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MILITARY SPECIFICATION

TITANIUM AND TITANIUM ALLOY BARS (ROLLED OR FORGED) AND REFORGING STOCK, AIRCRAFT QUALITY

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers aircraft quality, commercially pure titanium and alpha, alpha-beta and beta titanium alloy rolled or forged bar and reforging stock products.

1.2 Classification. Products shall be of the following compositions, as specified (see 6.2 and Table IX).

Commercially pure titanium

Ti-CP-70

Alpha titanium alloys

Ti-5Al-2.5Sn
Ti-5Al-2.5Sn (ELI)
6Al-2Cb-1Ta-0.8Mo
8Al-1Mo-1V

Alpha-Beta titanium alloy

Ti-3Al-2.5V
Ti-6Al-4V
Ti-6Al-4V (ELI)
Ti-6Al-6V-2Sn
Ti-6Al-2Sn-4Zr-2Mo
Ti-6Al-2Sn-4Zr-6Mo
Ti-7Al-4Mo

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to the Air Force Materials Laboratory, MXA, WPAFB, Ohio 45433 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FSC 9530

Beta titanium alloy

Ti-8Mo-8V-2Fe-3Al
Ti-11.5Mo-6Zr-4.5Sn
Ti-3Al-8V-6Cr-4Mo-4Zr
Ti-13V-11Cr-3Al

1.3 Condition.

1.3.1 Bars (see 6.1.1). Products shall be hot-worked, with or without subsequent cold finishing, and shall be supplied in one of the following heat treated conditions in accordance with Tables II, III and IV, as specified (see 6.2).

Condition A - Annealed
Condition DA - Duplex annealed.
Condition ST - Solution treated.
Condition STA - Solution treated and aged. (When multiple STA conditions are specified for a given alloy, as in Table IV, the applicable aging temperature shall be added in parenthesis as a suffix).

1.3.2 Heat treatment. Heat treatments shall be accomplished in accordance with MIL-H-81200. Requirements for heat treatments not listed in this specification shall be as agreed upon by the user and contractor or producer.

1.3.3 Reforging stock (see 6.1.2). Products shall be furnished in the condition ordered by the forging manufacturer (see 6.2).

1.4 Finish. Products shall be furnished in the following surface finishes, as ordered (see 6.2). When no surface finish is specified, Surface Finish I shall apply. When permitted by purchaser, product to be machined all over may have an oxygen rich layer, provided such layer is removable within the machining allowance for the part.

1.4.1 Surface Finish I. Ground, machined or otherwise descaled and pickled free of alpha case and other harmful surface contamination, and suitable for ultrasonic inspection.

1.4.2 Surface Finish II. Centerless ground, machined or otherwise specially prepared surface free of alpha case and other harmful surface contamination, and suitable for ultrasonic inspection by the immersion method.

2. APPLICABLE DOCUMENTS

2.1 Issues of documents. The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-H-81200	Heat Treatment of Titanium and Titanium Alloys

STANDARDS

FEDERAL

FED-STD-151	Metals; Test Methods

MILITARY

MIL-STD-105	Sampling Procedures and Tables
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-163	Steel Mill Products Preparation For Shipment and Storage

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the effect on date of invitation for bids or request for proposal shall apply.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E8	Tension Testing of Metallic Materials
ASTM E120	Chemical Analysis of Titanium and Titanium-Base Alloys
ASTM E146	Chemical Analysis of Zirconium and Zirconium-Base Alloys

(Application for copies should be addressed to the American Society for Testing and Materials, 1915 Race Street, Philadelphia, PA 19103.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI B46.1	Surface Texture

(Application for copies should be addressed to the American National Standards Institute, Incorporated, 1430 Broadway, New York, NY 10018.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

AMS 2241	Tolerances - Corrosion and Heat Resistant Steel, Bar and Wire and Titanium and Titanium Alloy Bars and Wire
AMS 2249	Chemical Check Analysis Limits - Titanium and Titanium Alloys
AMS 2631	Ultrasonic Inspection of Titanium Alloys
AMS 2643	Structural Examination of Titanium Alloys, Chemical Etch, Inspection Procedure
ARP 982	Minimizing Stress-Corrosion in Wrought Titanium Alloy Products

(Application for copies should be addressed to the Society of Automotive Engineers, Incorporated, 400 Commonwealth Drive, Warrendale, PA 15096.)

3. REQUIREMENTS

3.1 Material. Unless otherwise specified (see 6.2), material for products supplied in accordance with this specification shall be produced by mutiple melting using consumable electrode practice. The last melting cycle shall be under vacuum.

3.2 Chemical composition. The chemical composition, as determined by heat or lot analysis, shall be as specified in Table I.

