

AEROSPACE MATERIAL SPECIFICATION

Aluminum Alloy Forgings

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1. SCOPE AND CLASSIFICATION:

1.1 Scope:

This specification covers aluminum alloy die forgings and hand forgings.

1.2 Classification:

1.2.1 Composition: Aluminum alloy forgings covered by this specification shall be of the following compositions as specified in table I:

<u>Alloy number:</u>		
2014	2618	6151
2018	4032	7049
2025	5083	7075
2218	6061	7076
2219	6066	7079

1.2.2 Form: Aluminum alloy forgings shall be furnished in the form of die forgings or hand forgings, as specified. If the method is not specified, manufacturers may use any method of forging most convenient.

1.2.3 Temper: Forgings shall be supplied in the temper specified in the order or contract. Forgings supplied in the T652 or T852 tempers shall be solution heat treated, stress relieved by compression to produce a permanent set of 1 to 5 percent, and artificially aged. Forgings in 7049 and 7075 alloy supplied in the T73 or T7352 temper shall be solution heat treated and aged in a manner to develop the mechanical properties shown in tables II, III, and V, and shall be capable of passing the test for resistance to stress-corrosion cracking 4.4.3.

2. APPLICABLE DOCUMENTS:

The following publications, 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.

2.1 U.S. Government Publications:

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

FED-STD-123 Marking for Domestic Shipment (Civil Agencies)
FED-STD-151 Metals; Test Methods

MIL-H-6088 Heat Treatment of Aluminum Alloys
MIL-I-6866 Inspection, Penetrant Method of
MIL-I-8950 Inspection, Ultrasonic, Wrought Metals, Process for
MIL-S-13165 Shot Peening of Metal Parts

MIL-STD-129 Marking for Shipment and Storage
MIL-STD-410 Qualification of Inspection Personnel (Magnetic Particle and Penetrant)
MIL-STD-649 Aluminum and Magnesium Products, Preparation for Shipment and Storage

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM B 117 Test for Salt Spray (Fog) Testing
ASTM E 8 Tension Testing of Metallic Materials

2.3 National Bureau of Standards (NBS) Handbook:

Available from U.S. Department of Commerce, NSB, Washington, DC 20234.

Circular No. 31 International Annealed Copper Standards

TABLE I. Chemical composition limits ^{1/} percent maximum, except where indicated as range

Alloy No.	Copper	Silicon	Iron	Manganese	Magnesium	Zinc	Chromium	Titanium	Nickel	Other elements ^{2/}	Aluminum
2014	3.9-5.0	0.50-1.2	0.7	0.40-1.2	0.20-0.8	0.25	0.10	0.15	-	0.05	Rema Inder
2018	3.5-4.5	0.9	1.0	0.20	0.45-0.9	0.25	0.10	-	1.7-2.3	0.05	Rema Inder
2025	3.9-5.0	0.50-1.2	1.0	0.40-1.2	0.05	0.25	0.10	0.15	-	0.05	Rema Inder
2218	3.5-4.5	0.9	1.0	0.20	1.2-1.8	0.25	0.10	-	1.7-2.3	0.05	Rema Inder
2219	5.8-6.8	0.20	0.30	0.20-0.40	0.02	0.10	-	0.02-0.10	-	0.05 ^{3/}	Rema Inder
2618	1.9-2.7	0.25	0.9-1.3	-	1.3-1.8	-	-	0.40-0.10	0.9-1.2	0.05	Rema Inder
4032	0.50-1.3	11.0-13.5	1.0	-	0.8-1.3	0.25	0.10	-	0.50-1.3	0.05	Rema Inder
5083	0.10	0.40	0.40	0.30-1.0	4.0-4.9	0.25	0.05-0.25	0.15	-	0.05	Rema Inder
6061	0.15-0.40	0.40-0.8	0.7	0.15	0.8-1.2	0.25	0.04-0.35	0.15	-	0.05	Rema Inder
6066	0.7-1.2	0.9-1.8	0.50	0.6-1.1	0.8-1.4	0.25	0.40	0.20	-	0.05	Rema Inder
6151	0.35	0.6-1.2	1.0	0.20	0.45-0.8	0.25	0.15-0.35	0.15	-	0.05	Rema Inder
7049	1.2-1.9	0.25	0.35	0.20	2.0-2.9	7.2-8.2	0.10-0.22	0.10	-	0.05	Rema Inder
7075	1.2-2.0	0.40	0.5	0.30	2.1-2.9	5.1-6.1	0.18-0.35	0.20	-	0.05	Rema Inder
7076	0.30-1.0	0.40	0.6	0.30-0.8	1.2-2.0	7.0-8.0	-	0.20	-	0.05	Rema Inder
7079	0.40-0.8	0.30	0.40	0.10-0.30	2.9-3.7	3.8-4.8	0.10-0.25	0.10	-	0.05	Rema Inder

^{1/} Analysis shall be made only for the elements specifically mentioned in the above table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that these other elements are not present in excess of the limits specified.

