



AEROSPACE MATERIAL SPECIFICATION

AMS5934

REV. A

Issued 2004-07
Reaffirmed 2011-10
Revised 2014-11

Superseding AMS5934

Steel, Extra High Toughness, Corrosion-Resistant, Bars,
Wire, Forgings, Rings, and Extrusions
13Cr - 8.0Ni - 2.2Mo - 1.1Al
Vacuum Induction Plus Consumable Electrode Melted
Solution Heat Treated, Precipitation-Hardenable
(Composition similar to UNS S13800)

RATIONALE

AMS5934A revises the document to allow the purchasing of heat treated material (1.1.1), prohibits bar being cut from plate (3.3.1.2.1 & 4.4.8), clarifies solution treat holding times (3.4), revises macrostructure (3.5.1.1), provides for properties outside the specified size range (3.5.2.2.2.1, 4.4.4). requires short transverse tensile testing when possible (3.5.2.2.2.3), deletes hardness testing (4.2.1.4, 4.2.2), and revises reports (4.4).

1. SCOPE

1.1 Form

This specification covers an extra high toughness, corrosion-resistant steel in the form of bars, wire, forgings, flash welded rings, and extrusions 12 inches (305 mm) and under, and stock of any size for forging, flash welded rings, or extrusion (See 8.6).

1.1.1 For purchase of solution treated and aged product, use the applicable AMS slash specification. If a slash sheet description is not specified, solution annealed material shall be supplied. A specific example of a slash specification is:

AMS5934/H1000 – Precipitation Hardened to H1000 condition

1.2 Application

These products have been used typically for parts requiring extra high toughness, corrosion resistance, stress-corrosion resistance, high strength up to 600 °F (316 °C), and good ductility and strength in the transverse direction in large section sizes, but usage is not limited to such applications.

1.2.1 Certain design and processing procedures may cause these products to become susceptible to stress-corrosion cracking; ARP1110 recommends practices to minimize such conditions.

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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 724-776-4970 (outside USA), www.sae.org.

| | |
|---------|---|
| AMS2241 | Tolerances, Corrosion and Heat-Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire |
| AMS2248 | Chemical Check Analysis Limits, Corrosion and Heat-Resistant Steels and Alloys, Maraging and Other Highly-Alloyed Steels, and Iron Alloys |
| AMS2300 | Steel Cleanliness, Premium Aircraft-Quality, Magnetic Particle Inspection Procedure |
| AMS2315 | Determination of Delta Ferrite Content |
| 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 |
| ARP1110 | Minimizing Stress Corrosion Cracking in Wrought Forms of Steels and Corrosion Resistant Steels and Alloys |

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, Tel: 212-642-4900, www.astm.org.

| | |
|------------|---|
| ASTM A 370 | Mechanical Testing of Steel Products |
| ASTM A 604 | Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets |
| ASTM E 112 | Determining Average Grain Size |
| ASTM E 353 | Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys |
| ASTM E 399 | Plane-Strain Fracture Toughness of Metallic Materials |

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 353, by spectrochemical methods, or by other analytical methods acceptable to purchaser

TABLE 1 - COMPOSITION

| Element | min | max |
|------------|-------|--------|
| Carbon | -- | 0.05 |
| Manganese | -- | 0.10 |
| Silicon | -- | 0.10 |
| Phosphorus | -- | 0.010 |
| Sulfur | -- | 0.008 |
| Chromium | 12.25 | 13.25 |
| Nickel | 7.50 | 8.50 |
| Molybdenum | 2.00 | 2.50 |
| Aluminum | 0.90 | 1.35 |
| Nitrogen | -- | 20 ppm |

3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS2248 except that no variation over maximum is permitted for nitrogen.

3.2 Melting Practice

The steel covered by this specification shall be double melted using vacuum induction melting in the first melt cycle and vacuum-arc consumable process in the second melt cycle.

3.3 Condition

The product shall be supplied in the following condition:

3.3.1 Bars and Wire

3.3.1.1 Rounds

Centerless ground or turned after solution heat treatment.