3.2.1 Check analysis. Chemical composition variations shall meet the requirements of AMS 2249.

3.3 Tensile properties.

3.3.1 Bars.

3.3.1.1 Commercially pure and alpha-titanium alloys. Tensile properties shall conform to Table II.

TABLE I. Chemical composition, percent by weight. 1/ & 2/

Composition	ELEMENTS														
	Al	Sn	Zr	Cb	Ta	Mo	V	Cr	Fe 3/	C (max)	N (max)	H (max) 4/	O (max)	Cu or Si as noted	Total Other Elements (max) 5/
COMMERCIALLY PURE TITANIUM															
CP-70	-	-	-	-	-	-	-	-	0.50	0.08	0.05	0.0125	0.40	-	0.30
ALPHA TITANIUM ALLOY															
3Al-2.5V	2.50 -3.50	-	-	-	-	-	2.00 -3.00	-	0.30	0.05	0.02	0.015	0.12	-	0.40
5Al-2.5Sn	4.50 -5.75	2.00 -3.00	-	-	-	-	-	-	0.50	0.08	0.05	0.020	0.20	-	0.40
5Al-2.5Sn (ELI)	4.50 -5.75	2.00 -3.00	-	-	-	-	-	-	0.25 6/	0.05	0.035	0.0125	0.12 6/	-	0.30 7/
6Al-2Cb-1Ta-0.8Mo	5.50 -6.50	-	-	1.50 -2.50	0.50 -1.50	0.50 -1.00	-	-	0.25	0.05	0.03	0.0125	0.10		0.40
8Al-1Mo-1V	7.35 8.35	-	-	-	-	0.75-1.25	0.75-1.25	-	0.30	0.08	0.05	0.015	0.15	-	0.40

TABLE I. Chemical composition, percent by weight. 1/ & 2/ - (Continued)

Composition	ELEMENTS														
	Al	Sn	Zr	Cb	Ta	Mo	V	Cr	Fe 3/	C (max)	N (max)	H (max) 4/	O (max)	Cu or Si as noted	Total Other Elements (max) 5/
ALPHA-BETA TITANIUM ALLOY															
6Al-4V	5.50 -6.75	-	-	-	-	-	3.50 -4.50	-	0.30	0.08	0.05	0.015	0.20	-	0.40
6Al-4V (ELI)	5.50 -6.50	-	-	-	-	-	3.50 -4.50		0.25	0.08	0.05	0.0125	0.13	-	0.30
6Al-6V-2Sn	5.00 -6.00	1.50 -2.50	-	-	-	-	5.00 -6.00	-	0.35-1.00	0.05	0.04	0.015	0.20	8/	0.30
6Al-2Sn-4Zr-2Mo	5.50 -6.50	1.80 -2.20	3.60 -4.40	-	-	1.80 -2.20	-	-	0.25	0.05	0.04	0.015	0.15	9/	0.30
6Al-2Sn-4Zr-6Mo	5.50 -6.50	1.75 2.25	3.60 -4.40	-	-	5.50 -6.50	-	-	0.15	0.04	0.04	0.0125	0.15	-	0.40
7Al-4Mo	6.50 -7.30	-	-	-	-	3.50 -4.50	-	-	0.30	0.10	0.05	0.013	0.20	-	0.40
BETA TITANIUM ALLOY															
8Mo-8V-2Fe-3Al	2.60 -3.40	-	-	-	-	7.50 -8.50	7.50 -8.50	-	1.60 -2.40	0.05	0.05	0.015	0.16	-	0.40
11.5Mo-6Zr-4.5Sn	-	3.75-5.25	4.50 -7.50	-	-	10.00 -13.00	-	-	0.35	0.10	0.05	0.020	0.18	-	0.40
3Al-8V-6Cr-4Mo-4Zr	3.00 -4.00		3.50 -4.50	- -	- -	3.50 -4.50	7.50 -8.50	5.50 -6.50	0.30	0.05	0.03	0.020	0.12	-	0.40
13V-11Cr 3Al	2.50 -3.50	-	-	-	-	-	12.50 -14.50	10.00 -12.00	0.35 max.	0.05	0.05	0.025	0.17	-	0.40

TABLE I. Chemical composition, percent by weight. - Continued

NOTES:

1/ Balance is titanium.

2/ Yttrium shall not exceed 0.005 (50 ppm).

3/ Maximum, unless otherwise specified.

4/ Hydrogen shall be determined on each lot of the product as shipped.

5/ Need not be determined. Material shall meet this requirement when analyzed. Unless otherwise noted, other elements each shall be 0.10 percent maximum.

6/ Iron plus oxygen shall not exceed 0.32 percent.

7/ Other elements each shall be 0.05 percent maximum.

8/ 0.35 - 1.00 Cu.

9/ 0.13 (max) Si

TABLE II. Commercially pure and alpha titanium minimum tensile properties.

Alloy 2/	Thickness, Diameter or Distance Between Flats Inch (mm) 3/	MINIMUM TENSILE PROPERTIES 1/			
		Tensile Strength ksi (MPa)	Yield Strength at 0.2 Percent Offset ksi (MPa)	Elongation Percent in 4D 4/	Reduction of area Percent 4/
COMMERCIALLY PURE TITANIUM					
CP-70	4.00 & under (101.60 & under)	80 (551)	70 (482)	15	30
ALPHA TITANIUM ALLOYS					
5Al-2.5Sn	4.00 & under (101.60 & under)	115 (792)	110 (758)	10 [8]	25 [20]
5Al-2.5Sn (ELI)	3.00 & under (76.20 & under)	100 (689)	90 (620)	10 [8]	25 [20]
	3.00 to 4.00 (76.20 to 101.60)	100 (689)	90 (620)	10 [8]	20 [15]
6Al-2Cb-1Ta-0.8Mo	4.00 & under (101.60 & under)	103 (710)	95 (655)	10 [8]	20 [15]
8Al-1Mo-1V 5/	2.50 & under (63.50 & under)	130 (896)	120 (827)	10	20
	2.50 to 4.00 (63.50 to 101.60)	120 (827)	110 (758)	10 [8]	20 [15]

1/ Apply to products with a cross-sectional area of 16 sq.in. or less. Properties apply in any grain direction.
2/ Unless otherwise noted, properties apply to the annealed condition.
3/ Thickness given as X.XXX to X.XXX shall be read as "Over--to--, inclusive."
4/ Values in brackets [] apply to the short transverse direction for short transverse dimensions of 3.0 inches or greater.
5/ Duplex Annealed (Condition DA) only.