^{2/} Total of all elements not specified shall not exceed 0.15 percent.

^{3/} Vanadium 0.05-0.15 and zirconium 0.10-0.25.

3. REQUIREMENTS:

- 3.1 Forgings shall produced by hammering or pressing from a cast ingot or from as-fabricated (rolled, hand forged, or extruded) stock of suitable quality and of composition as specified in table I. Whether the forgings are produced from cast ingot or wrought stock, the material shall be sufficiently worked upon completion of forging operations to produce a thoroughly wrought structure.
- 3.2 Chemical composition:
- 3.2.1 The chemical composition of the forgings shall be as specified in table I.
- 3.3 Mechanical properties:
- 3.3.1 Die forgings: The mechanical properties of test specimens taken as specified in 4.2.3.1 shall be as specified in tables II and III.

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TABLE II. Mechanical properties of die forgings and separately forged test bars - test specimen parallel to forging flow (grain) lines

Alloy No.	Temper ^{3/}	Maximum heat treat section thickness Inches	Tensile strength ^{2/} minimum p.s.i.	Yield strength ^{2/} at 0.2 percent offset minimum. p.s.i.	Elongation in 2 inches or 4D ^{1/} minimum	
					Forging Percent	Test coupon (forged) Percent
2014	T4	4	55,000	30,000	11	16
2014	T6	Up thru 1	65,000	56,000	6	8
		Over 1 thru 2	65,000	56,000	6	(4)
		Over 2 thru 3	65,000	55,000	6	(4)
		Over 3 thru 4	63,000	55,000	6	(4)
2018	T61	4	55,000	40,000	7	10
2025	T6	4	52,000	33,000	11	16
2218	T61	4	55,000	40,000	7	10
2219	T6	4	58,000	38,000	8	10
2618	T61	4	58,000	45,000	4	6
4032	T6	4	52,000	42,000	3	5
5083	H111 ^{5/}	4	42,000	22,000	14	16
5083	H112 ^{5/}	4	40,000	18,000	16	16
6061	T6	4	38,000	35,000	7	10
6066	T6	4	50,000	45,000	8	12
6151	T6	4	44,000	37,000	10	14
7049	T73	Up thru 2	72,000	62,000	7	10
		Over 2 thru 4	71,000	61,000	7	10
		Over 4 thru 5	70,000	60,000	7	10
7075	T6	Up thru 1	75,000	64,000	7	10
		Over 1 thru 2	74,000	63,000	7	(4)
		Over 2 thru 3	74,000	63,000	7	(4)
		Over 3 thru 4	73,000	62,000	7	(4)
7075	T73	Up thru 3	66,000	56,000	7	10
		Over 3 thru 4	64,000	55,000	7	10
7075	T7352	Up thru 3	66,000	56,000	7	10
		Over 3 thru 4	64,000	53,000	7	10
7076	T61	4	70,000	60,000	10	14
7079	T6	Up thru 1	72,000	62,000	7	10
		Over 1 thru 2	72,000	62,000	7	(4)
		Over 2 thru 3	71,000	61,000	7	(4)
		Over 3 thru 4	71,000	61,000	7	(4)
		Over 4 thru 5	70,000	60,000	7	(4)
		Over 5 thru 6	70,000	59,000	7	(4)

^{1/} D is diameter of test specimen.

^{2/} Tensile and yield strength test requirements may be waived for material in any direction in which the dimension is less than 2 inches because of the difficulty to obtain a tension test specimen suitable for routine control testing.

^{3/} Die forgings in some configurations of these alloys can be purchased in the heat treated and mechanically stress relieved T652 temper conforming to the mechanical properties requirements specified for the T6 temper.

^{4/} When separately forged coupons are used to verify acceptability of forgings in the indicated thicknesses, the properties shown for thicknesses "Up thru 1 inch", including the test coupon elongation, apply.

^{5/} As-forged thickness. When forgings are machined prior to heat treatment the properties will also apply to the machined heat treat thickness provided the machined thickness is not less than one-half the original (as-forged) thickness.

^{6/} Maximum section thickness to which mechanical properties apply (non-heat-treatable-alloys).

