AEROSPACE MATERIAL SPECIFICATION

AMS5940™ REV. E

Issued 1996-09
Reaffirmed 2019-07
Revised 2024-09

Superseding AMS5940D

Alloy, Corrosion- and Heat-Resistant, Bars, Forgings, and Rings and Stock for Forging, Flash-Welded Rings and Heading, 34Co - 3.0Cr - 28Ni - 3.0Cb(Nb) - 5.5Al - 0.008B - 25.5Fe Multiple Melted, High Temperature, Oxidation-Resistant, Low Expansion, Solution Heat Treated, Precipitation-Hardenable (Alloy 783) (Composition similar to UNS R30783)

RATIONALE

AMS5940E is the result of a Five-Year Review and update of the specification. The revision prohibits unauthorized exceptions (see 3.8, 4.4.3, 5.2.1, and 8.6), updates the Title to match the Scope, revises composition testing and reporting (see 3.1 and 3.1.1), adds finish information on large bars (see 3.3.1.1.1), adds strain rate control (see 3.5.1.2.1.1.1), adds additional forging stock properties (see 4.4.4 and 8.7), and allows prior revisions (see 8.5).

1. SCOPE

1.1 Form

This specification covers a cobalt-nickel-iron 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 1300 °F (704 °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 cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2261 Tolerances, Nickel, Nickel Alloy, and Cobalt Alloy Bars, Rods, and Wire

AMS2269 Chemical Check Analysis Limits, Nickel, Nickel Alloys, and Cobalt Alloys

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

For more information on this standard, visit
https://www.sae.org/standards/content/AMS5940E/

AMS2283 Composition Testing Methods for Nickel- and Cobalt-Based Alloys

AMS2371 Quality Assurance Sampling and Testing, Corrosion and Heat-Resistant Steels and Alloys, Wrought Products and Forging Stock

AMS2374 Quality Assurance Sampling and Testing, Corrosion- and Heat-Resistant Steel and Alloy Forgings

AMS2750 Pyrometry

AMS2806 Identification Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels, and Corrosion and Heat-Resistant Steels and Alloys

AMS2808 Identification, Forgings

AMS7490 Rings, Flash Welded, Corrosion and Heat-Resistant Austenitic Steels, Austenitic-Type Iron, Nickel or Cobalt Alloys, or Precipitation-Hardenable Alloys

AS7766 Terms Used in Aerospace Metals Specifications

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E8/E8M Tension Testing of Metallic Materials

ASTM E18 Rockwell Hardness of Metallic Materials

ASTM E21 Elevated Temperature Tension Tests of Metallic Materials

ASTM E112 Determining Average Grain Size

ASTM E139 Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

ASTM E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

ASTM E228 Linear Thermal Expansion of Solid Materials with a Pushrod Dilatometer

ASTM E292 Conducting Time-for-Rupture Notch Tension Tests of Materials

ASTM E1181 Characterizing Duplex Grain Sizes

2.3 Definitions

Terms used in AMS are defined in AS7766.

3. TECHNICAL REQUIREMENTS

3.1 Composition

Composition shall conform to the percentages by weight shown in Table 1, determined in accordance with AMS2283 or by other analytical methods acceptable to the purchaser.

Table 1 - Composition

Element	Min	Max
Carbon	--	0.03
Manganese	--	0.50
Silicon	--	0.50
Phosphorus	--	0.015
Sulfur	--	0.005
Chromium	2.5	3.5
Nickel	26.0	30.0
Columbium (Niobium)	2.5	3.5
Aluminum	5.0	6.0
Boron	0.003	0.012
Iron	24.0	27.0
Titanium	--	0.40
Tantalum	--	0.05
Copper	--	0.50
Cobalt	remainder	

3.1.1 The producer may test for any element not listed in Table 1 and include this analysis in the report of 4.4. Reporting of any element not listed in the composition table is not a basis for rejection unless limits of acceptability are specified by the purchaser.

3.1.2 Check Analysis

Composition variations shall meet the applicable requirements of AMS2269.

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 that 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 shall be solution heat treated and descaled.

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

3.3.1.1.1 Bars, other than hexagons, over 2.75 inches (69.8 mm) in nominal diameter or least distance between parallel sides shall be hot finished or cold finished.

3.3.1.2 Bars shall not be cut from plate (see 4.4.2).

3.3.1.3 Flash-welded rings shall not be supplied unless specified or permitted on the purchaser's part drawing. When supplied, rings shall be manufactured in accordance with AMS7490.