3.3.1.2 Alpha-beta titanium alloys. Tensile properties shall conform to Table III for the condition ordered. If requested, the products shall have the following heat treat response: Products supplied in the annealed condition shall meet the solution treated and aged (STA) properties specified in Table III when heat treated to this condition in accordance with MIL-H-81200, except that composition 6Al-2Sn-4Zr-2Mo shall meet the duplex annealed (DA) properties specified in Table III when heat treated to this condition in accordance with MIL-H-81200.

3.3.1.3 Beta titanium alloys. Tensile properties shall conform to Table IV for the condition ordered. In addition, the products shall have the following heat treat response: Products supplied in the solution treated (ST) condition shall meet the solution treated and aged (STA) properties specified in Table IV when aged to this condition in accordance with MIL-H-81200.

3.3.2 Reforging stock. Tensile properties shall be as ordered by the forging manufacturer (see 6.2).

3.4 Heat treatment. Products supplied in accordance with this specification shall be heat treated in accordance with MIL-H-81200.

3.5 Ultrasonic quality.

3.5.1 Commercially pure, alpha and alpha-beta titanium products. The ultrasonic quality of products 0.500 inch or greater in diameter, thickness or distance between flats shall conform to Table V, as applicable.

3.5.1.1 In addition to meeting the requirements of Table V, products furnished with Surface Finish I shall be capable of meeting the requirements specified herein for Surface Finish II when surface finished in accordance with 1.4.2.

3.5.2 Beta titanium alloy products. When specified (see 6.2), the ultrasonic quality of beta titanium alloy products shall be as agreed upon by the procuring activity and producer.

3.6 Microstructure. Bars shall have a uniform and sound wrought metal structure throughout the entire product and, in addition, the non-beta titanium products other than 6Al-2Cb-1Ta-0.8Mo shall have a microstructure essentially free of prior beta grain boundaries or other evidence of processing above the beta transus. Unless the products show definite non-conformance to these requirements or to micrograph standards agreed upon by the procuring activity and the producer, microstructure shall not be cause for rejection.

TABLE III. Alpha-Beta titanium alloys minimum tensile properties.

Alloy	Condition	Thickness Diameter or Distance Between Flats Inch (mm) 2/	Width (In.) or Cross-Sect. Area Sq. In. ($m^2 \times 10^{-4}$) 2/	MINIMUM TENSILE PROPERTIES 1/			
				Tensile Strength ksi (MPa)	Yield Strength at 0.2 Percent Offset ksi (MPa)	Elongation Percent in 4D 3/	Reduction of Area, Percent 3/
6Al-4V	A	4.00 & under (101.50 & under)	48 max. (309.70)	130 (896)	120 (827)	10	25
		4.00 - 6.00 (101.40 - 152.40)		130 (896)	120 (827)	10 [8]	20 [15]
	STA (Rounds, Squares, Hexagons)	0.500 & under (12.70 & under)	Not Applicable	165 (1137)	155 (1068)	10	20
		0.500 - 1.00 (12.70 - 25.40)		160 (1103)	150 (1034)	10	20
		1.00 - 1.50 (25.40 - 38.10)		155 (1068)	145 (999)	10	20
		1.50 - 2.00 (38.10 - 50.40)		150 (1034)	140 (965)	10	20
		2.00 - 3.00 (50.80 - 76.20)		140 (965)	130 (896)	10	20
	STA Rectangles)	0.500 & under (12.70 & under)	0.50 - 8.00 (3.23 - 51.62)	150 (1103)	160 (1034)	10	25
		0.500 - 1.000 (12.70 - 25.40)	1.00 - 4.00 (6.45 - 25.81)	155 (1068)	145 (999)	10	20
			4.00 - 8.00 (25.81 - 51.62)	150 (1034)	140 (965)	10	20
		1.00 - 1.50 (25.40 - 38.10)	1.50 - 4.00 (9.68 - 25.81)	150 (1034)	140 (965)	10	20
			4.00 - 8.00 (25.81 - 51.62)	145 (999)	135 (930)	10	20