TABLE III. Mechanical properties of die forgings - specimens not parallel to forging flow lines

Alloy No.	Temper ^{3/}	Maximum heat treat section thickness inches	Tensile strength ^{2/} , minimum p. s. i.	Yield strength at 0.2 percent offset, minimum p. s. i.	Elongation percent in 2 inch or 4D ^{1/} , minimum
2014	T6	Up thru 1	64,000	55,000	3
		Over 1 thru 2	64,000	55,000	2
		Over 2 thru 3	63,000	54,000	2
		Over 3 thru 4	63,000	54,000	2
2219	T6	4	56,000	36,000	4
2618	T61	4	55,000	42,000	4
5083 ^{4/}	H111	4	39,000	20,000	12
5083 ^{4/}	H112	4	39,000	16,000	14
6061	T6	4	38,000	35,000	5
6161	T6	4	44,000	37,000	6
7049	T73	Up thru 1	71,000	61,000	3
		Over 1 thru 3	70,000	60,000	3
		Over 3 thru 4	70,000	60,000	2
		Over 4 thru 5	68,000	58,000	2
7075	T6	Up thru 1	71,000	61,000	3
		Over 1 thru 2	71,000	61,000	3
		Over 2 thru 3	70,000	60,000	3
		Over 3 thru 4	70,000	60,000	2
7075	T73	Up thru 3	62,000	53,000	3
		Over 3 thru 4	61,000	52,000	2
7075	T7352	Up thru 3	62,000	51,000	3
		Over 3 thru 4	61,000	49,000	2
7076	T61	4	67,000	58,000	3
7079	T6	Up thru 1	71,000	61,000	5
		Over 1 thru 2	70,000	60,000	5
		Over 2 thru 3	70,000	60,000	4
		Over 3 thru 4	70,000	60,000	4
		Over 4 thru 5	68,000	58,000	3
		Over 5 thru 6	68,000	58,000	3

- 1/ D is a diameter of test specimen.
- 2/ Tensile and yield strength test requirements may be waived for material in any direction in which the dimension is less than 2 inches because of the difficulty to obtain a tension test specimen suitable for routine control testing.
- 3/ Die forgings in some configurations of these alloys can be purchased in the heat treated and mechanically stress relieved T652 temper conforming to the mechanical properties requirements specified for the T6 temper.
- 4/ Maximum section thickness to which mechanical properties apply (non-heat-treatable alloys).

- 3.3.1.1 A forging representing the first production lot of forgings produced from new or significantly reworked dies, significantly changed forging production procedures, or from significantly changed stock (see 3.1), shall be tested in accordance with 4.2.3.1.
- 3.3.1.2 If test specimens are taken from forgings of the alloys listed in table III so that the axis is not substantially parallel (within plus or minus 15°) to the metal flow lines in the specimen, the mechanical properties shall conform to the requirements of table III except that the elongation requirements shall be as specified by the procuring activity for test specimens taken so that the reduced section (1) is in immediate proximity to an abrupt change in section thickness; or (2) intersects the parting plane within 1/4 inch of the flash line.
- 3.3.2 Hand forgings: The mechanical properties of hand forgings of 2014-T6, T652; 7049-T73; 7075-T6, T652, T73; 7079-T6, T652; 6061-T6 or T652; 2618-T61; 2219-T6, T852; and 5083-H111, H112 determined from specimens taken in accordance with 4.2.3.2 shall conform to the applicable properties specified in tables IV thru XI.
- 3.3.2.1 The properties in tables IV, V, VI, VII, VIII, and IX apply to hand forgings that are essentially rectangular in cross section. The requirements of long-transverse and short-transverse properties apply also to the squares even though both transverse dimensions are equal length. The cross-sectional grain direction, perpendicular to the longitudinal direction, of hexagons and rounds shall be considered the long transverse grain direction. The direction of the long transverse properties shall be identified as required in 3.7. Biscuits, octagons, rings, and contour hand forgings are considered to be special purpose forgings (see 3.3.3).

