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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 5884

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Submitted for recognition as an American National Standard

IRON-NICKEL ALLOY, BARS, FORGINGS, AND RINGS
42Fe - 37.5Ni - 14Co - 4.8(Cb + Ta) - 1.6Ti
Solution Heat Treated, Precipitation Hardenable
Multiple Melted, High Temperature, Low Expansion UNS N19909

1. SCOPE:

1.1 Form:

This specification covers an iron-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 a combination of high strength and low expansion properties up to 1200 °F (649 °C), but usage is not limited to such applications.

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 publications shall be the issue in effect on the date of the purchase order.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2261 Tolerances, Nickel, Nickel Alloy, and Cobalt Alloy Bars, Rods, and Wire
MAM 2261 Tolerances, Metric, Nickel, Nickel Alloy, and Cobalt Alloy Bars, Rods, and Wire
AMS 2269 Chemical Check Analysis Limits, Wrought Nickel Alloys and Cobalt Alloys
AMS 2371 Quality Assurance Sampling and Testing, Corrosion and Heat Resistant Steel and Alloys, Wrought Products and Forging Stock
AMS 2374 Quality Assurance Sampling and Testing, Corrosion and Heat Resistant Steel and Alloy Forgings

Printed in U.S.A.
91-0942/ EG

2.1 SAE Publications (Continued):

AMS 2750 Pyrometry
AMS 2806 Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels, 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, or Precipitation Hardenable Alloys

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

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 228 Linear Thermal Expansion of Solid Materials with a Vitreous Silica Dilatometer
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
ASTM E 930 Estimating the Largest Grain Observed in a Metallographic Section (ALA Grain Size)
ASTM E 1181 Characterizing Duplex Grain Sizes

2.3 U.S. Government Publications:

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

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

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, or by other analytical methods acceptable to purchaser.

TABLE 1 - Composition

Element	min	max
Carbon	--	0.06
Manganese	--	1.0
Silicon	0.25	0.50
Phosphorus	--	0.015
Sulfur	--	0.015
Nickel	35.0	40.0
Cobalt	12.0	16.0
Columbium + Tantalum	4.3	5.2
Titanium	1.3	1.8
Chromium	--	1.0
Aluminum	--	0.15
Boron	--	0.012
Copper	--	0.5
Iron	remainder	

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

3.2 Melting Practice:

Alloy shall be multiple melted using consumable electrode practice in the remelt cycle. 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, Forgings, and Flash Welded Rings: Solution heat treated and descaled.

3.3.1.1 Bars shall be hot finished; round bars shall be ground or turned.

3.3.1.2 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.

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

3.4 Solution Heat Treatment:

Bars, forgings, and flash welded rings shall be solution heat treated by heating to a temperature within the range 1775 to 1850 °F (968 to 1010 °C), holding at a selected temperature within ±25 °F (±14 °C) for a time commensurate with section thickness, and cooling at a rate equivalent to a still air cool (See 8.1).

3.4.1 Pyrometry shall be in accordance with AMS 2750.

3.4.2 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, determined in accordance with ASTM E 10 or ASTM E 103.

3.5.1.1.2 Grain Size:

3.5.1.1.2.1 Bars, forgings, and flash welded rings 9 square inches (58 cm^2) and under in cross-sectional area shall exhibit an average grain size, determined in accordance with ASTM E 112, of ASTM No. 5 or finer, with no more than 20% of the specimen area as large as ASTM No. 3. No single grain shall be larger than 0.010 inch (0.25 mm), determined in accordance with ASTM E 930.

3.5.1.1.2.2 Bars, forgings, and flash welded rings over 9 square inches (58 cm^2) in cross-sectional area shall exhibit an average grain size, determined in accordance with ASTM E 112, of ASTM No. 4 or finer, with no more than 20% of the specimen area as large as ASTM No. 2. No single grain shall be larger than 0.014 inch (0.36 mm), determined in accordance with ASTM E 930.

3.5.1.1.2.3 When agreed upon by purchaser and vendor, the grain size of 20% of the specimen area may be as large as ASTM No. 0. No single grain shall be larger than 0.020 inch (0.51 mm), determined in accordance with ASTM E 930.

