SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS5937

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Reaffirmed 2012-10

Steel, Corrosion-Resistant, Bars, Wire, and Forgings
12Cr - 11Ni - 2Mo 1.5Al 0.3Ti
Vacuum Induction Plus Vacuum Consumable Electrode Melted
Solution Heat Treated, Precipitation Hardenable

RATIONALE

This document has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE

1.1 Form

This specification covers a corrosion-resistant steel in the form of bars, wire, forgings, and forging stock.

1.2 Application

These products have been used typically for heat-treated parts requiring stress corrosion resistance, along with a combination of high strength and high toughness up to 800 °F (427 °C) with good ductility and strength in the transverse direction, but usage is not limited to such applications.

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

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.

AMS 2241	Tolerances, Corrosion and Heat-Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire
AMS 2248	Chemical Check Analysis Limits, Corrosion and Heat-Resistant Steels and Alloys, Maraging and Other Highly-Alloyed Steels, and Iron Alloys
AMS 2300	Steel Cleanliness, Premium Aircraft-Quality, Magnetic Particle Inspection Procedure

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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
AMS 2750	Pyrometry
AMS 2806	Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat-Resistant Steels and Alloys
AMS 2808	Identification, Forgings
AS1182	Standard Machining Allowance, Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing

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 A 370	Mechanical Testing of Steel Products
ASTM A 604	Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
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	--	0.02
Manganese	--	0.25
Silicon	--	0.25
Phosphorus	--	0.015
Sulfur	--	0.010
Chromium	11.00	12.50
Nickel	10.25	11.25
Molybdenum	1.75	2.25
Titanium	0.2	0.5
Aluminum	1.35	1.75
Nitrogen	--	0.01

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3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS 2248.

3.2 Melting Practice

Product shall be multiple melted using vacuum induction melting followed by vacuum consumable electrode remelt practice.

3.3 Condition

The product shall be supplied in the following condition:

3.3.1 Bars, Wire, and Forgings

3.3.1.1 Rounds

Solution heat treated, turned, and centerless ground or polished.

3.3.1.2 Hexagons

Solution heat treated and descaled.

3.3.1.3 Squares and Flats

Hot finished, solution heat treated, and machined or descaled.

3.3.1.4 Wire

Cold finished, solution treated and descaled.

3.3.1.5 Forgings

Solution heat treated and descaled.

3.3.2 Forging Stock

As ordered by the forging manufacturer.

3.4 Heat Treatment

Bars, wire, and forgings shall be solution heat treated by heating to 1545 °F ± 25 (840°C ± 14), holding at heat for 120 minutes ± 15, and quenching in oil or water, cooling to -100 °F (-73 °C) or colder, holding at that temperature for not less than eight hours, and warming in air to room temperature. Pyrometry shall be in accordance with AMS 2750.

3.5 Properties

The product shall conform to the following requirements; tensile and hardness 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, and forging stock, etched in hot hydrochloric acid in accordance with ASTM A 604, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections for product 36 squares inches (232 cm^2) and under in nominal cross-sectional area 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

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3.5.2 Bars, Wire, and Forgings

3.5.2.1 As Solution Heat Treated

3.5.2.1.1 Tensile Strength

Wire shall have tensile strength not higher than 160 ksi (1103 MPa).

3.5.2.1.2 Hardness

3.5.2.1.2.1 Bars

Not higher than 331 HB, or equivalent (See 8.2), determined at mid-radius or quarter thickness.

3.5.2.1.2.2 Forgings

Not higher than 331 HB, or equivalent (See 8.2).

3.5.2.2 After Precipitation Heat Treatment

The solution heat treated product, 12 inches (305 mm) and under in nominal diameter or maximum cross-sectional dimension, precipitation heat treated to the temperature and time shown in Table 3 and cooled in air, oil, or other suitable liquid quench (See 8.3), shall have the properties specified in 3.5.2.2.1, 3.5.2.2.2, and 3.5.2.2.3. Tensile and hardness tests need only be made in the H1000 condition unless purchaser specifies another heat treated condition for testing.

TABLE 3 - PRECIPITATION HEAT TREATING PARAMETERS

Condition	Temperature	Time
H950	950 °F ± 10 (510 °C ± 6)	8 hours ± 0.3
H1000	1000 °F ± 10 (538 °C ± 6)	8 hours ± 0.3

3.5.2.2.1 Tensile Properties

Shall be as shown in Table 4.

