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400 Commonwealth Drive, Warrendale, PA 15096-0001

# AEROSPACE MATERIAL SPECIFICATION

SAE AMS 5884B

Issued APR 1992
Revised OCT 2001
Reaffirmed APR 2006

Superseding AMS 5884A

## Iron-Nickel Alloy, Bars, Forgings, and Rings
## 42Fe - 37.5Ni - 14Co - 4.8Cb - 1.6Ti
## Solution Heat Treated, Precipitation Hardenable
## Multiple Melted, High Temperature, Low Expansion

(Composition similar to 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 issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified 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 canceled and no superseding document has been specified, the last published issue of that document shall apply.

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, 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 |



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2.1 (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, Austenitic-Type Iron, Nickel, or Cobalt Alloys, or Precipitation Hardenable Alloys |

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor, West Conshohocken, PA 19428-2959.

| | |
|---|---|
| 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 |

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 | 4.3 | 5.2 |
| Titanium | 1.3 | 1.8 |
| Chromium | -- | 1.0 |
| Tantalum | -- | 0.05 |
| Aluminum | -- | 0.15 |
| Boron | -- | 0.012 |
| Copper | -- | 0.5 |
| Iron | remainder | |



3.1.1 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. 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 1775to1850 °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 8.2).

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 (See 8.4), determined in accordance with ASTM E 10 or ASTM E 103.

3.5.1.1.2 Average 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 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 8.2 and 8.3).

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

| Property | 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

| Property | 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 agreed upon by purchaser and vendor.

3.5.1.2.2 Hardness: Shall be not lower than 331 HB, or equivalent (See 8.4), determined in accordance with ASTM E 10 or ASTM E 103.

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 (510MPa) 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 least distance between parallel sides; elongation of the smooth section, after rupture, for product over 5.0inches (127 mm) in nominal diameter or least distance between parallel sides, shall be agreed upon by purchaser and vendor.

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 ASTME292, 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 74.0ksi (510MPa) 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 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, 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 to 4.50 x $10^{-6}$ inch/inch/°F (7.2 to 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 3.5.1.2, 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 3.5.1.2 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 reentrant 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 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), and thermal expansion (3.5.1.2.4) 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 as solution heat treated.

4.2.1.3 Tensile properties (3.5.1.2.1), hardness (3.5.1.2.2), and stress rupture properties (3.5.1.2.3) of each lot after re-solution and precipitation heat treatment.

4.2.1.4 Tolerances (3.7) of each lot.

4.2.2 Periodic Tests: Grain flow of die forgings (3.6.1) is a periodic test and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

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:

The vendor of the product shall furnish with each shipment a report showing the results of tests for chemical composition and thermal expansion properties of each heat and for hardness and average grain size as solution heat treated and for tensile properties, hardness, and stress rupture properties re-solutioned and precipitation heat treated of each lot, and stating that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS 5884B, solution heat treatment temperature used, size, and quantity. If forgings are supplied, the size and melt source of stock used to make the forgings shall also be included.

4.5 Resampling and Retesting:

Shall be as follows:

4.5.1 Bars, Flash Welded Rings, and Stock for Forging, 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 (1.8to7.3m) 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 25pounds per foot (37 kg/m), short lengths down to 2 feet (610 m) 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.