



# AEROSPACE MATERIAL SPECIFICATION

**AMS4988****REV. C**Issued 2003-04  
Revised 2014-03

Superseding AMS4988B

Titanium Alloy Sheet, Strip, and Plate  
6Al - 6V - 2Sn  
Solution Heat Treated  
(Composition similar to UNS R56620)

## RATIONALE

AMS4988C results from an update of this specification that requires vacuum in the first consumable electrode melt (3.2), revises transition from sheet to plate in Tables 3 and 4, requires agreement on mechanical property values on material outside specification ranges (3.5.2.1.2 and 8.7) and ultrasonic testing of all plate 0.500 inch (12.7 mm) and over (3.6.1), adds AS6279 (3.8), 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 in thicknesses up through 4.000 inches (101.60 mm), inclusive (See 8.7).

### 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.

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## 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](http://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 of Titanium Alloys
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](http://www.astm.org).

ASTM E 8 / E 8M	Tension Testing of Metallic Materials
ASTM E 112	Determining Average Grain Size
ASTM E 290	Bend Testing of Material for Ductility
ASTM E 384	Knoop and Vickers 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 by Combustion Analysis
ASTM E 2371	Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Plasma 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 2371. Other analytical methods may be used if acceptable to the purchaser.

TABLE 1 - COMPOSITION

Element	min	max
Aluminum	5.00	6.00
Vanadium	5.00	6.00
Tin	1.50	2.50
Iron	0.35	1.00
Copper	0.35	1.00
Oxygen	--	0.20
Carbon	--	0.05
Nitrogen	--	0.04 (400 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.

3.1.3 Sample size, when using ASTM E 1447, may be as large as 0.35 gram.

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. 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 8.3).

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 8.3). 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

The product shall be solution heat treated as follows; pyrometry shall be in accordance with AMS2750:

3.4.1 Sheet, strip and plate shall be solution heat treated by heating to a temperature within the range 1550 to 1700 °F (843 to 927 °C), holding at selected temperature within  $\pm 25$  °F ( $\pm 14$  °C) for 2 to 60 minutes, and quenching in agitated water. Air cooling may be applied in thin material.

### 3.5 Properties

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 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  $\pm 0.002$  inch/inch/minute (0.002 mm/mm/minute) through the 0.2% offset yield strain.

TABLE 2A - TENSILE PROPERTIES, INCH/POUND UNITS (SEE 8.2)

Nominal Thickness Inch	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi, max	Elongation in 2 Inches or 4D %, min
Up to 0.1875, excl	(3.5.1.1.1)	160	10 (3.5.1.1.2)

TABLE 2B - TENSILE PROPERTIES, SI UNITS (SEE 8.2)

Nominal Thickness Millimeters	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa, max	Elongation in 50.8 mm or 4D %, min
Up to 4.76, excl	(3.5.1.1.1)	1103	10 (3.5.1.1.2)

3.5.1.1.1 Spread between tensile strength and yield strength shall be 15 ksi (103 MPa) minimum.

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

##### 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 E 290 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 show no evidence of cracking when examined at 15 to 25X magnification.

TABLE 3 - BEND FACTOR

Nominal Thickness Inch	Nominal Thickness Millimeters	Bend Factor
Up to 0.070, excl	Up to 1.78, excl	4
0.070 to 0.1875, excl	1.78 to 4.762, excl	4.5

##### 3.5.1.3 Microstructure

Shall be that structure resulting from processing within the alpha-beta phase field. Microstructure shall conform to 3.4.1.3.1 (See 8.5).

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

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

### 3.5.1.4 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: 3.5.1.4.1, 3.5.1.4.2, 3.5.1.4.3, or other method acceptable to purchaser.

3.5.1.4.1 The bend test of 3.5.1.2.

3.5.1.4.2 Microscopic examination at 400X minimum.

3.5.1.4.3 Hardness difference; 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.

### 3.5.1.5 Average Grain Size

Shall be ASTM No. 6 or finer determined by comparison of a polished and etched specimen with the chart in ASTM E 112.

### 3.5.2 Response to Heat Treatment

Product shall conform to the following requirements after being precipitation heat treated by heating to a temperature within the range of 875 to 1150 °F (468 to 621 °C), holding at selected temperature within  $\pm 15$  °F ( $\pm 8$  °C) for 2 to 10 hours, and cooling in air. Precipitation heat treatment shall precede final machining of specimens.

#### 3.5.2.1 Tensile Properties

Shall be as shown in Table 4, determined per 3.5.1.1.

TABLE 4A - MINIMUM TENSILE PROPERTIES (SEE 8.2)

Nominal Thickness Inches	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 2 in. or 4D %
Up to 0.1875, excl	170	160	8 (6) (See 3.5.2.1.1)
0.1875 to 1.500, excl	170	160	8
1.500 to 2.500, excl	160	150	6
2.500 to 4.000, incl	150	140	6

TABLE 4B - MINIMUM TENSILE PROPERTIES, SI UNITS (SEE 8.2)

Nominal Thickness Millimeters	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 50.8 mm or 4D %
Up to 4.76, excl	1172	1103	8 (6) (See 3.5.2.1.1)
4.76 to 38.10, excl	1172	1103	8
38.10 to 63.50, excl	1103	1034	6
63.50 to 101.60, incl	1034	965	6

3.5.2.1.1 Elongation value in parentheses is for transverse direction only.

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

### 3.6 Quality

The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from "oil cans" (See 8.4) 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

Shall conform to all applicable requirements of AMS2242.

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

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, Average Grain Size, 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.

#### 4.3.3 Ultrasonic Examination

Each plate 0.500 inch (12.70 mm) and over.