

**Titanium and Titanium Alloy, Bars (Rolled or Forged)
and Reforging Stock, Aircraft Quality**

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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 9).

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

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 (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 2, 3 and 4, as specified (See 6.2).

1.3.1 (Continued):

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 4, 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 (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:

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, 400 Commonwealth Drive, Warrendale PA 15096-0001 or www.sae.org.

AMS 2241 Tolerances - Corrosion and Heat Resistant Steel, Bar 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

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 or www.astm.org.

ASTM E8 Tension Testing of Metallic Materials
ASTM E 120 Chemical Analysis of Titanium and Titanium-Base Alloys
ASTM E 146 Chemical Analysis of Zirconium and Zirconium-Base Alloys

2.3 ANSI Publications:

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002 or www.ansi.org.

ANSI B46.1 Surface Texture

2.4 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-H-81200 Heat Treatment of Titanium and Titanium Alloys
FED-STD-151 Metals; Test Methods
MIL-STD-105 Sampling Procedures and Tables
MIL-STD-129 Marking for Shipment and Storage

3. REQUIREMENTS:

3.1 Material:

Unless otherwise specified (See 6.2), material for products supplied in accordance with this specification shall be produced using the following melting controls.

- 3.1.1 Commercially Pure Titanium: Commercially pure titanium shall be electron beam melted or shall be multiple melted with the last one of the melting cycles under vacuum. When multiple melted, the first melt shall be made by consumable electrode, nonconsumable electrode, or electron beam melting practice. The subsequent melt or melts shall be made using consumable electrode practice.
- 3.1.2 Alloyed Titanium: Alloys of titanium shall be multiple melted under vacuum or inert gas with the last one of the melting cycles under vacuum. The first melt shall be made by consumable electrode, nonconsumable electrode, or electron beam melting practice. The subsequent melt or melts shall be made using consumable electrode practice with no alloy additions permitted in the last consumable electrode melt.
- 3.1.3 Atmosphere: The atmosphere for nonconsumable electrode melting shall be vacuum or shall be inert gas at a pressure not higher than 250 mm of mercury.

3.1.4 Electrode Tip: The electrode tip for nonconsumable electrode melting shall be water cooled copper.

3.2 Chemical Composition:

The chemical composition, as determined by heat or lot analysis, shall be as specified in Table 1.

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 2.

3.3.1.2 Alpha-Beta Titanium Alloys: Tensile properties shall conform to Table 3 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 3 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 3 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 4 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 4 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 5, as applicable.

3.5.1.1 In addition to meeting the requirements of Table 5, 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.

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

ELEMENTS															
Composition	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/
COMMERCIAL PURE TITANIUM															
CP-70	-	-	-	-	-	-	-	-	0.50	0.08	0.05	0.0125	0.40	-	0.30
ALPHA TITANIUM ALLOY															
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 3/	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 3/	0.08	0.05	0.015	0.15	-	0.40
ALPHA-BETA 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
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

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

ELEMENTS															
Composition	Al	Sn	Zr	Cb	Ta	Mo	V	Cr	Fe <u>3/</u>	C (max)	N (max)	H (max) <u>4/</u>	O (max)	Cu or Si as noted	Total Other Elements (max) <u>5/</u>
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

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 2 - Commercially pure and alpha titanium minimum tensile properties.

Alloy <u>2/</u>	Thickness, Diameter or Distance Between Flats Inch (mm) <u>3/</u>	MINIMUM TENSILE PROPERTIES <u>1/</u>			
		Tensile Strength ksi (MPa)	Yield Strength at 0.2 Percent Offset ksi (MPa)	Elongation Percent <u>4/</u>	Reduction of Area Percent <u>4/</u>
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 <u>5/</u>	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. Mechanical properties of sections larger than 16 square inches shall be as specified in the contract or order.

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.

TABLE 3 - Alpha-Beta titanium alloys minimum tensile properties

Alloy	Condition	Thickness Diameter or Distance Between Flats Inch (mm)	Width (In.) or Cross-Sect. Area Sq. In. ($m^2 \times 10^{-4}$)	Minimum Tensile Properties			
				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)		165 (1137)	155 (1068)	10	20
		0.500 - 1.00 (12.70 - 25.40)	Not Applicable	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 (50.40 - 76.20)		140 (965)	130 (896)	10	20
		0.500 & under (12.70 & under)		150 (1103)	160 (1034)	10	25
	STA (Rectangles)	0.500 - 1000 (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
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)	4.000 - 8.000 (25.81 - 51.62)	130 (896)	120 (827)	8 [6]	15 [10]	

TABLE 3 - Alpha-Beta titanium alloys minimum tensile properties (Continued)

Alloy	Condition	Thickness Diameter or Distance Between Flats Inch (mm) 2/	Width (In.) or Cross-Sect. Area Sq. In. (m ² X 10 ⁻⁴) 2/	Minimum Tensile Properties			
				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 (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]
		1.00 & under (42.40 & under)	32 max. (206.46 max.)	175 (1206)	160 (1103)	8	20
6Al-6V-2Sn	STA	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]
		3.00 & under (76.20 & under)	10 max. (64.52 max)	130 (896)	120 (827)	10	25