3.3.1.2 Hexagons, Squares, and Flats

Cold finished, solution heat treated, straightened, and descaled, or hot finished, solution heat treated, straightened, and descaled, as ordered.

3.3.1.2.1 Bar shall not be cut from plate (Also see 4.4.7).

3.3.2 Forgings and Flash Welded Rings

Solution heat treated and descaled.

3.3.2.1 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 AMS7490.

3.3.3 Extrusions

Solution heat treated, straightened, and descaled.

3.3.4 Stock for Forging, Flash Welded Rings, or Extrusion

As ordered by the forging, flash welded ring, or extrusion manufacturer.

3.4 Heat Treatment

Bars, wire, forgings, flash welded rings, and extrusions shall be solution heat treated by heating to 1700 °F ± 25 (927 °C ± 14), holding at heat for a time commensurate with section thickness, heating equipment, and procedure used, and cooling to below 60 °F (16 °C). Pyrometry shall be in accordance with AMS2750.

3.5 Properties

The product shall conform to the following requirements; hardness and tensile testing shall be performed in accordance with ASTM A 370:

3.5.1 All Products

3.5.1.1 Macrostructure

Visual examination of transverse full cross-sections from bars, billets, extrusions, and stock for forging, flash welded rings, or extrusions, etched in hot hydrochloric acid in accordance with ASTM A 604, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections shall be no worse than the macrographs of ASTM A 604 shown in Table 2.

TABLE 2 - MACROSTRUCTURE LIMITS

| Class | Condition | Severity |
|-------|--------------------|----------|
| 1 | Freckles | A |
| 2 | White Spots | A |
| 3 | Radial Segregation | A |
| 4 | Ring Pattern | B |

3.5.1.2 Microstructure

The product shall contain not more than the following amount of free ferrite, determined in accordance with AMS2315:

Type 1 – 1.0% max., free ferrite

Type 2 – 0.5% max., free ferrite

3.5.1.2.1 Type 1 shall be supplied unless Type 2 is specified.

3.5.2 Bars, Wire, Forgings, Flash Welded Rings, and Extrusions

3.5.2.1 As Solution Treated

3.5.2.1.1 Tensile Strength

Wire shall have tensile strength not higher than 175 ksi (1207 MPa) or equivalent hardness (See 8.2).

3.5.2.1.2 Hardness

3.5.2.1.2.1 Bars

Shall be not higher than 363 HB or equivalent (See 8.3), determined at midradius or quarter thickness.

3.5.2.1.2.2 Forgings, Flash Welded Rings, and Extrusions

Shall be not higher than 363 HB, or equivalent (See 8.3).

3.5.2.1.3 Average Grain Size

Shall be ASTM No. 5 or finer for product up to 3.00-inches (76.2-mm) in nominal diameter or least distance between parallel sides and shall be ASTM No. 4 or finer for product 3.00-inches (76.2-mm) and over in diameter or least distance between parallel sides, determined in accordance with ASTM E 112.

3.5.2.2 After Precipitation Heat Treatment:

The solution heat treated product 12 inches (305 mm) and under in nominal diameter or least distance between parallel sides, when precipitation heat treated for 4 hours \pm 0.25 to a particular condition at the temperatures shown in Table 2 and cooled at a rate equivalent to air cooling shall have the properties specified in 3.5.2.2.2 and 3.5.2.2.3 for that particular condition. Tensile tests need be made in only the H1000 precipitation heat treated condition unless purchaser specifies a different heat treated condition.

3.5.2.2.1 Mechanical property requirements for product outside of the range covered by 1.1 shall be agreed upon between purchaser and producer.

TABLE 3 - PRECIPITATION HARDENING CONDITIONS

| Condition | Temperature |
|-----------|-----------------------------------|
| H950 | 950 °F \pm 10 (510 °C \pm 6) |
| H1000 | 1000 °F \pm 10 (538 °C \pm 6) |
| H1025 | 1025 °F \pm 10 (552 °C \pm 6) |
| H1050 | 1050 °F \pm 10 (566 °C \pm 6) |
| H1100 | 1100 °F \pm 10 (593 °C \pm 6) |
| H1150 | 1150 °F \pm 10 (621 °C \pm 6) |

3.5.2.2.2 Tensile Properties

Shall be as shown in Table 4.