TABLE 4A - MINIMUM TENSILE PROPERTIES, INCH/POUND UNITS

Condition	Specimen Orientation	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 2 Inches or 4D %	Reduction of Area %
H950	Longitudinal	240	220	10	45
	Transverse	240	220	8	35
H1000	Longitudinal	220	200	10	50
	Transverse	220	200	10	40

TABLE 4B - MINIMUM TENSILE PROPERTIES, SI UNITS

Condition	Specimen Orientation	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 50.8 mm or 4D %	Reduction of Area %
H950	Longitudinal	1655	1517	10	45
	Transverse	1655	1517	8	35
H1000	Longitudinal	1517	1379	10	50
	Transverse	1517	1379	10	40

3.5.2.2.1.1 Longitudinal tensile property requirements apply to specimens taken in the longitudinal direction from bars and wire and 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.

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3.5.2.2.1.2 Transverse tensile property requirements apply to specimens taken approximately perpendicular to the longitudinal direction of bars and to specimens taken from forgings with axis of specimens in the area of gage length varying not more than 15 degrees from perpendicular to the forging flow lines.

3.5.2.2.1.3 Transverse tensile property requirements apply only to products from which a test specimen not less than 2.5 inches (63.5 mm) long or 0.5 by 0.5 inch (12.7 × 12.7 mm) cross-section can be taken.

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

3.5.2.2.2 Hardness

Shall not be lower than shown in Table 5, or equivalent (See 8.2). Product shall not be rejected on the basis of hardness if the tensile property requirements of Table 4 are acceptable, determined on specimens taken from the same sample as that with nonconforming hardness or from another sample with similar nonconforming hardness.

TABLE 5 - MINIMUM HARDNESS

Condition	Hardness, HB	HRC
H950	448	47
H1000	426	45

3.5.2.2.3 Fracture Toughness

Shall not be lower than shown in Table 6, determined in accordance with ASTM E 399 on specimens in the L-T or L-R orientation from product 3.00 inches (76.2 mm) and over in nominal section thickness. If product size precludes use of specimens which will provide valid K_{IC} results, use of K_Q values for acceptance is permissible.

TABLE 6 - MINIMUM FRACTURE TOUGHNESS, K_{IC}

Condition	Fracture Toughness ksi$\sqrt{\text{inch}}$	Fracture Toughness MPa$\sqrt{\text{m}}$
H950	70	77
H1000	95	104.5

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 3.5.2.2.1, 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 3.5.2.2.1, 3.5.2.2.2 and 3.5.2.2.3, the tests shall be accepted as equivalent to tests of a forged coupon.

3.6 Quality

3.6.1 Steel shall be premium aircraft quality conforming to AMS 2300.

3.6.2 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.

3.6.3 Bars and wire ordered hot rolled or cold drawn, or ground, turned, or polished shall, after removal of the standard machining allowance in accordance with AS1182, be free from seams, laps, tears, and cracks open to the ground, turned, or polished surface.

3.6.4 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 and wire shall conform to all applicable requirements of AMS 2241.

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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 rating (3.5.1.1) of each heat.

4.2.1.2 Tensile properties (3.5.2.1.1) of wire as solution heat treated.

4.2.1.3 Hardness (3.5.2.1.2) of bars and forgings, as solution heat treated.

4.2.1.4 Tensile properties (3.5.2.2.1) and hardness (3.5.2.2.2) of bars, wire, and forgings after precipitation heat treatment at 1000 °F (538 °C).

4.2.1.5 Tolerances (3.7) of bars and wire.

4.2.2 Periodic Tests

The following requirements 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 heat treatment.

4.2.2.2 Ability of forging stock (3.5.3) to develop required properties.

4.2.2.3 Frequency-severity cleanliness rating (3.6.1).

4.2.2.4 Grain flow of die forgings (3.6.4).

4.2.2.5 Tensile properties (3.5.2.2.1) and hardness (3.5.2.2.2) of bars, wire, and forgings after precipitation heat treatment at 950 °F (510 °C).

4.3 Sampling and Testing

Shall be as follows:

4.3.1 Bars, Wire, and Forging Stock

In accordance with AMS 2371.

4.3.2 Forgings

In accordance with AMS 2374.

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