TABLE III. Alpha-Beta titanium alloys minimum tensile properties. - Continued

Alloy	Condition	Thickness Diameter or Distance Between Flats In. (mm) 2/	Width (In.) or Cross-Sect. Area Sq. In. ($m^2 \times 10^{-4}$) 2/	MINIMUM TENSILE PROPERTIES 1/			
				Tensile Strength ksi (MPa)	Yield Strength at 0.2 Percent Offset ksi (MPa)	Elongation Percent in 4D 3/	Reduction of Area, Percent 3/
6Al-4V	STA (Rectangles)	1.500 - 2.000 (38.10 - 50.80)	2.00 - 4.00 (12.90 - 25.81)	145 (999)	135 (930)	10	20
			4.00 - 8.00 (25.81 - 51.62)	140 (965)	130 (896)	10	20
		2.000 - 3.000 (50.80 - 76.20)	3.00 - 8.00 (19.36 - 51.62)	135 (930)	125 (861)	10	20
		3.000 - 4.000 (76.20 - 101.60)	4.00 - 8.00 (25.81 - 51.62)	130 (896)	120 (827)	8 [6]	15 [10]
6Al-4V (ELI)	A	1.50 & under (42.60 & under)	16 max. (103.23 max.)	130 (896)	120 (827)	10	25
		1.50 - 3.00 (38.10 - 76.20)		125 (861)	115 (793)	10	20
3Al-2.5V	A	1.00 & under (25.40 & under)	Not Applicable	90 (620)	75 (517)	15	30
6Al-6V-2Sn	A	1.50 & under (42.60 & under)	32 max. (204.46 max.)	148 (1020)	137 4/ (944)	10	20
		1.50 - 3.00 (38.10 - 76.20)		143 (986)	131 4/ (903)	10	20
		3.00 - 4.00 (76.20 - 101.60)		137 (944)	129 4/ (889)	10 [8]	20 [15]

TABLE III. Alpha-Beta titanium alloys minimum tensile properties. - Continued

Alloy	Condition	Thickness Diameter or Distance Between Flats In. (mm) 2/	Width (In.) or Cross-Sect. Area Sq. In. ($m^2 \times 10^{-4}$) 2/	MINIMUM TENSILE PROPERTIES 1/				
				Tensile Strength ksi (MPa)	Yield Strength at 0.2 Percent Offset ksi	(MPa)	Elongation Percent in 4D 3/	Reduction of Area, Percent 3/
6Al-6V-2Sn	STA	1.00 & under (42.40 & under)	32 max. (206.46 max.)	175 (1206)	160	(1103)	8	20
		1.00 - 2.00 (25.40 - 50.80)		170 (1172)	155	(1068)	8	20
		2.00 - 3.00 (50.80 - 76.20)		155 (1068)	145	(999)	8	20
		3.00 - 4.00 (76.20 - 101.60)		150 (1034)	140	(965)	8 [6]	20 [15]
6Al-2Sn-4Zr-2Mo	DA	3.00 & under (76.20 & under)	10 max. (64.52 max.)	130 (896)	120	(827)	10	25
6Al-2Sn-4Zr-6Mo	DA	2.00 & under (50.80 & under)	32 max. (206.46 max.)	160 (1103)	150	(1034)	10	25
		2.00 - 4.00 (50.80 - 101.60)		150 (1034)	140	(965)	8 [6]	20 [15]
	STA	2.50 & under (63.50 & under)	32 max. (206.46 max.)	170 (1172)	160	(1103)	10	20
		2.50 - 3.00 (63.50 - 76.20)		165 (1138)	155	(1068)	8 [6]	15 [12]
		3.00 - 4.00 (76.20 - 101.60)		160 (1103)	150	(1034)	8 [6]	15 [12]
7Al-4Mo	A	1.00 & under (25.40 & under	48 max. (309.70 max.)	145 (999)	135	(930)	10	20
		1.00 - 2.00 (25.40 - 50.80)		140 (965)	130	(896)	10	20
		3.00 - 6.00 (76.20 - 152.40)		140 (965)	130	(896)	10 [8]	20 [15]

TABLE III. Alpha-Beta titanium alloys minimum tensile properties. - Continued

Alloy	Condition	Thickness Diameter or Distance Between Flats In. (mm) 2/	Width (In.) or Cross-Sect. Area Sq. In. ($m^2 \times 10^{-4}$)	MINIMUM TENSILE PROPERTIES 1/				
				Tensile Strength ksi (MPa)	Yield Strength at 0.2 Percent Offset ksi	(MPa)	Elongation Percent in 4D 3/	Reduction of Area, Percent 3/
7Al-4Mo	STA	1.00 & under (25.40 & under)	48 max. (309.70 max.)	170 (1172)	160	(1103)	8	15
		1.00 - 2.00 (25.40 - 50.80)		160 (1103)	150	(1034)	8	15
		2.00 - 4.00 (50.80 - 101.60)		150 (1034)	140	(965)	8 [6]	15 [12]

1/ Unless otherwise noted, properties apply in any grain direction.

2/ Thicknesses given as X.XXX - X.XXX shall be read as "Over--to--inches, inclusive".

3/ Values in brackets [] apply to the short transverse direction for short transverse dimensions of 3.0 inches or greater.

4/ Maximum yield strength shall not exceed the minimum yield strength by more than 25 ksi.

TABLE IV. Beta titanium alloys minimum tensile properties.

