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400 Commonwealth Dr., Warrendale, PA 15096-0001

# AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

AMS 5661D

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Superseding AMS 5661C

## ALLOY BARS, FORGINGS, AND RINGS, CORROSION AND HEAT RESISTANT
## 42.5Ni - 12.5Cr - 5.8Mo - 2.9Ti - 0.015B - 35Fe
## Consumable Electrode or Vacuum Induction Melted
## Solution, Stabilization, and Precipitation Heat Treated

UNS N09901

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 or flash welded rings.

1.2 Application: Primarily for parts, such as turbine discs, shafts, and blades, requiring high strength up to 1400°F (760°C) and oxidation resistance up to 1600°F (871°C).

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2261 - Tolerances, Nickel, Nickel Alloy, and Cobalt Alloy Bars and Forging Stock
MAM 2261 - Tolerances, Metric, Nickel, Nickel Alloy, and Cobalt Alloy Bars and Forging Stock
AMS 2269 - Chemical Check Analysis Limits, Wrought Nickel Alloys and Cobalt Alloys
AMS 2350 - Standards and Test Methods
AMS 2371 - Quality Assurance Sampling of Corrosion and Heat Resistant Steels and Alloys, Wrought Products Except Forgings and Forging Stock
AMS 2374 - Quality Assurance Sampling of Corrosion and Heat Resistant Steels and Alloys, Forgings and Forging Stock
AMS 2375 - Control of Forgings Requiring First Article Approval
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 and Austenitic-Type Alloys

2.2 ASTM Publications: Available from ASTM, 1916 Race Street, Philadelphia, PA 19103.

ASTM E8 - Tension Testing of Metallic Materials
ASTM E8M - Tension Testing of Metallic Materials (Metric)
ASTM E10 - Brinell Hardness of Metallic Materials
ASTM E112 - Determining Average Grain Size
ASTM E139 - Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
ASTM E292 - Conducting Time-for-Rupture Notch Tension Tests of Materials
ASTM E354 - Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Standards:

MIL-STD-163 - Steel Mill Products, Preparation for Shipment and Storage

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, Ø determined by wet chemical methods in accordance with ASTM E354, by spectrochemical methods, or by other analytical methods acceptable to purchaser:

| | min | max |
|---|---|---|
| Carbon | -- | 0.10 |
| Manganese | -- | 0.50 |
| Silicon | -- | 0.40 |
| Phosphorus (3.1.1) | -- | 0.030 |
| Sulfur | -- | 0.030 |
| Chromium | 11.00 | 14.00 |
| Nickel | 40.00 | 45.00 |
| Molybdenum | 5.00 | 6.50 |
| Titanium | 2.70 | 3.10 |
| Boron | 0.010 | 0.020 |
| Cobalt (3.1.1) | -- | 1.00 |
| Aluminum | -- | 0.35 |
| Copper | -- | 0.50 |
| 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 Ø

3.1.2 Check Analysis: Composition variations shall meet the requirements of Ø AMS 2269; no variation is permitted for lead, bismuth, and selenium.

3.2 Condition: The product shall be supplied in the following condition:

3.2.1 Bars: Hot finished and solution, stabilization, and precipitation heat treated. Rounds shall be rough turned or ground.

3.2.2 Forgings and Flash Welded Rings: Solution, stabilization, and precipitation heat treated.

3.2.2.1 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.

3.2.3 Stock for Forging or Flash Welded Rings: As ordered by the forging or flash welded ring manufacturer.

3.3 Heat Treatment: Bars, forgings, and flash welded rings shall be heat treated Ø as follows; pyrometry shall be in accordance with AMS 2750:

3.3.1 Solution Heat Treatment: Heat to a temperature within the range 1950° - 2000°F (1066° - 1093°C), hold at the selected temperature within ±25°F (±14°C) for not less than 1 hour, and cool at a rate equivalent to air cool or faster.