TABLE IV. Mechanical properties of alloy 2014 hand forgings 1/

Temper	Thickness $\frac{4}{5}$ / inches	Axis of test specimen	Tensile strength $\frac{2}{}$ / minimum p. s. i.	Yield strength $\frac{2}{}$ / minimum p. s. i.	Elongation $\frac{2}{}$ / percent min. in 2 in. or 4D $\frac{3}{}$
T6	Up thru 2	Longitudinal	65,000	56,000	8
		Long trvs.	65,000	56,000	3
	Over 2 thru 3	Longitudinal	64,000	56,000	8
		Long. trvs.	64,000	55,000	3
		Short trvs.	62,000	55,000	2
	Over 3 thru 4	Longitudinal	63,000	55,000	8
		Long. trvs.	63,000	55,000	3
		Short trvs.	61,000	54,000	2
	Over 4 thru 5	Longitudinal	62,000	54,000	7
		Long trvs.	62,000	54,000	2
		Short trvs.	60,000	53,000	1
	Over 5 thru 6	Longitudinal	61,000	53,000	7
		Long trvs.	61,000	53,000	2
		Short trvs.	59,000	53,000	1
Over 6 thru 7	Longitudinal	60,000	52,000	6	
	Long trvs.	60,000	52,000	2	
	Short trvs.	58,000	52,000	1	
Over 7 thru 8	Longitudinal	59,000	51,000	6	
	Long trvs.	59,000	51,000	2	
	Short trvs.	57,000	51,000	1	
T652	Up thru 2	Longitudinal	65,000	56,000	8
		Long trvs.	65,000	56,000	3
	Over 2 thru 3	Longitudinal	64,000	56,000	8
		Long trvs.	64,000	55,000	3
		Short trvs.	62,000	52,000	2

TABLE IV (Continued)

Temper	Thickness ^{4/} _{5/} inches	Axis of test specimen	Tensile strength ^{2/} minimum p. s. i.	Yield strength ^{2/} minimum p. s. i.	Elongation ^{2/} percent min. in. 2 in. or 4D ^{3/}
T652 (Cont)	Over 3 thru 4	Longitudinal	63,000	55,000	8
		Long trvs.	63,000	55,000	3
		Short trvs.	61,000	51,000	2
	Over 4 thru 5	Longitudinal	62,000	54,000	7
		Long trvs.	62,000	54,000	2
		Short trvs.	60,000	50,000	1
	Over 5 thru 6	Longitudinal	61,000	53,000	7
		Long trvs.	61,000	53,000	2
		Short trvs.	59,000	50,000	1
	Over 6 thru 7	Longitudinal	60,000	52,000	6
		Long trvs.	60,000	52,000	2
		Short trvs.	58,000	49,000	1
	Over 7 thru 8	Longitudinal	59,000	51,000	6
		Long trvs.	59,000	51,000	2
		Short trvs.	57,000	48,000	1

- 1/ Maximum cross-sectional area is 256 square inches.
- 2/ Tensile property requirements may be waived for material in any direction in which the dimension is less than 2 inches because of the difficulty to obtain a tension test specimen suitable for routine control testing.
- 3/ D is diameter of test specimen.
- 4/ Thickness is measured in the short transverse direction and applies to the dimension as forged and before any machining operation.
- 5/ When the as-forged dimension is 8 inches or less, the guaranteed properties shall be based on the machined thickness at the time of heat treatment.

TABLE V. Mechanical properties of alloy 7049 hand forgings ^{1/}

Temper	Thickness ^{4/} ^{5/} inches	Axis of test specimen	Tensile strength ^{2/} minimum p. s. i.	Yield strength ^{2/} minimum p. s. i.	Elongation ^{2/} percent min. in 2 in. or 4D ^{3/}
T73	Over 2 thru 3	Longitudinal	71,000	61,000	9
		Long trvs.	71,000	59,000	4
		Short trvs.	69,000	58,000	3
	Over 3 thru 4	Longitudinal	69,000	59,000	8
		Long trvs.	69,000	57,000	3
		Short trvs.	67,000	56,000	2
	Over 4 thru 5	Longitudinal	67,000	56,000	7
		Long trvs.	67,000	56,000	3
		Short trvs.	66,000	55,000	2

- ^{1/} Maximum cross-sectional area is 256 square inches.
- ^{2/} Tensile property requirements may be waived for material in any direction in which the dimension is less than 2 inches because of difficulty in obtaining a tensile test specimen suitable for testing.
- ^{3/} D is diameter of test specimen.
- ^{4/} Thickness is measured in the short transverse direction and applies to the dimension as forged and before any machining operation.
- ^{5/} When the as-forged dimension is not greater than 6 inches, the guaranteed properties shall be based on the machined thickness at the time of heat treatment.

