responsible for the performance of all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to specified requirements.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: The following requirements are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.1.1 Composition (3.1) of each heat.

4.2.1.2 Hardness (3.5.1.1.1) and average grain size (3.5.1.1.2) of each lot of bars, forgings, and flash welded rings as solution heat treated.

4.2.1.3 Room-temperature tensile properties (3.5.1.2.1.1), hardness (3.5.1.2.2), and stress-rupture properties (3.5.1.2.3) of each lot of bars, forgings, and flash welded rings after precipitation heat treatment.

4.2.1.4 Microstructure (3.5.1.1.3) of each lot.

4.2.1.5 Tolerances (3.7) of bars.

4.2.2 Periodic Tests: The following requirements are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser:

4.2.2.1 Tensile properties at 1200 °F (649 °C) (3.5.1.2.1.2) of bars, forgings, and flash welded rings after precipitation heat treatment.

4.2.2.2 Tensile Properties (3.5.1.2.1), hardness (3.5.1.2.2), and stress-rupture properties (3.5.1.2.3) of bars, forgings, and flash welded rings after resolution and precipitation heat treatment (3.5.1.3).

4.2.2.3 Ability of forging stock (3.5.2) and of stock for flash welded rings or heading (3.5.3) to develop required properties.

4.2.2.4 Grain flow (3.6.1) of die forgings.

4.3 Sampling and Testing:

Shall be as follows:

4.3.1 Bars, Flash Welded Rings, and Stock for Forging, Flash Welded Rings, or Heading: In accordance with AMS 2371.

4.3.2 Forgings: In accordance with AMS 2374.

4.4 Reports:

4.4.1 The vendor of bars, forgings, and flash welded rings shall furnish with each shipment a report showing the results of tests for chemical composition of each heat and the results of tests on each lot to determine conformance to the other acceptance test requirements. This report shall include the purchase order number, heat and lot numbers, AMS 5662M, solution heat treatment temperature used, size, and quantity. If forgings are supplied, the part number and the size and melt source of stock used to make the forgings shall also be included.

4.4.2 The vendor of stock for forging, flash welded rings, or heading shall furnish with each shipment a report showing the results of tests for chemical composition of each heat. This report shall include the purchase order number, heat number, AMS 5662M, size, and quantity.

4.5 Resampling and Retesting:

Shall be as follows:

4.5.1 Bars, Flash Welded Rings, and Stock for Forgings, Flash Welded Rings, or Heading: In accordance with AMS 2371.

4.5.2 Forgings: In accordance with AMS 2374.

5. PREPARATION FOR DELIVERY:

5.1 Sizes:

Except when exact lengths or multiples of exact lengths are ordered, straight bars will be acceptable in mill lengths of 6 to 24 feet (1.8 to 7.3 m) but not more than 25% of any shipment shall be supplied in lengths of 6 to 9 feet (1.8 to 2.7 m) except that for bars weighing over 25 pounds per foot (37 kg/m), short lengths down to 2 feet (610 mm) may be supplied.

5.2 Identification:

Shall be as follows:

5.2.1 Bars: In accordance with AMS 2806.

5.2.2 Forgings: In accordance with AMS 2808.

5.2.3 Flash Welded Rings and Stock for Forging, Flash Welded Rings, or Heading: As agreed upon by purchaser and vendor.

5.3 Packaging:

The product shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the product to ensure carrier acceptance and safe delivery.

6. ACKNOWLEDGMENT:

A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS:

Product not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES:

- 8.1 A change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this specification. An (R) symbol to the left of the document title indicates a complete revision of the specification, including technical revisions. Change bars and (R) are not used in original publications, nor in specifications that contain editorial changes only.
- 8.2 Hardness conversion tables for metals are presented in ASTM E 140.
- 8.3 Terms used in AMS are clarified in ARP1917.
- 8.4 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

8.5 Purchase documents should specify not less than the following:

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Form and size or part number of product desired

Quantity of product desired

Specific location of tensile specimens from forgings and flash welded rings (See 3.5.1.2.1.5).

8.6 Key Words:

Solution heat treated, precipitation-hardenable, bars, forgings, rings, stress-rupture, grain size, microstructure, UNS N07718

PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE "F"