Society of Automotive Engineers, Inc.
TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001

AEROSPACE MATERIAL SPECIFICATION

AMS 4977A
Superseding AMS 4977
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TITANIUM ALLOY BARS AND WIRE
11.5Mo - 6.0Zr - 4.5Sn
1275-1350 F (690.6 - 732.2 C) Solution Heat Treated

1. SCOPE:

1.1 Form: This specification covers a titanium-base alloy in the form of bars and wire.

1.2 Application: Primarily for parts where cold formability is desirable or necessary and requiring high strength-to-weight ratio up to 700 F (371 C) after appropriate precipitation heat treatment. Suitable for fasteners and for structures requiring deep hardenability.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., Two Pennsylvania Plaza, New York, New York 10001.

2.1.1 Aerospace Material Specifications:

AMS 2241 - Tolerances, Corrosion and Heat Resistant Steel Bars and Wire and Titanium and Titanium Alloy Bars and Wire
AMS 2249 - Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2350 - Standards and Test Methods

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

ASTM E8 - Tension Testing of Metallic Materials
ASTM E18 - Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E120 - Chemical Analysis of Titanium and Titanium-Base Alloys

2.3 Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

2.3.1 Federal Standards:

Federal Test Method Standard No. 151 - Metals; Test Methods

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, determined by wet chemical methods in accordance with ASTM E120, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, or by other approved analytical methods:

	min	max	
Molybdenum	10.00	13.00	
Zirconium	4.50	7.50	
Tin	3.75	5.25	
Iron	--	0.35	
Oxygen	--	0.18	
Carbon	--	0.10	
Nitrogen	--	0.05	(500 ppm)
Hydrogen	--	0.0200	(200 ppm)
Other Elements, total (3.1.1)	--	0.40	
Titanium	remainder		

3.1.1 Determination not required for routine acceptance.

3.1.2 Check Analysis: Composition variations shall meet the requirements of AMS 2249.

3.2 Condition: The product shall be supplied in the following condition:

3.2.1 Bars: Hot finished, with or without subsequent cold reduction, solution heat treated, straightened, and descaled.

3.2.2 Wire: Hot finished, with or without subsequent cold reduction, solution heat treated, and descaled.

3.3 Heat Treatment: The product shall be solution heat treated by heating to a temperature within the range 1275 - 1350 F (690.6 - 732.2 C), holding at the selected temperature within ± 25 F (± 14 C) for not less than 15 min. nor more than 60 min., and quenching in water.

3.4 Properties:

3.4.1 As Solution Heat Treated:

3.4.1.1 Tensile Properties: Shall be as specified in Table I, determined in accordance with ASTM E8 with the rate of strain maintained at 0.003 - 0.007 in. per in. per min. (0.003 - 0.007 mm/mm/min.) through the yield strength and then increased so as to produce failure in approximately one additional minute. When a dispute occurs between purchaser and vendor over the yield strength values, a referee test shall be performed on a machine having a strain rate pacer, using a rate of 0.005 in. per in. per min. (0.005 mm/mm/min.) through the yield strength and a minimum crosshead speed of 0.10 in. per min. (2.5 mm/min.) above the yield strength.

TABLE I

Nominal Diameter or Distance Between Parallel Sides Inches	Tensile Strength psi, min	Yield Strength at 0.2% Offset psi, min	Elongation in 2 in. or 4D, %, min	Reduction of Area (round specimens) %, min
Up to 1.625, incl	110,000	90,000	15	50
Over 1.625 to 3.000, incl	100,000	90,000	15	50

TABLE I (SI)

Nominal Diameter or Distance Between Parallel Sides Millimeters	Tensile Strength MPa, min	Yield Strength at 0.2% Offset MPa, min	Elongation in 50.8 mm or 4D, %, min	Reduction of Area (round specimens) %, min
Up to 41.28, incl	758	621	15	50
Over 41.28 to 76.20, incl	690	621	15	50

3.4.1.1.1 Tensile property requirements for bars over 3.000 in. (76.20 mm) in diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.4.1.1.2 Yield strength and reduction of area requirements do not apply to wire under 0.125 in. (3.18 mm) in diameter.

3.4.1.1.3 Tests in the longitudinal direction are not required if tests in the transverse direction are made.

3.4.1.1.4 For cold heading applications tensile strength shall be not higher than 135,000 psi (931 MPa).

3.4.1.2 Hardness: The product should have hardness not higher than 30 HRC or equivalent, determined in accordance with ASTM E18, but shall not be rejected on the basis of hardness if the tensile property requirements are met.