TABLE 4A - MINIMUM TENSILE PROPERTIES AFTER PRECIPITATION HEAT TREATMENT, INCH/POUND UNITS

| Condition | Specimen Orientation | Tensile Strength ksi | Yield Strength at 0.2% Offset ksi | Elongation in 4D % | Reduction of Area % |
|-----------|----------------------|-------------------------|---|--------------------------|---------------------------|
| H950 | Longitudinal | 220 | 205 | 10 | 45 |
| | Transverse | 220 | 205 | 10 | 35 |
| H1000 | Longitudinal | 205 | 190 | 10 | 50 |
| | Transverse | 205 | 190 | 10 | 40 |
| H1025 | Longitudinal | 185 | 175 | 11 | 50 |
| | Transverse | 185 | 175 | 11 | 45 |
| H1050 | Longitudinal | 175 | 165 | 12 | 50 |
| | Transverse | 175 | 165 | 12 | 45 |
| H1100 | Longitudinal | 150 | 135 | 14 | 50 |
| | Transverse | 150 | 135 | 14 | 50 |
| H1150 | Longitudinal | 135 | 90 | 14 | 50 |
| | Transverse | 135 | 90 | 14 | 50 |

TABLE 4B - MINIMUM TENSILE PROPERTIES AFTER PRECIPITATION HEAT TREATMENT, SI UNITS

| Condition | Specimen Orientation | Tensile Strength MPa | Yield Strength at 0.2% Offset MPa | Elongation in 4D % | Reduction of Area % |
|-----------|----------------------|-------------------------|---|--------------------------|---------------------------|
| H950 | Longitudinal | 1517 | 1413 | 10 | 45 |
| | Transverse | 1517 | 1413 | 10 | 35 |
| H1000 | Longitudinal | 1413 | 1310 | 10 | 50 |
| | Transverse | 1413 | 1310 | 10 | 40 |
| H1025 | Longitudinal | 1276 | 1207 | 11 | 50 |
| | Transverse | 1276 | 1207 | 11 | 45 |
| H1050 | Longitudinal | 1207 | 1138 | 12 | 50 |
| | Transverse | 1207 | 1138 | 12 | 45 |
| H1100 | Longitudinal | 1034 | 931 | 14 | 50 |
| | Transverse | 1034 | 931 | 14 | 50 |
| H1150 | Longitudinal | 931 | 621 | 14 | 50 |
| | Transverse | 931 | 621 | 14 | 50 |

3.5.2.2.2.1 Longitudinal tensile property requirements apply to specimens taken in the longitudinal direction from bars, wire, and extrusions, to specimens taken from forgings with axis of specimen in the area of gage length varying not more than 15 degrees from parallel to the forging flow lines, and to specimens taken in the circumferential direction from flash welded rings.

3.5.2.2.2.2 Transverse tensile property requirements apply to specimens taken approximately perpendicular to the longitudinal direction of bars and extrusions, to specimens taken from forgings with axis of specimen in the area of gage length varying not more than 15 degrees from perpendicular to the forging flow lines, and to specimens taken in either the radial or axial direction from flash welded rings.

3.5.2.2.2.3 Transverse tensile property requirements apply only to products from which a test specimen not less than 2 1/2 inches (63.5-mm) long can be taken. If the cross-sectional dimensions of the product permit, the transverse testing shall be of the short-transverse (ST) direction; otherwise, the orientation shall be in the long transverse (LT) direction.

3.5.2.2.2.4 Products tested in the transverse direction need not be tested in the longitudinal direction.

3.5.2.2.3 Fracture Toughness

Shall be not lower than 120 ksi-inch^{1/2} (132 MPa-m^{1/2}) K_{IC}, determined in accordance with ASTM E 399 on specimens in all orientations from product 3.00 inches (76.2 mm) and over in nominal diameter or least distance between parallel sides on product tested in the H1000 condition. Unless otherwise specified by the purchaser, the product will be tested in the longitudinal LT or LR orientation. If product size precludes use of specimens which will provide valid K_{IC} results, use of K_Q values for acceptance is permissible.

