



AEROSPACE MATERIAL SPECIFICATION

AMS4939™**REV. D**Issued 2003-04
Revised 2022-05

Superseding AMS4939C

Titanium Alloy Sheet, Strip, and Plate
3Al - 8V - 6Cr - 4Mo - 4Zr
Solution Heat Treated
(Composition similar to UNS R58640)

RATIONALE

AMS4939D result from a Five-Year Review and update of the specification with changes to add ASTM E539 analytical method (3.1), prohibit unauthorized exceptions (3.5.3, 3.9 4.4.2, 5.1, 8.6), and update applicable documents (Section 2, 2.3) and ordering information (8.8), and allow the use of the immediate prior specification revision (8.7).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of sheet, strip, and plate through 4.000 inches (101.60 mm) nominal thickness.

1.2 Application

This material has been used typically for parts to be formed or machined in the solution heat treated condition and subsequently precipitation heat treated requiring high strength-to-weight ratio and stability up to 550 °F (288 °C) in the precipitation heat treated condition, but usage is not limited to such applications.

1.3 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 +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

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For more information on this standard, visit
<https://www.sae.org/standards/content/AMS4939D/>

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
AMS2750	Pyrometry
AMS2809	Identification, Titanium and Titanium Alloy Wrought Products
ARP982	Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy 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 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 Plasma 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 Test 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.

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
Vanadium	7.50	8.50
Chromium	5.50	6.50
Molybdenum	3.50	4.50
Zirconium	3.50	4.50
Aluminum	3.00	4.00
Iron	--	0.30
Oxygen	--	0.12
Carbon	--	0.05
Nitrogen	--	0.03
Hydrogen	--	0.020 (200 ppm)
Yttrium (3.1.1)	--	0.005 (50 ppm)
Other Elements, each (3.1.1)	--	0.15
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 under vacuum 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, solution heat treated, 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, solution heated, 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 Heat Treatment

The product shall be solution heat treated by heating to a temperature within the range 1450 to 1700 °F (788 to 927 °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 that 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:

3.5.1 As Solution Heat Treated

3.5.1.1 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.

Table 2A - Minimum tensile properties, inch/pound units (see 8.3)

Nominal Thickness Inches	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 2 Inches or 4D %
Up to 0.029, incl	125	120 (3.5.1.1.1)	6
Over 0.029 to 0.1874, incl	125	120 (3.5.1.1.1)	8
Over 0.1874 to 1.999, incl	125	120	10 (8) (3.5.1.1.2)
Over 1.999 to 4.000, incl	120	115	8 (6) (3.5.1.1.2)

Table 2B - Minimum tensile properties, SI units (see 8.3)

Nominal Thickness Millimeters	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 50.8 mm or 4D %
Up to 0.74, incl	862	827 (3.5.1.1.1)	6
Over 0.74 to 4.76, incl	862	827 (3.5.1.1.1)	8
Over 4.76 to 50.77, incl	862	827	10 (8) (3.5.1.1.2)
Over 50.77 to 101.60, incl	827	793	8 (6) (3.5.1.1.2)

3.5.1.1.1 Yield strength value is a maximum for this size in the solution treated condition.

3.5.1.1.2 Elongation value in parentheses applies in the transverse direction only.

3.5.1.2 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 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, incl	Up to 1.78, incl	3
Over 0.070 to 0.1875, excl	Over 1.78 to 4.762, excl	3.5

3.5.1.3 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: 3.5.1.3.1, 3.5.1.3.2, 3.5.1.3.3, or other method acceptable to purchaser.

3.5.1.3.1 The bend test of 3.5.1.2.

3.5.1.3.2 Microscopic examination at 400X minimum.

3.5.1.3.3 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.

3.5.2 Response to Precipitation Heat Treatment

Product shall conform to the following requirements after being precipitation heat treated by heating within the range 875 to 1150 °F (468 to 621 °C), holding at the selected temperature within ± 15 °F (± 8 °C) for 2 to 30 hours. Precipitation heat treatment shall precede final machining of specimens.

3.5.2.1 Tensile Properties

Shall be as shown in Table 4, determined in accordance with 3.5.1.1.

Table 4A - Minimum tensile properties, inch/pound units (see 8.3)

Nominal Thickness Inches	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 2 Inches or 4D %
Up to 0.1874, incl	180	170	6
Over 0.1874 to 1.999, incl	180	170	8
Over 1.999 to 4.000, incl	170	160	6 (4) (3.5.2.1.1)

Table 4B - Minimum tensile properties, SI units (see 8.3)

Nominal Thickness Millimeters	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 50.8 mm or 4D %
Up to 4.76, incl	1241	1172	6
Over 4.76 to 50.77, incl	1241	1172	8
Over 50.77 to 101.60, incl	1172	1103	6 (4) (3.5.2.1.1)

3.5.2.1.1 Elongation value in parentheses applies in the transverse direction only.

3.5.3 Mechanical property requirements for product outside the size range covered by 1.1 shall be agreed upon between purchaser and producer and reported per 4.4.3.

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 When specified, plate 0.500 inch (12.70 mm) and over in nominal thickness shall be ultrasonically inspected in accordance with AMS2631 and shall meet the quality standards agreed upon between the purchaser and supplier (see 8.5).

3.7 Tolerances

Shall conform to all applicable requirements of AMS2242.

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 4.4.3.

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 specified requirements.

4.2 Classification of Tests

All technical requirements are acceptance tests and shall be performed on each heat or lot as applicable.

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, Surface Contamination, and Tensile Properties after Precipitation Hardening

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. Alternately, two specimens from adjacent locations may be used.

4.3.2.3 Ultrasonic Quality

When specified, each plate required by 3.6.1 (see 8.5).

4.4 Reports

4.4.1 The producer shall furnish 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), the 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 state that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS4939D, product form, size, specific aging treatment used to develop precipitation hardened properties, and quantity.

4.4.2 When the product size is outside the range covered by 1.1, the report shall contain a statement to that effect.