3.5.1.1.2.4 Limitations on duplex grain structures as defined by ASTM E 1181 shall be as agreed upon by purchaser and vendor.

3.5.1.2 After Re-Solution and Precipitation Heat Treatment: The product shall have the following properties after being re-solution heat treated by heating to 1800 °F ± 25 (982 °C ± 14), holding at heat for 60 minutes ± 15, and cooling at a rate equivalent to an air cool and precipitation heat treated by heating to 1325 °F ± 15 (718 °C ± 8), holding at heat for eight hours ± 0.5, cooling at a maximum rate of 100 F (56 C) degrees per hour to 1150 °F ± 15 (621 °C ± 8), holding at heat for eight hours ± 0.5, and cooling at a rate equivalent to an air cool (See 8.1 and 8.2).

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 2 - Minimum Tensile Properties

Properties	Value
Tensile Strength	175 ksi (1207 MPa)
Yield Strength at 0.2% Offset	140 ksi (965 MPa)
Elongation in 4D %	8%
Reduction of Area %	12%

3.5.1.2.1.2 At 1200 °F (649 °C): Shall be as shown in Table 3, determined in accordance with ASTM E 21 on specimens heated to 1200 °F ± 5 (649 °C ± 3), held at heat for 20 to 30 minutes before testing, and tested at 1200 °F ± 5 (649 °C ± 3).

TABLE 3 - Minimum Tensile Properties

Properties	Value
Tensile Strength	135 ksi (931 MPa)
Yield Strength at 0.2% Offset	105 ksi (724 MPa)
Elongation in 4D %	10%
Reduction of Area %	15%

3.5.1.2.1.3 Specific location of specimens from forgings and flash welded rings shall be as agreed upon by purchaser and vendor.

3.5.1.2.2 Hardness: Should be not lower than 331 HB, or equivalent, determined in accordance with ASTM E 10 or ASTM E 103, but the product shall not be rejected on the basis of hardness if the tensile property requirements of 3.5.1.2.1.1 are met.

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 ± 3 (649 °C ± 2) while a load sufficient to produce an initial axial stress of 74.0 ksi (510 MPa) 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 2 inches (50.8 mm) for product 5.0 inches (127 mm) and under in nominal diameter or distance between parallel sides and shall be as agreed upon by purchaser and vendor for product over 5.0 inches (127 mm) 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 a load higher than required to produce an initial axial stress of 74.0 ksi (510 MPa) but load shall not be changed while test is in progress. Time to rupture, rupture location, and elongation requirements shall be as specified in 3.5.1.2.3.1.

3.5.1.2.3.4 When permitted by purchaser, 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 74.0 ksi (510 MPa) shall be used to rupture or for 23 hours, whichever occurs first. After the 23 hours and at intervals of 8 to 16 hours, preferably 8 to 10 hours, 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.

3.5.1.2.4 Thermal Expansion Properties: Shall be determined in accordance with ASTM E 228 on each heat of alloy.

3.5.1.2.4.1 Mean Coefficient of Linear Expansion: Shall be 4.00 - 4.50 x 10^{-6} inch/inch/°F (7.2 - 8.1 x 10^{-6} mm/mm/°C) at 780 °F (416 °C) using 77 °F (25 °C) as a reference temperature.

3.5.1.2.4.2 Inflection Temperature: Shall be 750 to 850 °F (399 to 454 °C), determined by establishing the intersection of the tangents of the upper and lower portions of the dilatometric expansion curve.

3.5.2 Forging Stock: When a sample of stock is forged to a test coupon and 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, 3.5.1.2.3, and 3.5.1.2.4. 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, 3.5.1.2.3, and 3.5.1.2.4, the tests shall be accepted as equivalent to tests of a forged coupon.

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, 3.5.1.2.3, and 3.5.1.2.4.

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 re-entrant grain flow.

3.7 Tolerances:

Bars 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. 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:

Tests for all technical requirements are acceptance tests and shall be performed on each heat or lot as applicable.

4.3 Sampling and Testing:

Shall be in accordance with the following:

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

4.3.2 Forgings: AMS 2374.