



AEROSPACE MATERIAL SPECIFICATION

AMS6946™**REV. E**Issued 2006-10
Revised 2024-04

Superseding AMS6946D

Titanium Alloy, Sheet, Strip, and Plate

4Al - 2.5V - 1.5Fe

Annealed

(Composition similar to UNS R54250)

RATIONALE

AMS6946E results from a Five-Year Review and update of this specification with changes to add a Yttrium limit to the composition (see Table 1), update general agreement language related to unauthorized exceptions (see .5.1.1 and 8.4), relocate Definitions (see 2.3), and update Applicable Documents (see Section 2) and Ordering Information (see 8.5).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of sheet, strip, and plate 0.020 inch (0.50 mm) through 2.10 inches (53.3 mm), inclusive, in nominal thickness (see 8.5).

1.2 Application

These products have been used typically for parts requiring strength up to 750 °F (400 °C), weldability, ductility, cold formability, and 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 +1 724-776-4970 (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

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

AMS2630 Inspection, Ultrasonic, Product Over 0.5 Inch (12.7 mm) Thick

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For more information on this standard, visit

<https://www.sae.org/standards/content/AMS6946E/>

AMS2750	Pyrometry
AMS2809	Identification, Titanium and Titanium Alloy Wrought Products
AS1814	Terminology for Titanium Microstructures
AS4194	Sheet and Strip Surface Finish Nomenclature
AS6279	Standard Practice for Production, Distribution, and Procurement of Metal Stock
AS7766	Terms Used in Aerospace Metals Specifications

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 A480/A480M	General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
ASTM E8/E8M	Tension Testing of Metallic Materials
ASTM E290	Bend Testing of Material for Ductility
ASTM E384	Microindentation Hardness of Materials
ASTM E539	Analysis of Titanium Alloys by Wavelength Dispersive X-Ray Fluorescence Spectrometry
ASTM E1409	Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion
ASTM E1447	Determination of Hydrogen in Reactive Metals and Reactive Metal Alloys by Inert Gas Fusion with Detection by Thermal Conductivity or Infrared Spectrometry
ASTM E1941	Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis
ASTM E2371	Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Atomic Emission Spectrometry (Performance -Based Test Methodology)
ASTM E2994	Analysis of Titanium and Titanium Alloys by Spark Atomic Emission Spectrometry and Glow Discharge Atomic Emission Spectrometry (Performance -Based Method)

2.3 Definitions

Terms used in AMS are defined in AS7766 and as follows:

2.3.1 Oil Can

An excess of material in a localized area of a sheet that causes the sheet to buckle in that area. When the sheet is placed on a flat surface and hand pressure applied to the buckle, the buckle will spring through to the opposite surface or spring up in another area of the sheet.

2.3.2 Commercial corrosion-resistant steel finishes are defined in ASTM A480/A480M and AS4194.

2.3.3 Terminology relating to titanium microstructures is presented in AS1814.

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 E1941, hydrogen in accordance with ASTM E1447, oxygen and nitrogen in accordance with ASTM E1409, and other elements in accordance with ASTM E539, ASTM E2371, or ASTM E2994. 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)
Yttrium (3.1.1)	--	0.005 (50 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

Alloy shall be multiple melted. The first melt shall be made by vacuum consumable electrode, nonconsumable electrode, electron beam cold hearth, or plasma arc cold hearth melting practice. The subsequent melt or melts shall be made using vacuum arc remelting (VAR) practice. Alloy additions are not permitted in the final VAR melt.

3.2.1 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.

3.2.2 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 2.3.2).

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 2.3.2). 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 °F (720 °C ± 14 °C), held at heat for 20 minutes ± 2 minutes, 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 E8/E8M with the rate of strain set at 0.005 inch/inch/min (0.005 mm/mm/min) and maintained within a tolerance of ±0.002 inch/inch/min (±0.002 mm/mm/min) 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

3.5.1.1 Mechanical property requirements for product outside the range covered by 1.1 shall be agreed upon between the purchaser and producer and reported in 4.4.2.

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 E290 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 to 25X magnification.

Table 3 - Bend factor

Nominal Thickness Inches	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 (see 2.3.3).

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 the purchaser.

3.5.4.1 The bend test of 3.5.2.

3.5.4.2 Examination of a metallographic cross section at 400X minimum magnification.

3.5.4.3 Hardness differential; a surface hardness more than 40 points higher than the subsurface hardness, determined in accordance with ASTM E384 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 the purchaser, shall be uniform in quality and condition, sound, and free from "oil cans" (see 2.3.1) 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 inch (12.70 mm) and over in thickness shall be ultrasonically inspected in accordance with AMS2630, Quality Class A, when specified in purchase documents (see 8.5).

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.

3.8 Production, distribution, and procurement of metal stock shall comply with AS6279.

3.9 Exceptions

Any exceptions shall be authorized by the purchaser and reported as in 4.4.2.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for the producer's tests and shall be responsible for the performance of all required tests. The 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 (see 3.1), condition (see 3.3), tensile properties (see 3.5.1), bending (see 3.5.2), microstructure (see 3.5.3), surface contamination (see 3.5.4), quality (see 3.6), and tolerances (see 3.7) are acceptance tests and shall be performed on each heat or lot as applicable.