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400 COMMONWEALTH DRIVE, WARRENDALE, PA 15096

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

MAM 4911

Issued 4-1-88

TITANIUM ALLOY SHEET, STRIP, AND PLATE
6Al - 4V
Annealed

UNS R56400

1. SCOPE:

1.1 Form: This specification covers a titanium alloy in the form of sheet, strip, and plate procured in metric units. AMS 4911 is the equivalent, specified in inch/pound units, of this MAM.

1.2 Application: Primarily for parts requiring strength up to 400°C. Certain processing procedures and service conditions may cause these products to become subject to stress-corrosion cracking; ARP 982 recommends practices to minimize such conditions.

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

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

MAM 2242 - Tolerances, Metric, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Sheet, Strip, and Plate
AMS 2249 - Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2350 - Standards and Test Methods
AMS 2631 - Ultrasonic Inspection of Titanium Alloy Bar and Billet

2.1.2 Aerospace Recommended Practices:

ARP 982 - Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products

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

ASTM E8 - Tension Testing of Metallic Materials
ASTM E120 - Chemical Analysis of Titanium and Titanium Alloys
ASTM E290 - Semi-Guided Bend Test for Ductility of Metallic Materials

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

2.3.1 Military Standards:

MIL-H-81200 - Heat Treatment of Titanium and Titanium Alloys

2.3.2 Military Standards:

MIL-H-163 - Steel Mill Products, Preparation for Shipment and Storage

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, Ø determined by wet chemical methods in accordance with ASTM E120 or by spectrochemical or other analytical methods approved by purchaser:

	min	max
Aluminum	5.50	6.75
Vanadium	3.50	4.50
Iron	--	0.30
Oxygen	--	0.20
Carbon	--	0.08
Nitrogen	--	0.05 (500 ppm)
Hydrogen	--	0.015 (150 ppm)
Yttrium (3.1.1)	--	0.005 (50 ppm)
Residual Elements, each (3.1.1)	--	0.10
Residual 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 Sheet and Strip: Hot rolled with or without subsequent cold reduction, annealed, descaled, and leveled, having a surface appearance comparable to a commercial corrosion-resistant steel No. 2D finish.

3.2.2 Plate: Hot rolled, annealed, descaled, and flattened, having a surface appearance comparable to a commercial corrosion-resistant steel No. 1 finish.

3.3 Annealing: The product shall be annealed by heating to a temperature within the range 705° - 900°C, holding at the selected temperature within +15°C for a time commensurate with product thickness and the heating equipment and procedure used, and cooling at a rate which will produce product meeting the requirements of 3.4. Furnace surveys and calibration of temperature controllers and recorders shall be in accordance with MIL-H-81200.

3.4 Properties: The product shall conform to the following requirements and shall meet the requirements of 3.4.1 and 3.4.2 after being heated in air to 720°C ± 15, held at heat for 20 min. ± 2, cooled at a rate equivalent to air cool or slower, and descaled.

3.4.1 Tensile Properties: Shall be as specified in Table I, on product 0.20 - 100.00 mm, incl, in nominal thickness, determined in accordance with ASTM E8 with the rate of strain maintained at 0.003 - 0.007 mm/mm per 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 mm/mm per min. through the yield strength.

TABLE I

Nominal Thickness Millimetres	Tensile Strength MPa, min	Yield Strength at 0.2% Offset MPa, min	Elongation in 50 mm or 4D %, min
Up to 0.20, excl	925	870	--
0.20 to 0.62, excl	925	870	6
0.62 to 1.60, excl	925	870	8
1.60 to 4.75, excl	925	870	10
4.75 to 100.00, incl	895	825	10

3.4.1.1 Tensile property requirements for product over 100.00 mm. in nominal thickness shall be as agreed upon by purchaser and vendor.

3.4.1.2 Tensile property requirements apply in both the longitudinal and transverse direction but tests in the transverse direction need be made only on product from which a specimen not less than 200 mm in length for sheet and strip and 63.5 mm in length for plate can be taken. Tests in the longitudinal direction are not required on product tested in the transverse direction.

3.4.2 Bending: Product up to 4.75 mm and under in nominal thickness shall withstand, without evidence of cracking when examined at 20X magnification, bending in accordance with ASTM E290 through an angle of 105 deg around a diameter equal to the bend factor times the nominal thickness of the product, using either V-block, U-channel, or free bend procedure. The axis of bend shall be parallel to direction of rolling. Only one of these tests will be required in routine inspection. In case of dispute, results of bend tests using the V-block procedure shall govern.

Nominal Thickness Millimetres	Bend Factor
Up to 1.75, incl	9
Over 1.75 to 4.75, excl	10

3.4.2.1 Bending requirements for product 4.75 mm and over in nominal thickness shall be as agreed upon by purchaser and vendor.

3.4.3 Microstructure: Shall be essentially that resulting from alpha-beta processing. Microstructure shall not be cause for rejection unless standards for acceptance have been agreed upon by purchaser and vendor except that no continuous network of alpha in the prior beta grain boundaries is acceptable.

3.4.4 Surface Contamination: The product shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination determined as in 3.4.4.1, 3.4.4.2, or by other method agreed upon by purchaser and vendor.

3.4.4.1 The bend test of 3.4.2.

3.4.4.2 Microscopic examination at 100X.

3.5 Quality:

3.5.1 Alloy shall be multiple melted; at least one of the melting cycles shall be under vacuum. The first melt shall be made by consumable electrode, nonconsumable electrode, electron beam, or plasma melting practice. The subsequent melt or melts shall be made using consumable electrode practice with no alloy additions permitted in the last consumable electrode melt.

3.5.1.1 The atmosphere for nonconsumable electrode melting shall be vacuum or shall be inert gas at a pressure not higher than 250 mm of mercury.

3.5.1.2 The electrode tip for nonconsumable electrode melting shall be water-cooled copper.

3.5.2 The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from "oil cans" (See 8.1) of depth in excess of the flatness tolerances, ripples, and foreign materials and from imperfections detrimental to usage of the product.

3.5.2.1 Plate 12.50 to 100.00 mm, incl, in nominal thickness when ultrasonically inspected in accordance with AMS 2631 shall meet Class A1 requirements of that specification.

3.6 Tolerances: Shall conform to all applicable requirements of MAM 2242.

3.6.1 Special flatness may be specified for plate, in which case the special flatness tolerances of AMS 2242 apply.

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 performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.4. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests of the product as received to determine conformance to requirements for composition (3.1), condition (3.2), tensile properties (3.4.1), bending (3.4.2), microstructure (3.4.3), surface contamination (3.4.4), and tolerances (3.6) are classified as acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests: Tests of the product after reheating as in 3.4 to determine conformance to requirements for tensile properties (3.4.1) and bending (3.4.2) and tests to determine conformance to requirements for ultrasonic inspection (3.5.2.1) are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.3 Sampling: Shall be in accordance with the following; a lot shall be all product of the same nominal size from the same heat processed at the same time:

4.3.1 For Acceptance Tests:

4.3.1.1 Composition: One sample from each heat except that for hydrogen determinations one sample from each lot, obtained after thermal and chemical processing is completed.

4.3.1.2 Tensile Property, Bending, Microstructure, and Surface Contamination Requirements: At least one sample from each lot.

4.3.1.2.1 Specimens for tensile tests of widths 225 mm and over shall be taken with the axis of the specimen perpendicular to the direction of rolling; for widths under 225 mm, specimens shall be taken with the axis parallel to the direction of rolling. Specimens from product under 50 mm in width shall be as agreed upon by purchaser and vendor.

4.3.1.2.2 For V-block or U-channel bend tests, specimen width shall be not less than 10 times the nominal thickness or 25 mm, whichever is greater. For free bend tests, minimum specimen width shall, when possible, be not less than 10 times the nominal thickness; maximum width need not be greater than 25 millimetres.

4.3.2 For Periodic Tests: As agreed upon by purchaser and vendor.