3.3.2 Stabilization Heat Treatment: Heat to a temperature within the range 1425° - 1475°F (774° - 802°C), hold at the selected temperature within ±15°F (±8°C) for 2 - 4 hours, and cool at a rate equivalent to air cool or faster.

3.3.3 Precipitation Heat Treatment: Heat to a temperature within the range 1300° - 1375°F (704° - 746°C), hold at the selected temperature within ±15°F (±8°C) for 24 hours ± 1, and cool in air.

3.4 Properties: The product shall conform to the following requirements:

3.4.1 Bars, Forgings, and Flash Welded Rings: Product 5.0 inches (127 mm) and under in nominal diameter or distance between parallel sides shall meet the requirements of 3.4.1.1, 3.4.1.2, 3.4.1.3, and 3.4.1.4; properties of product over 5.0 inches (127 mm) in nominal diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor:

3.4.1.1 Grain Size: Shall be 1 or finer, determined by comparison of a polished and etched specimen with the chart in ASTM E112; grain size shall be substantially uniform without pronounced segregation of fine and coarse grain areas and shall conform to standards agreed upon by purchaser and vendor.

3.4.1.1.1 Occasional grains as large as 0 are acceptable when agreed upon by purchaser and vendor.

3.4.1.2 Tensile Properties: Shall be as follows, determined in accordance with ASTM E8 or ASTM E8M; requirements apply in both the longitudinal and transverse direction but tests in the transverse direction need be made only on product from which a specimen not less than 2.50 inches (63.5 mm) in length can be obtained. Tests in the longitudinal direction are not required on product tested in the transverse direction.

| | |
|---|---|
| Tensile Strength, minimum | 165,000 psi (1138 MPa) |
| Yield Strength at 0.2% Offset, minimum | 120,000 psi ( 827 MPa) |
| Elongation in 4D, minimum | 12% |
| Reduction of Area, minimum | 15% |

3.4.1.2.1 When tensile specimens are machined from the center area of disc and hub forgings and this area lies within a 4 inch (102 mm) radius or 25% of the forging radius, whichever is the smaller dimension, elongation may be as low as 10% and reduction of area as low as 12%.

3.4.1.3 Hardness: Should be 302 - 388 HB, or equivalent, determined in accordance with ASTM E10, but the product shall not be rejected on the basis of hardness if the tensile property requirements are met. Tensile tests shall be made on the hardest piece in the lot if hardness is over the maximum or on the softest piece if hardness is below the minimum of the specified range.

3.4.1.4 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 E292 and of smooth specimens in accordance with ASTM E139:

3.4.1.4.1 Ø A standard cylindrical combination smooth-and-notched specimen conforming to ASTM E292, maintained at 1200°F ± 3 (649°C ± 2) while a load sufficient to produce an initial axial stress of 90,000 psi (621 MPa) is applied continuously, shall not rupture in less than 23 hours. The test shall be continued to rupture without change of load. After the 23 hours, if rupture occurs in the notch, the smooth section shall, by suitable means, be continued to rupture, or a separate smooth specimen shall be tested to rupture. Elongation of the smooth section after rupture, measured at room temperature, shall be not less than 5% in 4D if the specimen ruptures in 48 hours or less and not less than 4% in 4D if the specimen ruptures in more than 48 hours.

3.4.1.4.2 Ø 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 E292, may be tested individually under the conditions of 3.4.1.4.1. The smooth specimen shall not rupture in less than 23 hours and elongation after rupture, measured at room temperature, shall be not less than 5% in 4D. The notched specimen shall not rupture in less than 23 hours but need not be tested to rupture.

3.4.1.4.3 The tests of 3.4.1.4.1 and 3.4.1.4.2 may be conducted using a load higher than required to produce an initial axial stress of 90,000 psi (621 MPa) but load shall not be changed while test is in progress. Time to rupture and elongation requirements shall be as specified in 3.4.1.4.1.

