AEROSPACE MATERIAL SPECIFICATION

AMS6945	REV. B

Issued 2005-08
Revised 2014-04

Superseding AMS6945A

Titanium Alloy, Single Melt, Sheet, Strip, and Plate
6Al - 4V
Annealed
(Composition similar to UNS R56400)

RATIONALE

AMS6945B results from a Five Year Review and update of this specification that includes the removal of the additonal sample size allowance for hydrogen from Table 1, requires ultrasonic testing of all plate 0.500 inch (12.70 mm) and over (3.6.1), includes the addition of AS6279 (3.8) and AMS2368 (4.3), and revises the report paragraph (4.4).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of sheet, strip, and plate from 0.020 inch (0.50 mm) through 4.000 inches (101.6 mm) inclusive in thickness.

1.2 Application

These products have been used typically for parts requiring strength up to 750 °F (400 °C), but usage is not limited to such applications.

1.2.1 Certain processing procedures and service conditions may cause these products to become subject to stress-corrosion cracking; ARP982 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.

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

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/AMS6945B

AMS2368 Sampling and Testing of Wrought Titanium Raw Materials, Except Forging and Forging Stock

AMS2631 Ultrasonic Inspection, Titanium and Titanium Alloy Bar and Billet

AMS2750 Pyrometry

AMS2809 Identification, Titanium and Titanium Alloy Wrought Products

ARP982 Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products

AS6279 Industry Standard Practices for Production, Distribution, and Procurement of Metal Stock

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 E 8 / E 8M Tension Testing of Metallic Materials

ASTM E 290 Bend Testing Material for Ductility

ASTM E 384 Knoop and Vickers Hardness of Materials

ASTM E 539 Analysis of Titanium Alloys by X-Ray Fluorescence Spectrometry

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 by Combustion Analysis

ASTM E 2371 Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Atomic Emission 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 539 or ASTM E 2371. Other analytical methods may be used if acceptable to purchaser.

TABLE 1 - COMPOSITION

Element	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)
Other Elements, each (3.1.1)	--	0.10	
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 applicable requirements of AMS2249.

3.2 Melting Practice

3.2.1 Alloy shall be single cold hearth melted. Either electron beam cold hearth melting or plasma arc cold hearth melting may be used.

3.2.1.1 The melt source shall establish effective control procedures, including parameters for the critical variables that will consistently produce material suitable for the production of strip, sheet and plate meeting the requirements of this specification.

3.2.1.2 Controls shall include but are not limited to:

a. Raw Materials (including formulation, preparation and consolidation)

b. Furnace Preparation

c. Melting and Casting Parameters (including practices to deal with unplanned melt interruptions)

d. Furnace Atmosphere

e. Compositional Testing

f. Condensate Control and Fall-In (Electron Beam)

g. Inert Gas Entrapment (Plasma)

h. Withdrawal Time of Ingot or Slab from the Hearth Furnace

3.3 Condition

The product shall be supplied in the following condition:

3.3.1 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 (See 8.2).

3.3.2 Plate

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 the 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 1650 °F (740 to 899 °C), holding at the selected temperature within ±25 °F (±14 °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 3.5. Pyrometry shall be in accordance with AMS2750.

3.5 Properties

The product shall conform to the following requirements and shall meet the requirements of 3.5.1 and 3.5.2 after being reheated in air to 1325 °F ± 15 (718 °C ± 8), 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, 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, %
0.020	to	0.025	excl	146	133	6
0.025	to	0.063	excl	146	133	7
0.063	to	0.1874	incl	146	133	8
0.1875	to	1.000	incl	137	123	8
1.001	to	2.000	incl	132	122	8
2.001	to	3.000	incl	129	119	8
3.001	to	4.000	incl	129	115	8

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, %
0.50	to	0.63	excl	1000	922	6
0.63	to	1.60	excl	1000	922	7
1.60	to	4.76	incl	1000	922	8
4.77	to	25.4	incl	944	848	8
25.42	to	50.8	incl	910	841	8
51.82	to	76.2	incl	889	820	8
76.23	to	101.6	incl	889	792	8

3.5.1.1 Tensile property requirements apply in both the longitudinal and transverse directions but tests in the transverse direction need be made only on product from which a specimen not less than 8.0 inches (205 mm) in length for sheet and strip and 2.50 inches (65 mm) in length for plate can be taken. Tests in the transverse direction are not required on product tested in the longitudinal direction.

3.5.1.2 Mechanical property requirements for product outside the range covered by Table 2 shall be agreed upon between purchaser and producer.

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 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 show no evidence of cracking when examined at 15 to 25X magnification.

TABLE 3 - BENDING PARAMETERS

Nominal Thickness (inch)	Nominal Thickness (mm)	Bend Factor
Up to 0.070, incl	Up to 1.78, incl	4.5
Over 0.070 to 0.1874, incl	Over 1.78 to 4.76 incl	5

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 any one of the following: 3.5.4.1, 3.5.4.2, 3.5.4.3, or other method agreed upon by purchaser and vendor.

3.5.4.1 The bend test of 3.5.2.

3.5.4.2 Microscopic examination at 400X minimum.

3.5.4.3 A surface hardness more than 40 points higher than subsurface hardness, determined in accordance with ASTM E 384 on the Knoop scale using a 200-gram load, shall be evidence of unacceptable surface contamination.

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 tolerances, ripples, and foreign materials and from imperfections detrimental to usage of the product.

3.6.1 Plate 0.500 inch (12.70 mm) and over in nominal thickness shall be ultrasonically inspected in accordance with AMS2631and shall meet Class A1 requirements of AMS2631.

3.7 Tolerances

Shall conform to all applicable requirements of AMS2242.

3.7.1 Special flatness may be specified for plate; in which case, the special flatness tolerances of AMS2242 apply.

3.8 Production, distribution, and procurement of metal stock shall comply with AS6279. This requirement becomes effective October 1, 2015.

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), and tolerances (3.7) are acceptance tests and shall be performed on each heat or lot as applicable.