TABLE VI. Mechanical properties of alloy 7075 hand forgings ^{1/}

Temper	Thickness $\frac{4}{5}$ / inches	Axis of test specimen	Tensile strength $\frac{2}{}$ / minimum p. s. i.	Yield strength $\frac{2}{}$ / minimum p. s. i.	Elongation $\frac{2}{}$ / percent min. in 2 in. or 4D $\frac{3}{}$	
T6	Up thru 2	Longitudinal	74,000	63,000	9	
		Long trvs.	73,000	61,000	4	
	Over 2 thru 3	Longitudinal	73,000	61,000	9	
		Long trvs.	71,000	59,000	4	
		Short trvs.	69,000	58,000	3	
	Over 3 thru 4	Longitudinal	71,000	60,000	8	
		Long trvs.	70,000	58,000	3	
		Short trvs.	68,000	57,000	2	
	Over 4 thru 5	Longitudinal	69,000	58,000	7	
		Long trvs.	68,000	56,000	3	
		Short trvs.	66,000	56,000	2	
	Over 5 thru 6	Longitudinal	68,000	56,000	6	
		Long trvs.	66,000	55,000	3	
		Short trvs.	65,000	55,000	2	
	T652	Up thru 2	Longitudinal	74,000	63,000	9
			Long trvs.	73,000	61,000	4
		Over 2 thru 3	Longitudinal	73,000	61,000	9
			Long trvs.	71,000	59,000	4
Short trvs.			69,000	57,000	2	
Over 3 thru 4		Longitudinal	71,000	60,000	8	
		Long trvs.	70,000	58,000	3	
		Short trvs.	68,000	56,000	1	

TABLE VI (Continued)

Tempor	Thickness $\frac{4}{5}$ / inches	Axis of test specimen	Tensile strength $\frac{2}{}$ / minimum p. s. i.	Yield strength $\frac{2}{}$ / minimum p. s. i.	Elongation $\frac{2}{}$ / percent min. in 2 in. or 4D $\frac{3}{}$
T652 (Cont)	Over 4 thru 5	Longitudinal	69,000	58,000	7
		Long trvs.	68,000	56,000	3
		Short trvs.	66,000	55,000	1
	Over 5 thru 6	Longitudinal	68,000	56,000	6
		Long trvs.	66,000	55,000	3
		Short trvs.	65,000	54,000	1
T73	Up thru 3	Longitudinal	66,000	56,000	7
		Long trvs.	64,000	54,000	4
		Short trvs.	61,000	52,000	3
	Over 3 thru 4	Longitudinal	64,000	55,000	7
		Long trvs.	63,000	53,000	3
		Short trvs.	60,000	51,000	2
	Over 4 thru 5	Longitudinal	62,000	53,000	7
		Long trvs.	61,000	51,000	3
		Short trvs.	58,000	50,000	2
	Over 5 thru 6	Longitudinal	61,000	51,000	6
		Long trvs.	59,000	50,000	3
		Short trvs.	57,000	49,000	2
T7352	Up thru 3	Longitudinal	66,000	54,000	7
		Long trvs.	64,000	52,000	4
		Short trvs.	61,000	50,000	3
	Over 3 thru 4	Longitudinal	64,000	53,000	7
		Long trvs.	63,000	50,000	3
		Short trvs.	60,000	48,000	2

TABLE VI (Continued)

Temper	Thickness <u>4/</u> <u>5/</u> inches	Axis of test specimen	Tensile strength <u>2/</u> minimum p. s. i.	Yield strength <u>2/</u> minimum p. s. i.	Elongation <u>2/</u> percent min. in 2 in. or 4D <u>3/</u>
T7352 (Cont)	Over 4 thru 5	Longitudinal	62,000	51,000	7
		Long trvs.	61,000	48,000	3
		Short trvs.	58,000	46,000	2
	Over 5 thru 6	Longitudinal	61,000	49,000	6
		Long trvs.	59,000	46,000	3
		Short trvs.	57,000	44,000	2

1/ Maximum cross-sectional area is 256 square inches.

2/ Tensile property requirements may be waived for material in any direction in which the dimension is less than 2 inches because of difficulty in obtaining a tensile test specimen suitable for testing.

3/ D is diameter of test specimen.

4/ Thickness is measured in the short transverse direction and applies to the dimension as forged and before any machining operation.

5/ When the as-forged dimension is not greater than 6 inches, the guaranteed properties shall be based on the machined thickness at the time of heat treatment.

TABLE VII. Mechanical properties of alloy 7079 hand forgings 1/

Temper	Thickness <u>4/</u> <u>5/</u> inches	Axis of test specimen	Tensile strength <u>2/</u> minimum p. s. i.	Yield strength <u>2/</u> minimum p. s. i.	Elongation <u>2/</u> percent min. in 2 in. or 4D <u>3/</u>
T6	Up thru 2	Longitudinal	72,000	63,000	9
		Long trvs.	71,000	61,000	5
	Over 2 thru 3	Longitudinal	72,000	62,000	9
		Long trvs.	70,000	60,000	5
		Short trvs.	67,000	56,000	4
	Over 3 thru 4	Longitudinal	71,000	61,000	9
Long trvs.		70,000	59,000	5	
Short trvs.		67,000	56,000	4	

TABLE VII (Continued)