3.4.2 After Precipitation Heat Treatment: The product shall be capable of meeting the following requirements after being precipitation heat treated by heating to 1075 F ± 15 F (579.4 C ± 8.3), holding at heat for not less than 4 hr, and cooling in air and descaled. Precipitation heat treatment shall precede final machining of specimens.

3.4.2.1 Tensile Properties: Shall be as follows for sizes 1.625 in. (41.28 mm) and under in diameter or distance between parallel sides, determined in accordance with ASTM E8 with the rate of strain maintained at 0.003 - 0.007 in. per in. per min. (0.003 - 0.007 mm/mm/min.) through the yield strength and then increased so as to produce failure in approximately one additional minute. When a dispute occurs between purchaser and vendor over the yield strength values, a referee test shall be performed on a machine having strain rate pacer, using rate of 0.005 in. per in. per min. (0.005 mm/mm/min.) through the yield strength and a minimum crosshead speed of 0.10 in. per min. (2.5 mm/min.) above the yield strength.

Tensile Strength, min	135,000 psi (931 MPa)
Yield Strength at 0.2% Offset, min	130,000 psi (896 MPa)
Elongation in 2 in. (50.8 mm) or 4D, min	12%
Reduction of Area (round specimens), min	40%

3.4.2.1.1 Tensile property requirements for sizes over 1.625 in. (41.28 mm) in diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.4.2.1.2 Yield strength and reduction of area requirements do not apply to wire under 0.125 in. (3.18 mm) in diameter.

3.4.2.1.3 Tests in the longitudinal direction are not required if tests in the transverse direction are made.

3.4.2.2 Hardness: The product should have hardness of 30 - 38 HRC or equivalent but shall not be rejected on the basis of hardness if the tensile property requirements are met.

3.5 Quality: Unless otherwise specified, material shall be produced by multiple melting using consumable electrode practice; at least one of the melting cycles shall be under vacuum. The product shall be uniform in quality and condition, clean, sound, and free from foreign materials and from internal and external imperfections detrimental to fabrication or to performance of parts.

3.6 Tolerances: Unless otherwise specified, tolerances for bars and wire shall conform to all applicable requirements of AMS 2241. Tolerances for sizes not covered by AMS 2241 shall be as agreed upon by purchaser and vendor.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of the product shall supply all samples and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.4. Purchaser reserves the right to perform such confirmatory testing as he deems necessary to assure that the product conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to composition (3.1), tensile properties as solution heat treated (3.4.1.1), and tolerance (3.6) requirements are classified as acceptance or routine control tests.

4.2.2 Qualification Tests: Tests to determine conformance to tensile properties after precipitation heat treatment (3.4.2.1) are classified as qualification or periodic control tests.

4.3 Sampling: Shall be in accordance with the following; when sampling is on a lot basis, a lot shall be all material of the same nominal size from the same heat processed at the same time.

4.3.1 Composition: One sample from each heat except that for hydrogen determinations, one sample from each lot.

4.3.2 Tensile Properties: At least one sample from each lot.

4.3.3 All Other Requirements: As agreed upon by purchaser and vendor.

4.4 Reports:

4.4.1 The vendor of the product shall furnish with each shipment three copies of a report showing the results of tests for chemical composition of each heat in the shipment, the results of tests on each lot to determine conformance to the hydrogen and tensile property requirements, as solution heat treated, and a statement that the product conforms to all other technical requirements of this specification. This report shall include the purchase order number, heat number, material specification number and its revision letter, size, specific solution heat treatment used, and quantity from each heat.

4.4.2 The vendor of finished or semi-finished parts shall furnish with each shipment three copies of a report showing the purchase order number, material specification number and its revision letter, contractor or other direct supplier of material, part number, and quantity. When material for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of material to determine conformance to the requirements of this specification, and shall include in the report a statement that the material conforms, or shall include copies of laboratory reports showing the results of tests to determine conformance.

4.5 Resampling and Retesting: If any specimen used in the above tests fails to meet the specified requirements, disposition of the product may be based on the results of testing three additional specimens for each original nonconforming specimen. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the product represented and no additional testing shall be permitted. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Identification: The product shall be identified as follows:

5.1.1 Each straight bar 0.500 in. (12.70 mm) and over in diameter or least width of flat surface shall be marked in a row of characters recurring at intervals not greater than 3 ft (914 mm) with AMS 4977A, heat number, and manufacturer's identification. The characters shall be of such size as to be clearly legible, shall be applied using a suitable marking fluid whose residue shall contain not more than traces of halogen-bearing compounds, and shall be capable of being removed in hot alkaline cleaning solution without rubbing. The markings shall have no deleterious effect on the material or its performance and shall be sufficiently stable to withstand normal handling.