AEROSPACE MATERIAL SPECIFICATION

AMS4989™	REV. E
Issued 2003-04 Revised 2023-02 Superseding AMS4989D	

Titanium Alloy Sheet, Strip, and Plate
3Al - 2.5V
Annealed
(Composition similar to UNS R56320)

RATIONALE

AMS4989E results from a Five-Year Review and update of this specification with changes to update wording to prohibit unauthorized exceptions (3.5.1.1.2, 5.1.1, 8.4), relocate definitions (2.3) and statement on data and statistical procedures (3.5.1.1.3), and update applicable documents (Section 2), and ordering information (8.5).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of sheet, strip, and plate up through 1.000 inch (25.40 mm), inclusive.

1.2 Application

This material has been used typically for parts requiring strength and oxidation resistance up to 600 °F (316 °C) and weldability, 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), 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

AMS2631 Ultrasonic Inspection, Titanium and Titanium Alloy Bar, Billet and Plate

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**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS4989E/

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, 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 Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method

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 which 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 Terminology relating to titanium microstructures is presented in AS1814.

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

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	2.50	3.50
Vanadium	2.00	3.00
Iron	--	0.30
Oxygen	--	0.12
Carbon	--	0.050
Nitrogen	--	0.020 (200 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

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 non-consumable 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 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 2.3.3).

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 2.3.3). 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 Heat Treatment

Pyrometry shall be in accordance with AMS2750.

3.4.1 The product shall be annealed by heating to a temperature within the range 1200 to 1450 °F (649 to 788 °C), holding at the selected temperature within ±25 °F (±14 °C) for a time commensurate with the thickness and the heating equipment and procedure used, and cooling as required.

3.4.2 Continuous Anneal of Sheet and Strip

When continuous annealing is used, process parameters (e.g., furnace temperature set points, heat input, travel rate, etc.) for continuous heat treating lines shall be established by the material producer and validated by testing of product to requirements of 3.5.

3.5 Properties

Product 1.000 inch (25.40 mm) thick and under shall conform to the following requirements:

3.5.1 Tensile Properties

Shall be as specified in Table 2, determined in accordance with ASTM E8/E8M with the rate of strain set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ±0.002 in/in/min (±0.002 mm/mm/min) through the 0.2% offset yield strain.

3.5.1.1 Tensile property requirements listed in Table 2 apply in both the longitudinal and transverse directions.

Table 2 - Minimum tensile properties (see 3.5.1.1.3)

Property	Value
Tensile Strength	90 ksi (621 MPa)
Yield Strength at 0.2% Offset	75 ksi (517 MPa)
Elongation in 2 Inches (50.8 mm)	15% (3.5.1.2)

3.5.1.1.1 For thickness under 0.025 inch (0.64 mm), elongation values shall be as agreed upon (see 8.5).

3.5.1.1.2 Mechanical property requirements for product outside the range covered by 1.1 shall be agreed upon between purchaser and producer and reported per 4.4.2 (see 8.5).

3.5.1.1.3 These mechanical properties have been taken from MIL-T-9046 and have not been substantiated by AMS statistical procedures.

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 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 0.070, excl	Up to 1.78, excl	2.5
0.070 to 0.1875, excl	1.78 to 4.762, incl	3

3.5.3 Microstructure

Shall be that structure resulting from processing within the alpha-beta phase field. Microstructure shall conform to 3.5.3.1, 3.5.3.2, or 3.5.3.3 (see 2.3.2).

3.5.3.1 Equiaxed and/or elongated primary alpha in a transformed beta matrix with no continuous network of alpha at prior beta grain boundaries.

3.5.3.2 Essentially complete field of equiaxed and/or elongated alpha with or without intergranular beta and with no continuous network of alpha at prior beta grain boundaries.

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

3.5.3.4 A microstructure showing a continuous network of alpha in prior beta grain boundaries is not acceptable.

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 acceptable to purchaser.

3.5.4.1 The bend test of 3.5.1.2.

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

3.5.4.3 Hardness Difference

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 g load, being 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 2.3.1) of depth in excess of the flatness tolerances, ripples, and foreign materials and from imperfections detrimental to usage of the product.

3.6.1 Ultrasonic Inspection

Plate 0.500 inch (12.70 mm) and over in nominal thickness shall meet Class A1 requirements of AMS2631.

3.7 Tolerances

3.7.1 Thickness, Width, Length, and Straightness

In accordance with all applicable requirements of AMS2242.

3.7.2 Flatness

Flatness tolerance for product 36 inches (914 mm) and under in width shall be 5% if nominal thickness is under 0.025 inch (0.64 mm) and 3% if nominal thickness is 0.025 to 0.1875 inch (0.64 to 4.762 mm), exclusive. Flatness tolerance for product under 0.1875 inch (4.762 mm) in nominal thickness and over 36 inches (914 mm) in width and for product 0.1875 inch (4.762 mm) and over in nominal thickness in all widths shall be as agreed upon by purchaser and producer (see 8.5).

3.7.2.1 Flatness shall be determined from the expression 100H/L where “H” is the distance from the straight edge to the product at the point of greatest separation and “L” is the distance between contact points of a straight edge laid in any direction on the product.

3.7.2.2 Flatness tolerances do not apply to coiled products.

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

3.9 Exceptions

Any exceptions shall be authorized by 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 producer'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 the specified requirements.

4.2 Classification of 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.

4.2.1 Ultrasonic quality (3.6.1) of each plate, when required, is an acceptance test.

4.3 Sampling and Testing

Shall be in accordance with AMS2368 and the following; a lot shall be all product of the same nominal size from the same heat processed at the same time and in the same heat treatment batch.

4.3.1 Composition

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

4.3.2 Tensile Properties, Bending, Microstructure, and Surface Contamination

At least one sample from each lot.

4.3.2.1 Specimens for tensile tests of widths 9 inches (229 mm) and over shall be taken in both the longitudinal and transverse directions; for widths under 9 inches (229 mm), specimens shall be taken in the longitudinal direction.

4.3.2.2 Bend Specimens

Whenever possible, the specimen shall be long enough to permit two separate bends so that each surface is tested in tension.

4.4 Reports

4.4.1 The producer shall provide with each shipment a report showing producer identity, country where the metal was melted (i.e., final melt in the case of metal processed by multiple melting operations), results of tests for composition of each heat and for the hydrogen content, tensile and bending properties, and surface contamination of each lot, ultrasonic quality of each plate when required, and stating that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS4989E, product form, size, and quantity.

4.4.2 When material produced to this specification is beyond the sizes allowed in the scope or tables, or exceptions authorized by purchaser are taken to the technical requirements listed in Section 3, the report shall contain a statement "This material is certified as AMS4989E(EXC) because of the following exceptions:" and the specific exceptions shall be listed (see 5.1.1).

4.5 Resampling and Retesting

Shall be in accordance with AMS2368.