Temper	Thickness $\frac{4}{5}$ / inches	Axis of test specimen	Tensile strength $\frac{2}{3}$ / minimum p. s. i.	Yield strength $\frac{2}{3}$ / minimum p. s. i.	Elongation $\frac{2}{3}$ / percent min. in 2 in. or 4D $\frac{3}{4}$
T6 (Cont)	Over 4 thru 5	Longitudinal	70,000	60,000	9
		Long trvs.	69,000	58,000	4
		Short trvs.	66,000	55,000	4
	Over 5 thru 6	Longitudinal	69,000	59,000	9
		Long trvs.	68,000	56,000	4
		Short trvs.	66,000	54,000	4
	Over 6 thru 7	Longitudinal	68,000	58,000	9
		Long trvs.	67,000	54,000	4
		Short trvs.	65,000	53,000	4
	Over 7 thru 8	Longitudinal	67,000	57,000	9
		Long trvs.	66,000	53,000	4
		Short trvs.	64,000	52,000	4
T652	Up thru 2	Longitudinal	72,000	63,000	9
		Long trvs.	71,000	61,000	5
	Over 2 thru 3	Longitudinal	72,000	62,000	9
		Long trvs.	70,000	60,000	5
		Short trvs.	67,000	55,000	3
	Over 3 thru 4	Longitudinal	71,000	61,000	9
		Long trvs.	70,000	59,000	5
		Short trvs.	67,000	55,000	3
	Over 4 thru 5	Longitudinal	70,000	60,000	9
		Long trvs.	69,000	58,000	4
		Short trvs.	66,000	54,000	3

TABLE VII (Continued)

Temper	Thickness ^{4/} / _{5/} inches	Axis of test specimen	Tensile strength ^{2/} minimum p. s. i.	Yield strength ^{2/} minimum p. s. i.	Elongation ^{2/} percent min. in 2 in. or 4D ^{3/}
T652 (Cont)	Over 5 thru 6	Longitudinal	69,000	59,000	9
		Long trvs.	68,000	56,000	4
		Short trvs.	66,000	53,000	3
	Over 6 thru 7	Longitudinal	68,000	58,000	9
		Long trvs.	67,000	54,000	4
		Short trvs.	65,000	51,000	2
	Over 7 thru 8	Longitudinal	67,000	57,000	9
		Long trvs.	66,000	52,000	4
		Short trvs.	64,000	50,000	3

1/ Maximum cross-sectional area is 256 square inches.

2/ Tensile property requirements may be waived for material in any direction in which the dimension is less than 2 inches because of difficulty in obtaining a tensile test specimen suitable for testing.

3/ D is diameter of test specimen.

4/ Thickness is measured in the short transverse direction and applies to the dimension as forged and before any machining operation.

5/ When the as-forged dimension is not greater than 8 inches, the guaranteed properties shall be based on the machined thickness at the time of heat treatment.

TABLE VIII. Mechanical properties of alloy 6061 hand forgings ^{1/}

Temper	Thickness ^{4/} / _{5/} inches ^{6/}	Axis of test specimen	Tensile strength ^{2/} minimum p. s. i.	Yield strength ^{2/} minimum p. s. i.	Elongation ^{2/} percent min. in 2 in. or 4D ^{3/}
T6 or	Up thru 4	Longitudinal	38,000	35,000	10
		Long trvs.	38,000	35,000	8
		Short trvs.	37,000	33,000	5
T652	Over 4 thru 8	Longitudinal	37,000	34,000	8
		Long trvs.	37,000	34,000	6
		Short trvs.	35,000	32,000	4

1/ Maximum cross-sectional area is 256 square inches.

2/ Tensile property requirements may be waived for material in any direction in which the dimension is less than 2 inches because of difficulty in obtaining a tensile test specimen for testing.

3/ D is diameter of test specimen.

4/ Thickness is measured in the short transverse direction and applies to the dimension as forged and before any machining operation.

5/ For T652 forging thicknesses greater than 8 inches at the time of heat treatment, the properties shall be as specified in the contract or purchase order.

6/ When the as-forged dimension is not greater than 8 inches, the guaranteed properties shall be based on the machined thickness at the time of heat treatment.

TABLE IX. Mechanical properties of hand forgings
(maximum thickness - 4 inches) 3/ - alloy 2618

Temper	Thickness <u>4/</u> Inches	Axis of test specimen	Tensile strength <u>2/</u> minimum p. s. i.	Yield strength <u>2/</u> minimum p. s. i.	Elongation <u>2/</u> percent min. in 2 in. or 4D <u>1/</u>
T61	Up thru 2	Longitudinal	58,000	47,000	7
		Long trvs.	55,000	42,000	5
		Short trvs.	52,000	42,000	4
	Over 2 thru 3	Longitudinal	57,000	46,000	7
		Long trvs.	55,000	42,000	5
		Short trvs.	52,000	42,000	4
	Over 3 thru 4	Longitudinal	56,000	45,000	7
		Long trvs.	53,000	40,000	5
		Short trvs.	51,000	39,000	4

1/ D is diameter of test specimen.

