

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)

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, extrusions, and stock for forging, flash welded rings, or extrusion.

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.

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.

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2011 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

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
http://www.sae.org

**SAE values your input. To provide feedback
on this Technical Report, please visit
<http://www.sae.org/technical/standards/AMS5934>**

SAE WEB ADDRESS:

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or 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
AMS 2315	Determination of Delta Ferrite Content
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
AMS 7490	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, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959 or 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 AMS 2248 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.

3.3.2 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 AMS 7490.

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 \pm 25 (927 °C \pm 14), holding at heat for not less than 30 minutes, and cooling to below 60 °F (16 °C). Pyrometry shall be in accordance with AMS 2750.

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 for product 81 square inches (523 cm²) 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

- 3.5.1.2 Microstructure: The product shall contain not more than the following amount of free ferrite, determined in accordance with AMS 2315:

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 cross-sectional thickness and shall be ASTM No. 4 or finer for product 3.00-inches (76.2-mm) and over in nominal cross-sectional thickness, 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 maximum cross-section dimension, 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 3.5.2.2.1 and 3.5.2.2.2 for that particular condition. Tensile and hardness tests need be made in only the H1000 precipitation heat treated condition unless purchaser specifies a different heat treated condition.

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)

3.5.2.2.1 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

- 3.5.2.2.1.1 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.

- 3.5.2.2.1.2 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.
- 3.5.2.2.1.3 Transverse tensile property requirements apply only to products from which a test specimen not less than 2-1/2 inches (63.5-mm) long or 1/2-inch (12.7-mm) x 1/2-inch (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: Should not be lower than shown in Table 5, or equivalent (See 8.3), for the corresponding precipitation heat treated condition, but the product shall not be rejected on the basis of hardness if the applicable tensile property requirements 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 After Precipitation Heat Treatment

Condition	Hardness, HRC
H950	45
H1000	43
H1025	41
H1050	40
H1100	34
H1150	30

- 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 section thickness 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 3.5.2.2.1 and 3.5.2.2.2. 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 and 3.5.2.2.2, 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 3.5.2.2.1 and 3.5.2.2.2.

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 AMS 2300.

3.7 Tolerances:

Bars and wire shall conform to all applicable requirements of AMS 2241. 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 (3.5.2.2.1) and hardness (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 (3.5.2.2.1) and hardness (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.