SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

AMS 4911L

Issued JUL 1957
Revised JUN 2007

Superseding AMS 4911

Titanium Alloy, Sheet, Strip, and Plate
6Al - 4V
Annealed

(Composition similar to UNS R56400)

RATIONALE

AMS 4911L results from a correction to the SI units in paragraph 3.4. AMS 4911K resulted from a review and update that includes revision of reporting requirements and correction of the heading in Table 2.

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of sheet, strip, and plate.

1.2 Application

These products have been used typically for parts requiring strength up to 750 °F (399 °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), or www.sae.org.

AMS 2242	Tolerances, Corrosion and Heat-Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Sheet, Strip, and Plate
AMS 2249	Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2631	Ultrasonic Inspection, Titanium and Titanium Alloy Bar and Billet
AMS 2750	Pyrometry
AMS 2809	Identification, Titanium and Titanium Alloy Wrought Products
ARP982	Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products

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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 E 8	Tension Testing of Metallic Materials
ASTM E 290	Bend Testing Material for Ductility
ASTM E 384	Microindentation Hardness of Materials
ASTM E 539	X-Ray Emission Spectrometric Analysis of 6Al-4V Titanium Alloy
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
ASTM E 2371	Analysis of Titanium and Titanium Alloys by Atomic Emission Plasma 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 the 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 (3.1.2)	--	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 Sample size, when using ASTM E 1447, may be as large as 0.35 gram.

3.1.3 Check Analysis

Composition variations shall meet the applicable requirements of AMS 2249.

3.2 Melting Practice

3.2.1 Alloy shall be multiple melted. Melting cycle(s) prior to the final melting cycle shall be made using vacuum consumable electrode, nonconsumable electrode, electron beam cold hearth, or plasma arc cold hearth melting practice. The final melting cycle shall be made under vacuum using vacuum arc remelting (VAR) practice with no alloy additions permitted.

3.2.1.1 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.

3.2.1.2 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 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 (704 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 AMS 2750.

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 with the rate of strain maintained at 0.003 to 0.007 inch/inch per minute (0.003 to 0.007 mm/mm per minute) through the yield strength and then increased so as to produce failure in approximately one additional minute. When a dispute occurs between purchaser and vendor over the yield strength values, a referee test shall be performed on a machine having a strain rate pacer using a rate of 0.005 inch/inch per minute (0.005 mm/mm per minute) through the yield strength.

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 %
Up to 0.008, excl	134	126	--
0.008 to 0.025, excl	134	126	6
0.025 to 0.063, excl	134	126	8
0.063 to 0.1875, excl	134	126	10
0.1875 to 4.000, incl	130	120	10

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, %
Up to 0.20, excl	920	866	--
0.20 to 0.63, excl	920	866	6
0.63 to 1.60, excl	920	866	8
1.60 to 4.76, excl	920	866	10
4.76 to 101.6, incl	893	823	10

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 (203 mm) in length for sheet and strip and 2.50 inches (63.5 mm) in length for plate can be taken. Tests in the transverse direction are not required on product tested in the longitudinal direction.

3.5.2 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 Millimeters	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 acceptable to purchaser.

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 to 4.000 inches (12.7 to 101.6 mm), inclusive, in nominal thickness, shall be ultrasonically inspected in accordance with AMS 2631 and shall meet Class A1 requirements of AMS 2631.

3.7 Tolerances

Shall conform to all applicable requirements of AMS 2242.

3.7.1 Special flatness may be specified for plate; in which case, the special flatness tolerances of AMS 2242 apply.

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), ultrasonic quality (3.6.1), and tolerances (3.7) are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests

Tests of the product after reheating as in 3.5 for tensile properties (3.5.1) and bending properties (3.5.2) are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing

Shall be in accordance with the following; a lot shall be all product of the same nominal size from the same heat processed at the same time:

4.3.1 For Acceptance Tests

4.3.1.1 Composition

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

4.3.1.2 Tensile Properties, Bending, Microstructure, and Surface Contamination

One or more samples from each lot.

4.3.1.2.1 Specimens for tensile tests of widths 9 inches (229 mm) and over shall be taken with the axis of the specimen perpendicular to the direction of rolling; for widths under 9 inches (229 mm), specimens shall be taken with the axis parallel to the direction of rolling. Specimens from product under 2 inches (50.8 mm) in width shall be as agreed upon by purchaser and vendor.

4.4 Reports

4.4.1 Raw Material

The vendor shall provide a copy of the original material manufacturer's report (material certification) including: producer name, product form, mill produced size, and country where the metal was melted (i.e., final melt in the case of metal processed by multiple melting operations). The vendor of the product shall furnish with each shipment a report showing the results of tests for composition of each heat and for hydrogen content, tensile properties, bending, ultrasonic inspection, and surface contamination of each lot, and stating that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS 4911L, size, specific annealing treatment used, and quantity.

4.4.2 Fabricated Parts

A copy of the original manufacturer's report (material certification) shall be provided by the vendor to the purchaser when the purchase order specifies AMS 4911.

4.5 Resampling and Retesting

If any specimen used in the above tests fails to meet the specified requirements, disposition of the product may be based on the results of testing three additional specimens for each original nonconforming specimen. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the product represented. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY

5.1 Identification

Shall be in accordance with AMS 2809.

5.2 Packaging

The product shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the product to ensure carrier acceptance and safe delivery.

6. ACKNOWLEDGMENT

A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS

Product not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES

8.1 A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of a specification. An (R) symbol to the left of the document title indicates a complete revision of the specification, including technical revision. Change bars and (R) are not used in original publications, nor in specifications that contain editorial changes only.

8.1.1 AMS 4911L is an editorial correction necessary to correct an error in the K revision. In this instance, the change bar symbol(s) included herein are for the convenience of the user in locating areas where technical changes have been made to the K and L revisions.

8.2 Commercial corrosion-resistant steel finishes are defined in ASTM A 480/A 480 M and AS4194.

8.3 Terms used in AMS are clarified in ARP1917 and as follows:

8.3.1 "Oil Can" is defined as 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.

8.4 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

8.5 Purchase documents should specify not less than the following:

AMS 4911L
Product form and size of product desired
Quantity of product desired.