Alloy	Condition	Thickness, Diameter or Distance Between Flats 1/ Inches (mm)	MINIMUM TENSILE PROPERTIES 2/			
			Tensile Strength ksi (MPa)	Yield Strength at 0.2 Percent Offset ksi (MPa)	Elongation Percent in 4D 3/	Reduction of Area, Percent 3/
8Mo-8V-2Fe-3Al	ST	2.00 & under (50.80 & under)	130 (896)	120 (827)	10	24
		2.00 - 4.00 (50.80 - 101.60)	125 (861)	120 (827)	8 [6]	16 [12]
	STA	2.00 & under (50.80 & under)	180 (1241)	170 (1172)	8	16
		2.00 - 4.00 (50.80 - 101.60)	180 (1241)	170 (1172)	6 [4]	12 [10]
11.5Mo-6Zr-4.5Sn	ST	1.625 & under (41.27 & under)	110 (756)	90 (620)	15	50
		1.625 - 3 00 (41.27 - 76.20)	100 (689)	90 (620)	15	50
		3.00 - 4.00 (76.20 - 101.60)	100 (689)	90 (620)	10	35
	STA 1075F	3.00 & under (76.20 & under)	135 (930)	130 (896)	12	40
	STA 925F	1.625 & under (41.27 & under)	180 (1241)	175 (1206)	8	22
		1.625 - 3.00 (41.27 - 76.20)	180 (1241)	175 (1206)	6	10
3Al-8V-6Cr-4Mo-4Zr	ST	1.50 & under (38.10 & under)	125 (861)	120 (827)	10	30
		1.50 - 4.00 (38.10 - 101.60)	120 (827)	115 (793)	10 [8]	25 [20]

TABLE IV. Beta titanium alloys minimum tensile properties. - Continued

Alloy	Condition	Thickness, Diameter or Distance Between Flats 1/ Inches (mm)	MINIMUM TENSILE PROPERTIES 2/			
			Tensile Strength ksi (MPa)	Yield Strength at 0.2 Percent Offset ksi (MPa)	Elongation Percent in 4D 3/	Reduction of Area, Percent 3/
3Al-8V-6Cr-4Mo-4Zr	STA	1.50 & under (38.10 & under)	190 (1310)	180 (1241)	8	15
		1.50 - 3.00 (38.10 - 76.20)	180 (1241)	170 (1172)	8 [6]	15 [5]
		3.00 - 4.00 (76.20 - 101.60)	170 (1172)	160 (1103)	8 [3]	15 [5]
13V-11Cr-3Al	ST	7.00 & under (177.80 & under)	125 (861)	120 (827)	10	25
	STA	4.00 & under (101.60 & under)	170 (1172)	160 (1103)	6 [2]	10 [5]

1/ Thicknesses given as X.XXX - X.XXX shall be read as "over--to--inches, inclusive".

2/ Apply to products with a cross-sectional area of 16 square inches or less. Unless otherwise noted, properties apply in any grain direction.

3/ Value in brackets [] apply to short transverse direction for products with a short transverse dimension of 3.000 inches or greater.

TABLE V. Minimum ultrasonic quality levels.

Product Thickness, Diameter or Distance Between Flats Inches (Millimeters) 2/	Ultrasonic Classification 1/	
	Surface Finish I (see 1.4 and 6.2)	Surface Finish II (see 1.4 and 6.2)
0.500 - 2.500, Incl. (12.70 - 38.10, Incl.)	A1	A
Over 1.500 - 6,000, Incl. (Over 38.10 - 152.40, Incl.)	A	A1
Over 6.000 - 14,000, Incl. (Over 152.40 - 355.60, Incl.)	B	A

1/ Acceptance classes shall be in accordance with AMS 2631 as specified for Grade 1 material.

2/ Surface area to be scanned shall be as specified in AMS 2631, except that the minimum size for round and flat-faced products shall be 0.500 inch in diameter or distance between flats.

3.6.1 Reforging stock shall have a microstructure as ordered by the forging manufacturer (see 6.2).

3.7 Dimensional tolerances.

3.7.1 Rolled Bar. Tolerances shall conform to AMS 2241.

3.7.2 Forged Bar and Reforging stock. Tolerances shall conform to Table VI.

3.8 Identification of product.

3.8.1 Bars. Each bar 0.5 inch and greater in diameter or least width of flat surface shall be marked in a row of characters recurring at intervals not greater than three feet. Marking shall include the basic number and revision letter of this specification, producer's name or trademark, mill heat or lot number, composition (1.2), heat treat condition (1.3), and finish (1.4). The characters shall be of such size and clarity as to be legible with unaided normal vision and shall be applied using a suitable marking fluid, whose residue shall contain not more than traces of halogen bearing compounds and which shall be capable of being removed in hot alkaline cleaning solution without rubbing. The markings shall have no deleterious effect on the product or the performance of parts, and shall be sufficiently stable to withstand normal handling.

3.8.1.1 Bars smaller in size than specified in 3.8.1 shall be securely bundled or containerized (crated, boxed, etc.,) for shipping. Each bundle or container shall be marked at both ends with the following identification: the number and revision letter of this specification, producer's name or trademark, heat and lot numbers, composition (1.2), heat treat condition (1.3), and finish (1.4). This identification shall be marked on the container or on durable tags securely attached to the bundle or container.

3.8.2 Reforging stock. Identification shall be as specified by the forging manufacturer (see 6.2).

3.9 Workmanship. Products shall be uniform in quality and condition, free of alpha-case and other harmful surface contamination, clean, sound, and free from foreign materials and from internal imperfections detrimental to fabrication or performance of parts.