3.5.2.2.3.1 Minimum fracture toughness values for product in other than the H1000 condition shall be agreed upon between purchaser and supplier.

3.5.3 Forging Stock

When a sample of stock is forged to a test coupon and heat treated as in 3.4 and 3.5.2.2, specimens taken from the heat treated coupon shall conform to the requirements of 3.5.2.2.2 and 3.5.2.2.3. If specimens taken from the stock after heat treatment as in 3.4 and 3.5.2.2 conform to the requirements of 3.5.2.2.2 and 3.5.2.2.3, the tests shall be accepted as equivalent to tests of a forged coupon.

3.5.4 Stock for Flash Welded Rings or Extrusion

A sample of stock heat treated as in 3.4 and 3.5.2.2 shall conform to the requirements of 3.5.2.2.2 and 3.5.2.2.3.

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 Steel shall be premium aircraft-quality conforming to AMS2300.

3.7 Tolerances

Bars and wire shall conform to all applicable requirements of AMS2241. Tolerances for extrusions shall be as specified on the extrusion drawing.

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 macrostructure (3.5.1.1) of each heat.

4.2.1.2 Hardness (3.5.2.1.2) as solution heat-treated, microstructure (3.5.1.2), and average grain size (3.5.2.1.3 and 4.3.3) of each lot of bars, forgings, flash welded rings, and extrusions.

4.2.1.3 Tensile strength (3.5.2.1.1) of each lot of wire as solution heat-treated.

4.2.1.4 Tensile properties (3.5.2.2.2) of each lot of bars, wire, forgings, flash welded rings, and extrusions after precipitation heat treatment to hardened condition (H1000 or as specified by purchaser) (3.5.2.2).

4.2.1.5 Tolerances (3.7) of bars, wire, and extrusions.

4.2.2 Periodic Tests

Tensile properties (3.5.2.2.2) of all product forms in other than the specified precipitation hardened condition, and frequency-severity cleanliness rating (3.6.1) are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.2.1 Fracture toughness (3.5.2.2.3) of bars and forgings after precipitation heat treatment.

4.3 Sampling and Testing

4.3.1 Bars, Wire, Flash Welded Rings, Extrusions, and Stock for Forging, Flash Welded Rings, or Extrusion

In accordance with AMS2371.

4.3.2 Forgings

In accordance with AMS2374.

4.3.3 Samples for average grain size (3.5.2.1.3) may be hardened to any of the conditions of Table 3 to better define the grain boundaries.

4.4 Reports

The vendor of the product shall furnish with each shipment a report showing the vendor's name and country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations) and the following results of tests and relevant information:

4.4.1 For each heat

Composition
Macrostructure.

4.4.2 For each lot of bars, wire, flash welded rings, extrusions, and forgings

If wire, tensile strength solution heat treated

If product form other than wire, hardness and average grain size (3.5.2.1.3) as solution heat treated

All product forms, tensile properties after precipitation heat treatment

4.4.3 A statement that the product conforms to the other technical requirements.

4.4.4 When the product size is outside the range covered by 1.1, the report shall contain a statement to that effect.

4.4.5 Purchase order number

Heat and lot numbers
AMS5934A
Size
Quantity.

4.4.6 If forgings are supplied, the size and melt source of stock used to make the forgings.

4.4.7 The vendor of stock for forging, flash welded rings, or extrusions shall furnish with each shipment a report showing the vendor's name and country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), composition, macrostructure, and ability to develop required properties of each heat. This report shall include the purchase order number, heat number, AMS5934A, product form, size, and quantity.

4.4.8 If the size being shipped is different from the nominal metallurgically-worked cross-sectional size, the size of the larger product and details of how the shipped size was extracted from the larger product shall be reported (See 3.3.1.2.1).

4.5 Resampling and Retesting

4.5.1 Bars, Wire, Flash Welded Rings, Extrusions, and Stock for Forging, Flash Welded Rings, or Extrusion

In accordance with AMS2371.

4.5.2 Forgings

In accordance with AMS2374.