2/ Tensile and yield strength test requirements may be waived for material in any direction in which the dimension is less than 2 inches because of the difficulty to obtain a tension test specimen suitable for routine control.

3/ Maximum cross-sectional area is 144 square inches.

4/ When the as-forged dimension is not greater than 4 inches, the guaranteed properties shall be based on the machined thickness at the time of heat treatment.

TABLE X. Mechanical properties of hand forgings
(maximum thickness - 4 inches) 3/ alloy 2219-T6, 2219-T852

Temper	Direction	Tensile <u>2/</u> strength, minimum p. s. i.	Yield strength <u>2/</u> at 0.2 percent offset, minimum p. s. i.	Elongation percent in 2 inches or 4D <u>1/</u> , minimum percent
T6	Longitudinal	58,000	40,000	6
	Long trvs.	55,000	37,000	4
	Short trvs.	53,000	35,000	2
T852	Longitudinal	62,000	50,000	6
	Long trvs.	62,000	49,000	4
	Short trvs.	60,000	46,000	3

1/ D is diameter of test specimen.

2/ Tensile and yield strength test requirements may be waived for material in any direction in which the dimension is less than 2 inches because of the difficulty to obtain a tension test specimen suitable for routine control.

3/ For cross-sectional areas greater than 144 square inches, or thickness greater than 4 inches at the time of heat treatment, the properties shall be as specified in the contract or purchase order.

TABLE XI. Mechanical properties of hand forgings
(maximum section thickness - 4 inches) ^{1/} - alloy 5083

Temper	Direction	Tensile ^{2/} strength, minimum p. s. i.	Yield strength ^{2/} at 0.2 percent offset, minimum p. s. i.	Elongation percent in 2 inches or 4D ^{3/} , minimum percent
H111	Longitudinal	42,000	22,000	14
	Long trvs.	39,000	20,000	12
H112	Longitudinal	40,000	18,000	14
	Long trvs.	39,000	16,000	14

- ^{1/} For thickness greater than 4 inches, the properties shall be as specified in the contract or purchase order.
- ^{2/} Tensile and yield strength test requirements may be waived for material in any direction in which the dimension is less than 2 inches because of the difficulty to obtain a tension test specimen suitable for routine control testing.
- ^{3/} D is diameter of test specimen.

- 3.3.3 Special purpose and large forgings: For die forgings and hand forgings (1) of greater cross-sectional area or (2) heat treated in section thickness greater than covered by this specification or (3) when the purpose or conditions under which the forging is to be used so dictates, the requirements shall be as specified in the contract, order, or drawing. In such cases the mechanical properties of test specimens taken from locations indicated on the drawing shall be as specified in the contract, order, or drawing.
- 3.3.4 When die forgings, other than 2014, 7075 and 7079 and as covered in 3.3.3, are machined before heat treatment, the properties of the as-forged thickness will apply unless the forgings are machined to less than half the original (as-forged) section thickness. Properties of material machined to less than half of original thickness shall be as agreed upon between the contractor and the vendor for properties required greater than covered by the specification.
- 3.3.4.1 When hand forgings, other than covered in 3.3.3 are machined before heat treatment, the properties of the as-forged thickness will apply regardless of machined section thickness.
- 3.3.5 The mechanical properties of any forging supplied in any temper (see 6.2) other than one shown for that alloy in tables II through XI, inclusive, shall after suitable heat treatment conform to the applicable properties shown in tables II through XI, inclusive. Specimens shall be taken in accordance with 4.2.3.1 and 4.2.3.2.
- 3.4 Resistance to stress-corrosion cracking (7049-T73, 7075-T73 and 7075-T7352).
- 3.4.1 Resistance: Susceptibility to stress-corrosion cracking shall be established by the criteria as covered in 4.9.

3.4.2 Capability: Forgings supplied shall be capable of exhibiting no evidence of stress-corrosion cracking when subjected to the test specified in 4.4.3. The supplier shall maintain records of all lots so tested.

3.5 Internal defects:

When so specified (see 6.2), forgings shall be inspected ultrasonically for internal defects. Test methods and limits of acceptability shall be as agreed upon by the vendor and purchasing activity.

3.5.1 Internal defects (Air Force only): Forgings shall be ultrasonically inspected for internal defects in accordance with MIL-I-8950.