TABLE VI. Forged bar and reforging stock dimensional tolerances.

Size, Millimeters	Dimensional Tolerance, Inches (mm), (Except Width and Straightness) 1/					
Thickness Range / Width Range	Over 0.250-1.000 (6.35-25.40) Incl.	Over 1.000-2.000 (25.40-50.80) Incl	Over 2.000-4.000 (50.80-101.60) Incl	Over 4.000-10.000 (101.50-254.00) Incl	Over 10.000-12.000 (254.00-304.80) Incl	Width Tolerance Millimeters
Over 1.000-2.000 (25.40-50.80) Incl.	+3/64, -0 (+1.19, -0)	+1/16, -0 (+159, -0)	-	-	-	+1/8, -0 (+3.17, -0)
Over 2.000-4.000 (50.80-101.60) Incl.	+1/16, -0 (+1.59, -0)	+1/4, -0 (+6.35, -0)	+1/4, -0 (+6.35, -0)	-	-	+1/4, -0 (+6.35, -0)
Over 4.000-6.000 (101.60-152.40) Incl.	-	+1/4, -0 (+6.35, -0)	+1/4, -0 (+6.35, -0)	+3/8, -0 (+9.53, -0)	-	+3/8, -0 (+9.53, -0)
Over 6.000-10.000 (152.60-254.00) Incl.	-	+3/8, -0 (+9.53, -0)	+3/8, -0 (+9.53, -0)	+3/8, -0 (+9.53, -0)	-	+1/2, -0 (+12.70, -0)
Over 10,000-12.000 (254.00-304.80) Incl.	-	-	+3/8, -0 (+9.53, -0	+3/8, -0 (+9.53, -0	+1/2, -0 (+12.70, -0)	+5/8, -0 (+15.87, -0)

1/ Straightness Tolerance: Maximum deviation from straightness (bow) up to 60 inches (1.524×10^3 mm) in length shall not exceed 1/8-inch (3.175 mm) and for lengths greater than 60 inches (1.524×10^3 mm) shall not exceed L/480 inch ($L/1.2192 \times 10^4$ mm), where "L" denotes length in inches (mm).

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to assure products and services conform to prescribed requirements. The word "inspections" in this case refers to the inspection and tests specified in Table VII.

4.2 Lot. A lot shall consist of products of the same mill heat, size and shape processed at the same time.

4.3 Sampling.

4.3.1 Bar. Sampling shall be accomplished in accordance with Table VII.

4.3.2 Reforging Stock. Sampling shall be as specified by the forging manufacturer.

4.4 Quality conformance examination. Bar products shall be examined in accordance with the following provisions. Reforging stock shall be examined as specified by the forging manufacturer (see 6.2).

4.4.1 Visual examination. Samples selected in accordance with Table VII shall be visually examined for conformance to the surface finish (1.4), identification (3.8), and workmanship (3.9) requirements. Surface roughness measurement shall be in accordance with ANSI B46.1.

4.4.2 Metallographic examination.

4.4.2.1 Macrostructure. A specimen at least 0.5 inch long by full cross-section from each end of each sample selected in accordance with Table VII shall be macrostructurally examined for conformance to the workmanship requirements of 3.9. Unless otherwise specified or approved by the procuring activity (see 6.2), macrostructural examination shall be performed in accordance with AMS 2643.

4.4.2.2 Microstructure. In addition to the macrostructure examination required by AMS 2643, conformance to the microstructure (3.6) and workmanship (3.9), requirements shall be determined by examining at least one polished and etched specimen from each sample selected in accordance with Table VII. Examination of microstructure and for alpha-case shall be made at an approximate magnification of 250X and 100X, respectively. Other magnifications shall be used as required to ensure acceptable quality.

TABLE VII. Bar products quality conformance sampling.

Inspection or Test	Samples			
	Heat 1/	Lot 2/		
Visual Examination		Random samples per MIL-STD-105, Inspection Level II, AOL of 1.5.		
Dimensional Inspection	3/			
Chemical Analysis	Each Ingot 4/ 5/	Random samples per MIL-STD-105, Inspection Level S-3, Acceptance No. of Zero. 4/		
Tensile Test and Metallographic Examination	3/	Lot Quantity (Bars)	Sample Quantity per Lot (Random Bars)	
			Tensile Tests	Metallographic Examination
		1-15	2	1
		16-50	4	2
		51-150	6	3
		151-500	8	5
		Over 500	6/	7/
Ultrasonic Inspection	3/	per 4.5.2		

1/ Unit of sample is ingot.

2/ Unit of sample is bar of as processed (rolled or forged and heat treated) length.

3/ Not applicable.

4/ Either heat or lot analysis is acceptable, except that hydrogen shall be determined on each lot.

5/ Complete ingot analysis shall be available to the procuring activity.

6/ Eight bars plus additional bars as required above for equivalent quantities over 500.

7/ Four bars plus additional bars as required above for equivalent quantities over 500.

4.5 Quality conformance inspection.

4.5.1 Dimensional inspection. Samples selected in accordance with Table VII for dimensional inspection shall be measured for conformance to the applicable dimensional tolerance.

4.5.2 Ultrasonic inspection. When required (see 3.5 through 3.5.2), all products 0.500 inch or greater in diameter, thickness or distance between flats shall be inspected in accordance with AMS 2631 for conformance to the applicable ultrasonic quality requirements. Ultrasonically inspected material shall be identified as agreed upon by the procuring activity and producer (see 6.2).

4.5.3 Packing. Each shipment shall be inspected for conformance to the packing and marking requirements specified in 3.8.1.1 and Section 5.

4.6 Quality conformance tests.

4.6.1 Chemical analysis. Conformance to the chemical composition requirements shall be determined either by heat or lot analysis of samples selected in accordance with Table VII using ASTM E120 methods of chemical analysis or FED-STD-151, Method 112.2 of spectrochemical analysis. Hydrogen analysis shall be in accordance with ASTM E146 and shall be determined on each lot of material as shipped. Other analytical methods may be used with the written approval of the procuring activity.

4.6.1.1 In case of dispute, the results of chemical analysis by the ASTM E120 and E146 methods shall govern.

4.6.2 Tension tests. Conformance to the tensile properties requirement shall be determined by sampling each lot in accordance with Table VII and testing tensile specimens excised from each sample in accordance with Table VIII. The products shall be tested in the heat treat condition ordered (see 6.2). If requested, alpha-beta titanium products supplied in the annealed condition (A) or duplex annealed condition (DA), as applicable, and beta titanium products supplied in the solution treated condition (ST) shall be tested for heat treat response to condition STA tensile properties, and the test results shall be reported. Tension tests shall be accomplished in accordance with ASTM E8, except that the rate of strain will be 0.003 to 0.007 inch per inch per minute through the yield strength and then is increased so as to produce failure in approximately one additional minute. In case of dispute over the tensile test results, a referee test shall be performed on a tensile machine having a strain pacer and using a strain rate of 0.005 inch per inch per minute through the yield strength and a minimum cross-head speed of 0.10 inch per minute above the yield strength.

TABLE VIII. Tension specimen requirements.

Product	Size, Inch (Millimeters)		Tension Specimen	
	Thickness, Diameter or Distance Between Flats	Width	Configuration 2/ 3/	Test Direction and Location
Round Square and Hexagonal Bar	0.375-1.500 Incl. (9.52-3810) Incl.	1/	R1, R2 or R3	Longitudinal from center of cross section.
	Over 1.500 (Over 38.10)	1/	R1, R2 or R3	Longitudinal from between mid-radius and center of cross-section
Rectangular Bar	0.375-0.500, Incl. (9.52-12.70 Incl.)	3.000 and under (76.20 & under)	F2 or R3	Longitudinal from center of cross-section
	Over 0.500 (Over 12.70)	Over 3.000 (Over 76.20)	R1, R2 R3	Longitudinal and transverse from between mid-radius and center of cross-section. 4/

1/ Not applicable.

2/ R1, R2 and R3 designates specimens corresponding to round tension specimens as specified in ASTM E8 for 0.500, 0.350 and 0.250 inch nominal diameters in the reduced test section, respectively. In case of dispute, the results obtained from testing the largest possible of these three specimen sizes shall govern.

3/ F2 designates standard sheet-type specimens with a 1/2 inch width reduced test section as specified in ASTM E8 for rectangular tension specimens.

4/ Transverse specimen shall be in the short transverse dimension for products with short transverse dimension of 3.000 inches and greater.

4.7 Rejection and retests.

4.7.1 Rejection. Failure of the test samples to meet the requirements of this specification shall be cause for rejection of the represented lot, except that retesting in accordance with 4.7.2 shall be permitted in the case of non-conformance to the tensile property requirements.

4.7.2 Retests. Duplicate tensile specimens shall be tested from each failed bar in the original sampling. Retest specimens shall be taken from the area adjacent to the failed tensile specimen. Failure of any retest specimens to meet the tensile property requirements shall be cause for: (a) rejection of the sample bars represented by failed tensile specimens and (b) 100 percent tensile testing of the entire lot. Only bars which meet the requirements of this specification shall be accepted.

4.7.3 Replacement of test specimens. Replacement of test specimens for reasons other than inferior or defective material shall be in accordance with FED-STD-151.

5. PACKAGING

5.1 Application. The requirements of Section 5 apply only to direct purchases by or direct shipments to the Government.

5.2 Unless otherwise specified, products shall be separated by size, heat number and heat treat condition when packed for shipment.

5.3 Packing.

5.3.1 Level A - For domestic shipment and storage and overseas shipment. Products shall be packed in accordance with the requirements of MIL-STD-163, as referenced for stainless steel.

5.3.2 Level C - Minimum military pack (for domestic shipment) with immediate use at initial destination. Packages which require over-packing for acceptance by the carrier shall be packed in exterior-type shipping containers in a manner that will assure safe transportation at the lowest rate to the point of delivery. Container shall meet, as a minimum, the requirements of rules and regulations applicable to the mode of transportation.

5.4 Marking of shipments. In addition to any special marking required by the contract or order (see 6.2), shipping containers shall be marked in accordance with MIL-STD-129. The identification shall be composed of the following information listed in the order shown.

