



AEROSPACE MATERIAL SPECIFICATION

AMS4904™

REV. D

Issued 2003-04
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Superseding AMS4904C

Titanium Alloy Sheet, Strip, and Plate
6Al - 4V
Solution Heat Treated and Aged
(Composition similar to UNS R56400)

RATIONALE

AMS4904D results from a Five-Year Review and update of this specification that adds ASTM E2994 as analytical method (3.1), revises gage range for tensile testing to match MIL-T-9046 and MMPDS (Table 2), prohibits unauthorized exceptions (3.9), and revises reporting (4.4.2) and identification (5.1).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of sheet, strip, and plate up through 2.000 inches (50.80 mm), inclusive.

1.2 Application

This material has been used typically requiring high strength-to-weight ratio and stability up to 550 °F (288 °C) in the precipitation heat treated condition in material thicknesses 2.000 inches (50.80 mm) and under, 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 +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
AMS2750	Pyrometry
AMS2809	Identification, Titanium and Titanium Alloy Wrought Products
ARP982	Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products
ARP1917	Clarification of Terms Used in Aerospace Metals Specifications
AS4194	Sheet and Strip Surface Finish Nomenclature
AS6279	Standard Practice 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.

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 E112	Determining Average Grain Size
ASTM E384	Microindentation Hardness of Materials
ASTM E539	Analysis of Titanium Alloys by 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 Plasma Atomic Emission Spectrometry
ASTM E2994	Analysis of Titanium and Titanium Alloys by Spark Atomic Emission Spectrometry and Glow Discharge 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 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	5.50	6.75
Vanadium	3.50	4.50
Iron	--	0.30
Oxygen	--	0.20
Carbon	--	0.08
Nitrogen	--	0.05 (500 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 melt cycle.

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, leveled, and precipitation hardened (aged), having a surface appearance comparable to a commercial corrosion-resistant steel sheet ASTM No. 2D finish (see 8.3).

3.3.2 Plate

Hot rolled, solution treated, flattened, and precipitation hardened (aged), having a surface appearance comparable to a commercial corrosion-resistant steel ASTM 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 substituted for plate.

3.4 Heat Treatment

The product shall be solution heat treated and aged by heating in a suitable atmosphere to a temperature within the range 1650 to 1775 °F (899 to 968 °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 equivalent to a water quench and then aged by heating to 900 to 1275 °F ± 15 °F (482 to 691 °C ± 8 °C), holding at heat for 2 to 8 hours, and cooling in air. Pyrometry shall be in accordance with AMS2750.

3.5 Properties

Product 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.

Table 2

Table 2A - Tensile properties, inch/pound units (see 8.2)

Nominal Thickness			Tensile Strength	Yield Strength	Elongation in	
Inches			ksi	at 0.2% Offset	2 Inches or 4D	
				ksi	%	
Up	to	0.032,	incl	160	145	3 (see 3.5.1.1)
Over 0.032	to	0.049,	incl	160	145	4
Over 0.049	to	0.1875,	incl	160	145	5
Over 0.1875	to	0.750,	incl	160	145	8
Over 0.750	to	1.000,	incl	150	140	6
Over 1.000	to	2.000,	incl	145	135	6

Table 2B - Tensile properties, SI units (see 8.2)

Nominal Thickness			Tensile Strength	Yield Strength	Elongation in	
mm			MPa	at 0.2% Offset	50.8 mm or 4D	
				MPa	%	
Up	to	0.81,	incl	1103	1000	3 (see 3.5.1.1)
Over 0.81	to	1.24,	incl	1103	1000	4
Over 1.24	to	4.76,	incl	1103	1000	5
Over 4.76	to	19.05,	incl	1103	1000	8
Over 19.05	to	25.40,	incl	1034	965	6
Over 25.40	to	50.80,	incl	1000	931	6

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

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

3.5.2 Microstructure

Shall be that structure resulting from processing within the alpha-beta phase field. Microstructure shall conform to 3.5.2.1 or 3.5.2.2 (see 8.5).

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

3.5.2.2 Primary alpha in an aged transformed beta matrix.

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

3.5.3 Surface Contamination

The product shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination, determined as in 3.5.3.1 or 3.5.3.2, or other method acceptable to purchaser.

3.5.3.1 Microscopic examination at 400X minimum.

3.5.3.2 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-gram 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 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

In accordance with AMS2242.

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 specified requirements.

4.2 Classification of Tests

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

4.2.1 When required, ultrasonic inspection (3.6.1) of each plate.

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, 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.

4.3.3 Ultrasonic Inspection

Each plate, when required (3.6.1).

4.4 Reports

4.4.1 The producer shall furnish with each shipment a report showing producer identity, country where the metal was melted (e.g., 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 properties, and surface contamination of each lot, and ultrasonic quality, 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, AMS4904D, product form, mill produced size, solution and aging treatment used, 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 AMS4904D(EXC) because of the following exceptions," and the specific exceptions shall be listed (also see 5.1).

4.5 Resampling and Retesting

In accordance with AMS2368.

5. PREPARATION FOR DELIVERY

5.1 Identification

In accordance with AMS2809. When technical exceptions are taken (see 4.4.2), the material shall be marked with AMS4904D(EXC).

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. ACKNOWLEDGEMENT

A producer shall include 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 Revision Indicator

A change bar (I) 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 this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

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

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

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

8.4.1 "Oil Can"

An excess of material in a localized area of a sheet that causes the sheet to buckle in that area. When a 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.

8.5 Terminology relating to titanium microstructures is presented in AS1814.

8.6 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.

8.7 Purchase documents should specify not less than the following:

AMS4904D

Product form and size of product desired

Quantity of product desired

Property and acceptance requirements from the cognizant engineering organization applicable to sizes outside the size ranges listed in 1.1

8.8 Unless otherwise specified, the material producer shall work to the revision of this specification (AMS4904) in effect on the date of order placement. Unless otherwise specified, material manufactured and certified to the immediately previous revision of this specification (AMS4904) may be procured and used until inventory is depleted.

8.9 Similar Specifications

AMS-T-9046 (AB-1) and MIL-T-9046 (AB-1).

PREPARED BY AMS COMMITTEE "G"