

**AEROSPACE
MATERIAL
SPECIFICATION**

AMS 5661C
Superseding AMS 5661B

Issued 1-31-64
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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 (870°C).

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) 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.

SAE Technical Board rules provide that: "All technical reports, including standards approved and practices recommended, are advisory only. Their use by anyone engaged in industry or trade or their use by governmental agencies is entirely voluntary. There is no agreement to adhere to any SAE standard or recommended practice, and no commitment to conform to or be guided by any technical report. In formulating and approving technical reports, the Board and its Committees will not investigate or consider patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against liability for infringement of patents."

AMS 5661C

2.1.1 Aerospace Material Specifications:

- AMS 2261 - Tolerances, 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 2806 - Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Heat and Corrosion 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 American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

- ASTM E8 - Tension Testing of Metallic Materials
- ASTM E10 - Brinell Hardness of Metallic Materials
- ASTM E112 - Estimating the Average Grain Size of Metals
- 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 Federal Standards:

Federal Test Method Standard No. 151 - Metals; Test Methods

2.3.2 Military Standards:

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

3. TECHNICAL REQUIREMENTS:

AMS 5661C

3.1 Composition: Shall conform to the following percentages by weight, determined by wet chemical methods in accordance with ASTM E354, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, or by other analytical methods approved by purchaser:

	min	max
Carbon	--	0.10
Manganese	--	0.50
Silicon	--	0.40
Phosphorus	--	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	--	1.00
Aluminum	--	0.35
Copper	--	0.50
Iron	remainder	

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

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, they 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 as follows:

3.3.1 Solution Heat Treatment: Heat to a temperature within the range 1950° - 2000°F (1065° - 1095°C), hold at the selected temperature within +25°F (+15°C) for not less than 1 hr, and cool at a rate equivalent to air cool or faster.

AMS 5661C

3.3.2 Stabilization Heat Treatment: Heat to a temperature within the range 1425° - 1475°F (775° - 800°C), hold at the selected temperature within $\pm 15^\circ\text{F}$ ($\pm 8^\circ\text{C}$) for 2 - 4 hr, 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 (705° - 745°C), hold at the selected temperature within $\pm 15^\circ\text{F}$ ($\pm 8^\circ\text{C}$) for 24 hr ± 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 in. (125 mm) and \emptyset 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 in. (125 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 \emptyset 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 \emptyset purchaser and vendor.

3.4.1.2 Tensile Properties: Shall be as follows, determined in accordance with \emptyset ASTM E8 on specimens from either the longitudinal or transverse direction except that testing in the transverse direction applies only to product from which a tensile specimen not less than 2.50 in. (62.5 mm) in length can be obtained; testing in the longitudinal direction is not required on product tested in the transverse direction:

Tensile Strength, min	165,000 psi (1140 MPa)
Yield Strength at 0.2% Offset, min	120,000 psi (825 MPa)
Elongation in 4D, min	12%
Reduction of Area, min	15%

3.4.1.2.1 When tensile specimens are machined from the center area of disc and \emptyset hub forgings and this area lies within a 4 in. (100 mm) radius of the disc center 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 \emptyset 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 (650°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 A combination smooth-and-notched specimen machined to the dimensions shown in Fig. 1 and Table I, maintained at 1200°F + 3 (650°C + 2) while a load sufficient to produce an initial axial stress of 90,000 psi (620 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 hr, 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 hr or less and not less than 4% in 4D if the specimen ruptures in more than 48 hours.
- 3.4.1.4.2 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 of Table I may be tested individually under the conditions of 3.4.1.4.1. The smooth specimen shall not rupture in less than 23 hr 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 hr 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 (620 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 (620 MPa) shall be used to rupture or for 48 hr, whichever occurs first. After the 48 hr and at intervals of 8 - 16 hr, preferably 8 - 10 hr, thereafter, the stress shall be increased in increments of 5000 psi (35 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.

AMS 5661C

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,
unless otherwise permitted by purchaser. 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 internal and
external imperfections detrimental to usage of the product.

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

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 ft (2 - 7 m) but
not more than 25% of any shipment shall be supplied in lengths of 6 - 9 ft
(2 - 3 m) except that for bars weighing over 25 lb per ft (37 kg/m), short
lengths down to 2 ft (600 mm) may be supplied.

3.7 Tolerances: Unless otherwise specified, tolerances for bars and forging
stock 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 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 or processing, or both, 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, the contracting officer, or the request for procurement.
- 4.3 Sampling: Shall be in accordance with the following; a heat shall be the consumable electrode remelted ingots produced from alloy originally melted as a single furnace charge:
- 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 the product shall furnish with each shipment three copies of 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, heat number, AMS 5661C, size, quantity from each heat, 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.

AMS 5661C

4.5.2 The vendor of finished or semi-finished parts shall furnish with each shipment three copies of a report showing the purchase order number, AMS 5661C, contractor or other direct supplier of material, part number, and quantity. When material for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of material to determine conformance to the requirements of this specification and shall include in the report either a statement that the material conforms or copies of laboratory reports showing the results of tests to determine conformance.

4.6 Resampling and Retesting: Shall be in accordance with the following:

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

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4.6.2 Forgings and Forging Stock: AMS 2374.

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5. PREPARATION FOR DELIVERY:

5.1 Identification: The product shall be identified as follows:

5.1.1 Bars: In accordance with AMS 2806.

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5.1.2 Forgings: In accordance with AMS 2808.

5.1.3 Flash Welded Rings and Stock for Forging or Flash Welded Rings: As agreed upon by purchaser.

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5.2 Packaging:

5.2.1 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. Packaging shall conform to carrier rules and regulations applicable to the mode of transportation.

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5.2.2 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-163, Level A or Level C, as specified in the request for procurement. Commercial packaging as in 5.2.1 will be acceptable if it meets the requirements of Level C.

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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: