SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS6946 REV. B

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Superseding AMS6946A

Titanium Alloy, Sheet, Strip, and Plate
4Al - 2.5V - 1.5Fe
Annealed

(Composition similar to UNS R54250)

RATIONALE

AMS6946B results from a Five Year Review and update of this document that includes a revision to the minimum tensile properties.

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of sheet, strip, and plate.

1.2 Application

These products have been used typically for parts requiring strength up to 750 °F (400 °C), weldability, ductility and cold formability, superplastic forming capability, but usage is not limited to such applications.

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, or www.sae.org.

AMS2242	Tolerances, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Sheet, Strip, and Plate
AMS2249	Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS2630	Inspection, Ultrasonic Product Over 0.5 inch (12.7 mm) Thick
AMS2750	Pyrometry
AMS2809	Identification, Titanium and Titanium Alloy Wrought Products

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
SAE WEB ADDRESS: **http://www.sae.org**

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS6946B

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, or www.astm.org.

ASTM E 8 / E 8M Tension Testing of Metallic Materials

ASTM E 290 Bend Testing of Material for Ductility

ASTM E 384 Microindentation Hardness of Materials

ASTM E 1409 Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique

ASTM E 1447 Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method

ASTM E 1941 Determination of Carbon in Refractory and Reactive Metals and Their Alloys

ASTM E 2371 Analysis of Titanium and Titanium Alloys by Atomic Emission Plasma Spectrometry

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the percentages by weight shown in Table 1; carbon shall be determined in accordance with ASTM E 1941, hydrogen in accordance with ASTM E 1447, oxygen and nitrogen in accordance with ASTM E 1409, and other elements in accordance with ASTM E 2371. Other analytical methods may be used if acceptable to the purchaser.

TABLE 1 - COMPOSITION

Element	min	max
Aluminum	3.5	4.5
Vanadium	2.0	3.0
Iron	1.2	1.8
Oxygen	0.20	0.30
Carbon	--	0.08 (800 ppm)
Nitrogen	--	0.03 (300 ppm)
Hydrogen	--	0.015 (150 ppm)
Other Elements, each (3.1.1)	--	0.10
Other Elements, total (3.1.1)	--	0.30
Titanium	remainder	

3.1.1 Determination not required for routine acceptance.

3.1.2 Check Analysis

Composition variations shall meet the applicable requirements of AMS2249.

3.2 Melting Practice

3.2.1 Alloy shall be multiple melted. Melting cycle(s) prior to the final melting cycle shall be made using vacuum consumable electrode, nonconsumable electrode, electron beam cold hearth, or plasma arc cold hearth melting practice(s). The final melting cycle shall be made under vacuum using vacuum arc remelting (VAR) practice with no alloy additions permitted.

3.2.1.1 The atmosphere for nonconsumable electrode melting shall be vacuum or shall be argon and/or helium at an absolute pressure not higher than 1000 mm of mercury.

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

3.3 Condition

The product shall be supplied in one of the following conditions:

3.3.1 Sheet or strip hot rolled to an intermediate stage, finished to nominal size by cold reduction, and annealed. Product shall be leveled and pickled, as required, and have surface appearance comparable to a commercial corrosion-resistant steel 2D, 2B, or bright anneal finish (See 8.2).

3.3.2 Plate or sheet hot rolled, annealed, descaled, and flattened, having a surface appearance comparable to a commercial corrosion resistant steel No. 1 finish (See 8.2). Plate product shall be produced using standard industry practices designed strictly for the production of plate stock to procured thickness. Bar, billet, forgings, or forging stock shall not be supplied in lieu of plate.

3.4 Annealing

The product shall be annealed by heating to a temperature within the range 1300 to 1500 °F (705 to 815 °C), holding at the selected temperature ±25 °F (±14 °C) for a time commensurate with product thickness, and heating equipment and procedure used, and cooling at a rate that will produce product meeting the requirements of 3.5. Pyrometry shall be in accordance with AMS2750.

3.5 Properties

The product, as furnished, shall conform to the requirements of 3.5.1, 3.5.2, 3.5.3, and 3.5.4. Product shall also meet the requirements of 3.5.1 and 3.5.2 after being heated in air to 1325 °F ± 25 (720 °C ± 14), held at heat for 20 minutes ± 2, cooled at a rate equivalent to an air cool or slower, and descaled:

3.5.1 Tensile Properties

Shall be as specified in Table 2 on product 0.020 to 2.10 inches (0.50 to 53.3 mm), inclusive, in nominal thickness, determined in accordance with ASTM E 8 / E 8M with the rate of strain set at 0.005 inch/inch/minute (0.005 mm/mm/minute) and maintained within a tolerance of ± 0.002 inch/inch/minute (0.002 mm/mm/minute) through the 0.2% offset yield strain.

TABLE 2A - MINIMUM TENSILE PROPERTIES, INCH/POUND UNITS

Nominal Thickness Inches	Tensile Strength ksi		Yield Strength at 0.2% Offset ksi		Elongation in 2 inches or 4D %	
	L	LT	L	LT	L	LT
Cold Rolled						
0.020 to 0.156, incl	134	139	112	129	10	10
Hot Rolled						
0.125 to 2.10, incl	131	131	118	118	12	12

TABLE 2B - MINIMUM TENSILE PROPERTIES, SI UNITS

Nominal Thickness Millimeters	Tensile Strength MPa		Yield Strength at 0.2% Offset MPa		Elongation in 50.8 mm or 4D %	
	L	LT	L	LT	L	LT
Cold Rolled						
0.508 to 3.96, incl	924	958	772	889	10	10
Hot Rolled						
3.20 to 53.4, incl	903	903	814	814	12	12

3.5.2 Bending

Product under 0.1875 inch (4.762 mm) in nominal thickness, shall have a test sample prepared nominally 0.750 inch (19.06 mm) in width, with its axis of bending parallel to the direction of rolling. The sample shall be bend tested at room temperature in conformance with the guided bend test defined in ASTM E 290 through an angle of 105 degrees. The test fixture supports shall have a contact radius 0.010 inch (0.25 mm) minimum, and the plunger shall have a radius equal to the bend factor shown in Table 3 times the nominal thickness. Examination of the bent sample shall not show evidence of cracking when examined at 15 - 25X magnification.

TABLE 3 - BEND FACTOR

Nominal Thickness Inch	Nominal Thickness Millimeters	Bend Factor
Up to 0.1875, excl	Up to 4.76, excl	4

3.5.3 Microstructure

Shall be that structure resulting from alpha-beta processing. Microstructure shall conform to 3.5.3.1, or 3.5.3.2, or 3.5.3.3, or 3.5.3.4. A microstructure showing a continuous network of alpha in prior beta grain boundaries is not acceptable.

3.5.3.1 Lamellar alpha with some equiaxed alpha in a transformed beta matrix.

3.5.3.2 Equiaxed alpha in a transformed beta matrix.

3.5.3.3 Equiaxed alpha and elongated alpha in a transformed beta matrix.

3.5.3.4 Partially broken and distorted grain boundary alpha with plate-like alpha.

3.5.4 Surface Contamination

The product shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination, determined as in 3.5.4.1, 3.5.4.2, 3.5.4.3, or other method acceptable to purchaser.

3.5.4.1 The bend test of 3.5.2.

3.5.4.2 Microscopic examination at 400X minimum.

3.5.4.3 Hardness differential; a surface hardness more than 40 points higher than the subsurface hardness, determined in accordance with ASTM E 384 on the Knoop scale using a 200 gram load, being evidence of unacceptable surface contamination.

3.5.4.4 In case of dispute, the method of 3.5.4.3 shall apply.

3.6 Quality

The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from "oil cans" (See 8.3.1) of depth in excess of the flatness tolerance, ripples, and foreign materials and from imperfections detrimental to usage of the product.

3.6.1 Plate 0.500 to 2.10 inches (12.70 to 53.4 mm) inclusive shall be ultrasonically inspected in accordance with AMS2630, Quality Class A, when specified in Purchase Documents (See 8.6).

3.7 Tolerances

3.7.1 Shall conform to all applicable requirements of AMS2242.

3.7.2 Flatness tolerances do not apply to coiled products.

3.7.3 Special flatness may be specified for plate, in which case the special flatness tolerances of AMS2242 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 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

Composition (3.1), condition (3.3), tensile properties (3.5.1), bending (3.5.2), microstructure (3.5.3), surface contamination (3.5.4), quality (3.6), and tolerances (3.7) are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.1.1 When specified, ultrasonic quality (3.6.1) of each plate.

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 Surface contamination, as determined by 3.5.4.2 and 3.5.4.3.

4.2.2.2 Tensile (3.5.1) and bending (3.5.2) properties of product after reheating to 1325 °F ± 25 (720 °C ± 14).

4.3 Sampling and Testing

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 are completed.