TABLE 3 - Alpha-Beta titanium alloys minimum tensile properties (Continued)

Alloy	Condition	Thickness Diameter or Distance Between Flats Inch (mm) 2/	Width (In.) or Cross-Sect. Area Sq. In. (m ² X 10 ⁻⁴) 2/	Minimum Tensile Properties			
				Tensile Strength ksi (MPa)	Yield Strength at 0.2 Percent Offset ksi (MPa)	Elongation Percent in 4D 3/	Reduction of Area, Percent 3/
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]
				145 (999)	135 (930)	10	20
7Al-4Mo	A	1.00 & under (25.40 & under)	48 max. (309.70 max.)	140 (965)	130 (896)	10	20
		1.00 - 2.00 (25.40 - 50.80)		140 (965)	130 (896)	10 [8]	20 [15]
	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]
				145 (999)	135 (930)	10	20

1/ Apply to products with a cross-sectional area of 16 square inches or less. Properties apply in any grain direction.

2/ Mechanical properties of sections larger than 16 square inches shall be as specified in the contract or order.

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

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

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

TABLE 4 - Beta titanium alloys minimum tensile properties

Alloy	Condition	Thickness Diameter or Distance Between Flats Inch (mm) <u>2/</u>	Minimum Tensile Properties			
			Tensile Strength ksi (MPa)	Yield Strength at 0.2 Percent Offset ksi (MPa)	Elongation Percent in 4D <u>3/</u>	Reduction of Area, Percent <u>3/</u>
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
	ST 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]
	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	4.000 & under (101.60 & under)	170 (1172)	160 (1103)	6 [2]	10 [5]

1/ Thickness 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. Properties apply in any grain direction. Mechanical properties of sections larger than 16 square inches shall be as specified in the contract or order.

3/ Values in brackets [] apply to the short transverse direction for short transverse dimensions of 3.000 inches or greater.

TABLE 5 - Minimum ultrasonic quality levels

Product Thickness, Diameter or Distance Between Flats Inches (Millimeters) <u>2/</u>	Ultrasonic Classification <u>1/</u>	
	Surface Finish I (See 1.4 and 6.2)	Surface Finish II (See 1.4 and 6.2)
0.500 -1.500, incl. (12.70 - 38.10, incl.)	A1	AA
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 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.

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 6.

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 agreed 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.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except, as otherwise specified in the contract or purchase order, 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 the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Certification of Quality Compliance: A certificate of quality compliance shall be prepared for each lot of material offered for acceptance (See 6.1.1). The certificate shall include actual data of specified chemical and mechanical tests. Qualitative results of nondestructive tests and other inspections or tests shall be recorded on the certificate. The certificate shall also state that each lot has been sampled, tested, and inspected in accordance with the specification and meets all specification requirements. The certificate shall be signed by a responsible representative of the contractor.

TABLE 6 - Forged bar and reforging stock dimensional tolerances

Size, Millimeters		Dimensional Tolerance. Inches (mm), Except Width and Straightness) 1/					Width Tolerance Millimeters
Thickness 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 Range	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 (+159, -0)	+1/4, -0 (+6.35, -0)	+1/4, -0 (+6.35, -0)	--	--	+1/4, -0 (+6.35, -0)
	Over 4.000 - 6.000 (101.50 - 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 (152.40 - 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 X 10³ mm) in length shall not exceed 1/8-inch (3.175 mm) and for lengths greater than 60 inches (1.524 X 10³ mm) shall not exceed L/480 inch (L/1.2192 X 10⁴ mm), where "L" denotes length in inches (mm).

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 7.

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 7 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.

TABLE 7 - Bar products quality conformance sampling

Inspection or Test	Samples			
	Heat <u>1/</u>	Lot <u>2/</u>		
Visual Examination	<u>3/</u>	Random samples per MIL-STD-105, Inspection Level II, AQL of 1.5.		
Dimensional Inspection				
Chemical Analysis	Each Ingot <u>4/ 5/</u>	Random samples per MIL-STD-105, Inspection Level S-3, Acceptance No. of Zero. <u>4/</u>		
Tensile Test and Metallographic Examination	<u>3/</u>	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	<u>6/</u>	<u>7/</u>		
Ultrasonic Inspection	<u>3/</u>	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.

4.4.2 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 7 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 7. 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 8 - Tension specimen requirements

Product	Size, Inch (Millimeters)		Tension Specimen	
	Thickness, Diameter or Distance Between Flats	Width	Configuration <u>2/</u> <u>3/</u>	Test Direction and Location
Round Square and Hexagonal Bar	0.375 - 1.500 Incl. (9.52 - 38.10) Incl.	<u>1/</u>	R1, R2, or R3	Longitudinal from center of cross section.
	Over 1.500 (Over 38.10)	<u>1/</u>	R1, R2, or R3	Longitudinal from between and 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 and mid-radius and center of cross-section. <u>4/</u>

1/ Not applicable

2/ R1, R2 and R3 designates specimens corresponding to round tension specimens as specified in ASTM E 8 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 E 8 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.

4.5 Quality Conformance Inspection:

4.5.1 Dimensional Inspection: Samples selected in accordance with Table 7 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.