3.3.2 Stock for forging, flash-welded rings, or heading shall be 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 2025 to 2050 °F (1107 to 1121 °C), holding at the selected temperature within ±25 °F (±14 °C) for a time commensurate with section thickness, and cooling at a rate equivalent to an air cool or faster (see 8.2).

3.4.1 Pyrometry shall be in accordance with AMS2750.

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 the 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

Hardness shall be not higher than 29 HRC, or equivalent (see 8.3), determined in accordance with ASTM E18.

3.5.1.1.2 Average Grain Size

Average grain size shall be as follows, determined by the comparative method of ASTM E112. 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 cm^2) in cross-sectional area shall exhibit average grain size of ASTM No. 5 or finer. Areas of non-recrystallized grains with an average grain size, determined by the intercept method, of ASTM No. 3 to 5 are permitted but shall not account for more than 20% of the cross section.

3.5.1.1.2.2 Bars and flash-welded rings 9 to 50 square inches (58 to 323 cm^2), inclusive, in cross-sectional area and all forgings shall exhibit average grain size of ASTM No. 4 or finer. Areas of non-recrystallized grains with an average grain size, determined by the intercept method, of ASTM No. 2 to 4 are permitted but shall not account for more than 20% of the cross section.

3.5.1.1.2.3 Limitations on duplex grain structures as defined by ASTM E1181 shall be as agreed upon by the purchaser and producer.

3.5.1.2 Response to Heat Treatment

Samples from the product shall have the following properties after being precipitation heat treated by heating to 1550 °F ± 15 °F (843 °C ± 8 °C), holding at heat for 2 to 4 hours, cooling at a rate equivalent to an air cool to room temperature, heating to 1325 °F ± 15 °F (718 °C ± 8 °C), holding at heat for 8 hours ± 0.5 hour, cooling at a rate of approximately 100 °F (56 °C) per hour to 1150 °F ± 15 °F (621 °C ± 8 °C), holding at 1150 °F ± 15 °F (621 °C ± 8 °C) for 8 hours ± 0.5 hour, and cooling at a rate equivalent to an air cool (see 8.2).

3.5.1.2.1 Tensile Properties

3.5.1.2.1.1 At Room Temperature

Response to heat-treatment tensile properties shall be as shown in Table 2, determined in accordance with ASTM E8/E8M.

Table 2 - Minimum room temperature tensile properties - response to heat treatment

Property	Value
Tensile Strength	160 ksi (1103 MPa)
Yield Strength at 0.2% Offset	105 ksi (724 MPa)
Elongation in 4D	12%
Reduction of Area	20%

3.5.1.2.1.1.1 Unless otherwise specified, the strain rate shall be set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ±0.002 in/in/min (±0.002 mm/mm/min) through 0.2% offset yield strain. After the yield strain, the speed of the testing machine shall be set between 0.05 in/in and 0.5 in/in (0.05 mm/mm and 0.5 mm/mm) of the length of the reduced parallel section (or distance between the grips for specimens not having a reduced section) per minute. Alternatively, an extensometer and strain rate indicator may be used to set the strain rate between 0.05 in/in/min and 0.5 in/in/min (0.05 mm/mm/min and 0.5 mm/mm/min). The requirement for compliance becomes effective for material produced 1 year after the publication date of this specification.

3.5.1.2.1.2 At 1200 °F (649 °C)

High-temperature tensile properties shall be as shown in Table 3, determined in accordance with ASTM E21 on specimens heated to 1200 °F ± 5 °F (649 °C ± 3 °C), held at heat for not less than 20 minutes before testing, and tested at 1200 °F ± 5 °F (649 °C ± 3 °C).

Table 3 - Minimum 1200 °F (649 °C) tensile properties

Property	Value
Tensile Strength	130 ksi (896 MPa)
Yield Strength at 0.2% Offset	90 ksi (621 MPa)
Elongation in 4D	15%
Reduction of Area	25%

3.5.1.2.2 Hardness

Hardness shall be not lower than 27 HRC, or equivalent (see 8.3), determined in accordance with ASTM E18. Product shall not be rejected on the basis of hardness if the tensile properties of 3.5.1.2.1.1 are acceptable, determined on product taken from the same sample as that with nonconforming hardness or from another sample with similar nonconforming hardness.