3.4.1.4.4 When permitted by purchaser, the tests of 3.4.1.4.1 and 3.4.1.4.2 may be conducted using incremental loading. In such case, the load required to produce an initial axial stress of 90,000 psi (621 MPa) shall be used to rupture or for 48 hours, whichever occurs first. After the 48 hours and at intervals of 8 - 16 hours, preferably 8 - 10 hours, thereafter, the stress shall be increased in increments of 5000 psi (34.5 MPa). Time to rupture and elongation requirements shall be as specified in 3.4.1.4.1.

3.4.2 Forging Stock: When a sample of stock is forged to a test coupon and heat treated as in 3.3, specimens taken from the heat treated coupon shall conform to the requirements of 3.4.1.2, 3.4.1.3, and 3.4.1.4. If specimens taken from the stock after heat treatment as in 3.3 conform to the requirements of 3.4.1.2, 3.4.1.3, and 3.4.1.4, the tests shall be accepted as equivalent to tests of a forged coupon.

3.4.3 Stock for Flash Welded Rings: A sample of stock heat treated as in 3.3 shall conform to the requirements of 3.4.1.2, 3.4.1.3, and 3.4.1.4.

3.5 Quality:

3.5.1 Alloy shall be produced by multiple melting 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.

3.5.2 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.

3.5.2.1 Forgings shall have substantially uniform macrostructure. Standards for acceptance shall be as agreed upon by purchaser and vendor.

3.5.2.2 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 re-entrant grain flow.

3.6 Sizes: Except when exact lengths or multiples of exact lengths are ordered, straight bars will be acceptable in mill lengths of 6 - 24 feet (1.8 - 7.3 m) but not more than 25% of any shipment shall be supplied in lengths of 6 - 9 feet (1.8 - 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.

3.7 Tolerances: Bars and forging stock shall conform to all applicable requirements of AMS 2261 or MAM 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 performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to the following requirements are classified as 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 Grain size (3.4.1.1), tensile properties (3.4.1.2), hardness (3.4.1.3), and stress-rupture properties (3.4.1.4) of each lot of bars, forgings, and flash welded rings.

4.2.1.3 Tolerances (3.7) of bars and forging stock.

4.2.2 Periodic Tests: Tests of forging stock (3.4.2) and stock for flash welded rings (3.4.3) to demonstrate ability to develop required properties are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: Tests of forgings to determine conformance to all applicable technical requirements of this specification when AMS 2375 is specified are classified as preproduction tests and shall be performed prior to or on the first-article shipment of a forging to a purchaser, when a change in material and/or processing requires reapproval as in 4.4, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S. Military procurement of forgings, substantiating test data and, when requested, preproduction forgings shall be submitted to the cognizant agency as directed by the procuring activity, contracting officer, or request for procurement.

4.3 Sampling: Shall be in accordance with the following; a heat shall be the Ø consumable electrode remelted ingots produced from alloy originally melted as a single furnace charge or shall be the ingots produced from a single vacuum induction melt:

4.3.1 Bars, Flash Welded Rings, and Stock for Flash Welded Rings: AMS 2371.

4.3.2 Forgings and Forging Stock: AMS 2374.

4.4 Approval: When specified, approval and control of forgings shall be in accordance with AMS 2375.

4.5 Reports:

4.5.1 The vendor of bars, forgings, and flash welded rings shall furnish with Ø 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 of this specification. This report shall include the purchase order number, lot number, AMS 5661D, size, quantity, and a statement of record of specific heat treating temperatures and cycles used to provide reported properties. If forgings are supplied, the part number and the size and melt source of stock used to make the forgings shall also be included.

4.5.2 The vendor of stock for forging or flash welded rings shall furnish with Ø each shipment a report showing the results of tests for chemical composition of each heat. This report shall include the purchase order number, lot number, AMS 5661D, size, and quantity.