(a) Stock No. or other identification number as specified in the purchase document 1/

(b) TITANIUM OR TITANIUM ALLOY BAR, as applicable

(c) Heat No. _____ Length ____ (inches) ____

(d) Width (inches) Thickness or Diameter (inches)

(e) Number and revision letter of this Specification

(f) Composition _____

(g) Heat Treatment Condition _____

(h) Gross Weight _____

(i) Manufacturer's Name or Trademark _____

1/ NOTE: The contractor shall enter the Federal Stock No. specified in the purchase document or as furnished by the procuring activity. When the Federal Stock No. is not provided or available from the procuring activity, leave space therefore and enter the Stock No. or other identification when provided by the procuring activity.

6. NOTES

6.1 Intended use.

6.1.1 Bar is a finished mill product intended for structural applications in airborne vehicles and equipment.

6.1.2 Reforging stock is a semi-finished mill product which requires further hot reduction and appropriate thermal treatment to meet the tensile properties and microstructure requirements of this specification or applicable forging specifications prior to structural use.

6.2 Ordering data. Procurement documents shall state the following as applicable:

(a) Title, number, revision letter and amendment number (if any) of this specification.

(b) Composition (1.2).

(c) Heat treat condition (1.3).

(d) Finish (1.4)

(e) Melting practice if other than specified in 3.1.

(f) Reforging stock tensile properties (3.3.2).

(g) Ultrasonic quality of titanium alloys, when required (3.5.2 and 4.5.2).

(h) Microstructure standards, when required (3.6 and 3.6.1).

(i) Reforging stock identification (3.8.2) and sampling for quality conformance examination, inspection and tests (4.3.2).

(j) Macrostructure examination of other than specified (4.4.2.1).

(k) Identification of ultrasonic inspected products (4.5.2).

(l) Packing level (5.3).

6.3 Stress corrosion. Certain processing procedures and service conditions may cause these titanium products to be subject to stress corrosion cracking. ARP 982 recommends practices to minimize the susceptibility to such stress corrosion cracking.

6.4 Cross-reference. Table IX shows the correlation between the composition classifications used in this specification and those used in earlier revisions of MIL-T-9047.

Custodians:
Air Force - 11
DSA-IS

Review activities:
Air Force - 99
Army - MR
Navy - AS

Preparing activity:
Air Force - 11

(Project Number: 9530-0174)

TABLE IX. Cross-reference composition classifications.

MIL-T-9047D	MIL-T-9047E and MIL-T-009047F	MIL-T-9047G
Type I commercially pure Ti Comp. A - unalloyed	Alpha Alloys Comp. 1 - unalloyed	Commercially Pure Ti CP-B
Type II Alpha Titanium Alloys 1/ Comp. A - 5Al-2.5Sn Comp. B - 5Al-2.5Sn (ELI) Comp. C - 5Al-5Zr-5Sn Comp. D - 8Al-1Mo-1V 1/	Alpha Alloys 1/ Comp. 2 - 5Al-2.5Sn Comp. 3 - 5Al-2.5Sn (ELI) 2/ Comp. 5 - 8Al-1Mo-1V 1/	Alpha Titanium Alloys 3Al-2.5V 5Al-2.5Sn 5Al-2.5Sn (ELI) 2/ 8Al-1Mo-1V 6Al-2Cb-1Ta-0.8Mo
Type III Alpha-Beta Ti Alloy Comp. A - 6Al-4V Comp. B - 6Al-4V (ELI) Comp. C - 6Al-6V-2Sn Comp. D - 7Al-4Mo Comp. E - 4Al-4Mn Comp. F - 5Al-1.5Fe-1.5Cr-1.5Mo Comp. G - 11Sn-5Zr-2Al-1Mo Comp. H - 4Al-3Mo-1V Comp. I - 6Al-2Sn-4Zr-2Mo 1/	Alpha-Beta Alloys Comp. 6 - 6Al-4V Comp. 7 - 6Al-4V (ELI) Comp. 8 - 6Al-6V-2Sn Comp. 9 - 7Al-4Mo 2/ 2/ Comp. 10 - 11Sn-5Zr-2Al-1Mo 2/ Comp. 11 - 6Al-2Sn-4Zr-2Mo Comp. 14 - 6Al-2Sn-4Zr-6Mo	Alpha-Beta Ti Alloys 6Al-4V 6Al-4V (ELI) 6Al-6V-2Sn 7Al-4Mo 2/ 2/ 2/ 2/ 6Al-2Sn-4Zr-2Mo 6Al-2Sn-4Zr-6Mo
Type IV Beta Ti Alloys Comp. A - 13V-11Cr-3Al 1/ 1/ 1/	Beta Alloys Comp. 12 - 13V-11Cr-3Al Comp. 13 - 11.5Mo-6Zr-4.5Sn 1/ 1/	Beta Titanium Alloys 13V-11Cr-3Al 11.5Mo-6Zr-4.5Sn 8Mo-8V-2Fe-3Al 3Al-8V-6Cr-4Mo-4Zr

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5 PROBLEM AREAS

a. Paragraph Number and Wording

b Recommended Wording

c Reason/Rationale for Recommendation

6 REMARKS

7a NAME OF SUBMITTER *(Last First MI)* – Optional	b WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
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