3.5.1.2.3 Stress-Rupture Properties at 1200 °F (649 °C)

Stress-rupture properties shall be as follows; testing of notched specimens and of combination smooth-and-notched specimens shall be performed in accordance with ASTM E292, and testing of smooth specimens shall be performed in accordance with ASTM E139:

3.5.1.2.3.1 A standard cylindrical combination smooth-and-notched specimen conforming to ASTM E292, maintained at 1200 °F ± 3 °F (649 °C ± 2 °C) while a load sufficient to produce an initial axial stress of 85.0 ksi (586 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 8% in 4D for product 5.0 inches (127 mm) and under in nominal diameter or least distance between parallel sides and shall be reported for product over 5.0 inches (127 mm) in nominal diameter and least 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 E292, 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 85.0 ksi (586 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.

3.5.1.2.4 Thermal Expansion Properties

The mean coefficient of linear expansion shall not exceed 7.5 x 10^{-6} inch/inch/°F (13.5 x 10^{-6} mm/mm/°C) at 1200 °F (649 °C) using 77 °F (25 °C) as the reference temperature, determined in accordance with ASTM E228.

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 the 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 that contain flash-line end grain, shall follow the general contour of the forgings showing no evidence of reentrant grain flow.

3.7 Tolerances

Bar tolerances shall conform to all applicable requirements of AMS2261.

3.8 Exceptions

Any exceptions shall be authorized by the purchaser and reported as in 4.4.3.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for the producer's tests and shall be responsible for the performance of all required tests. The 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

Tests for the following requirements are acceptance tests and shall be performed on each heat or lot as applicable:

- Composition (see 3.1) and mean coefficient of linear expansion (see 3.5.1.2.4) of each heat
- Hardness (see 3.5.1.1.1) and average grain size (see 3.5.1.1.2) of each lot of bars, forgings, and flash-welded rings as solution heat treated
- Room-temperature tensile properties (see 3.5.1.2.1.1), hardness (see 3.5.1.2.2), and stress-rupture properties (see 3.5.1.2.3) of each lot of bars, forgings, and flash-welded rings after precipitation heat treatment
- Tolerances (see 3.7) of bars

4.2.2 Periodic Tests

Tests for the following requirements are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by the purchaser:

- Tensile properties at 1200 °F (649 °C) (see 3.5.1.2.1.2) of bars, forgings, and flash-welded rings after precipitation heat treatment
- Ability of forging stock (see 3.5.2) and of stock for flash-welded rings or heading (see 3.5.3) to develop required properties
- Grain flow (see 3.6.1) of die forgings

4.3 Sampling and Testing

4.3.1 Bars, flash-welded rings, and stock for forging, flash-welded rings, or heading shall be sampled and tested in accordance with AMS2371.

4.3.2 Forgings shall be sampled and tested in accordance with AMS2374.

4.3.3 Specific location of specimens from forgings and flash-welded rings shall be as agreed upon by the purchaser and producer.

4.4 Reports

4.4.1 The producer of bars, forgings, and flash-welded rings shall furnish with each shipment a report showing: the producer's name; the country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations); and the results of tests for composition and mean coefficient of linear expansion of each heat, for hardness and average grain size for each lot of bars, forgings, and flash-welded rings as solution treated, and for hardness, room-temperature tensile properties, and stress-rupture properties of each lot of bars, forgings, and flash-welded rings after precipitation heat treatment. The report shall state that the product conforms to the other technical requirements and shall include the purchase order number, heat and lot numbers, AMS5940E, size, and quantity. If forgings are supplied, the size and melt source of stock used to make the forgings shall also be included.

4.4.2 Report the nominal metallurgically worked cross-sectional size and the cut size, if different (see 3.3.1.2).

4.4.3 When material produced to this specification has exceptions taken to the technical requirements listed in Section 3 (see 5.2.1), the report shall contain a statement "This material is certified as AMS5940E(EXC) because of the following exceptions:" and the specific exceptions shall be listed.

4.4.4 The producer of stock for forging, flash-welded rings, or heading shall furnish with each shipment a report showing the producer's name, the country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), and the results of tests for composition, coefficient of linear expansion properties, and the results of any additional property requirements imposed by 8.8. This report shall include the purchase order number, heat number, AMS5940E, size, and quantity.

4.5 Resampling and Retesting

4.5.1 Bars, flash-welded rings, and stock for forging, flash-welded rings, or heading shall be resampled and retested in accordance with AMS2371.

4.5.2 Forgings shall be resampled and retested in accordance with AMS2374.