3.6 Tolerances:

The forgings shall conform to the shape and dimensions specified (see 6.2), within such variations as may be shown on the drawings.

3.7 Marking of hand forgings:

Unless otherwise specified (see 6.2), hand forgings shall be marked continuously along their length with the alloy and temper designation, if applicable, in characters that are clearly legible and that will not be obliterated by ordinary handling. For squares, the marking shall be on the face that is parallel to the direction of the long transverse properties.

3.8 Heat treatment:

Unless otherwise specified (see 6.2), applicable tempers of forgings shall be heat treated in accordance with the requirements of MIL-H-6088.

3.9 Workmanship:

The forgings shall be of uniform quality and condition, free from blisters, fins, folds, seams, laps, cracks, segregations, spongy areas, or other defects, which would adversely affect their serviceability. Surface defects may be explored and if they can be removed so they do not appear on re-etching (see 4.6) and the required section thickness can be maintained, they shall not be cause for rejection.

3.9.1 When specified (see 6.2), the grainflow pattern shall conform with that of a sample forging, photograph or drawing approved by the procuring activity.

3.9.2 The forgings shall not be repaired by plugging or welding.

3.10 Surface conditioning (Air Force only):

Unless otherwise specified, all heat treated and machined die forgings purchased for use on Air Force contracts shall be processed to produce surface compressive stresses in both internal and external parting line areas and areas where "end grains" have been exposed by machining. Surface working by means of shot peening or rolling to induce residual residual surface compressive stresses shall be applied.

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: For the Naval Sea Systems Command, a certificate of quality compliance shall be prepared by the manufacturer or supplier for each lot of material offered for acceptance (see 6.2.1). It shall show the results of the required tests performed by the manufacturer and 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.

4.2 Sampling:

4.2.1 Lot:

4.2.1.1 Die forgings: A lot shall consist of forgings of the same shape or group of forgings of similar size and shape of the same alloy and heat treated in the same furnace charge. If forgings are heat treated in a continuous furnace, forgings charged consecutively during continuous operation of the furnace shall be considered a furnace charge. For forgings weighing 5 pounds or less, the maximum weight of a lot shall be 2000 pounds, and for larger forgings it shall be 6000 pounds.

4.2.1.2 Hand Forgings: A lot shall consist of not more than 6000 pounds of forgings of the same alloy, temper, heat treat furnace charge (when heat treated), and dimensions submitted for inspection at one time.

4.2.2 Sampling for chemical analysis:

- 4.2.2.1 Ingot analysis: At least one sample shall be taken from each group of ingots of the same alloy poured simultaneously from the same source of molten metal by the producer and analyzed to determine conformance to 3.2. Ingots not conforming to this specification shall be rejected. Complete ingot analysis records shall be available at the producer's plant to the procuring activity.
- 4.2.2.2 Finished product analysis: Unless compliance with 4.2.2.1 is established, an analysis shall be made as specified in method 111 or 112 of FED-STD-151, for each 4,000 pounds or less of material comprising the lot, except that not more than one analysis shall be required per piece.
- 4.2.3 Mechanical property and stress corrosion test: Unless otherwise specified (see 6.2), at least two standard 0.500 inch round tensile test specimen per FED-STD-151 method ASTM E8 (Figure 8) shall be taken to represent the lot. If the cross-sectional area of the forging is too small to permit use of the standard specimen, small size round specimens per Figure 8 or rectangular specimens per Figure 6 of method ASTM E8 shall be used. If the forging is too small to obtain any of these specimens, the test method shall be as directed by the procuring activity (see 6.2). The tensile test specimen used for testing in accordance with 4.4.2 may be utilized for the stress corrosion acceptance test of 4.9.
- 4.2.3.1 Die forgings:
- a) At least two tensile specimens, one parallel to forging flow lines and one transverse to forging flow lines, shall be taken from a forging representative of the first production lot of forgings produced from each new die or significantly reworked die, and tested to determine conformance with the requirements of tables II and III. Results of such first item tests shall be made available to the procuring activity.
 - b) For production, the tension test specimen shall be taken from a test coupon forged from the stock used in making the forgings and heat treated with the lot which represents or from a prolongation of the forgings or from a forging chosen to represent the lot. The test specimen shall be taken so that the axis of the specimen is substantially parallel to the direction of forging flow lines in the test coupon or forging, except that, when specified, an additional test specimen shall be taken so that the axis of the specimen is transverse to the direction of forging flow lines in the test coupon or forging.
- 4.2.3.2 Hand forgings: The tension test specimens shall be taken from a prolongation of the forgings or from a forging chosen to represent the lot. The specimen representing the longitudinal direction shall be taken so that its axis coincides with the longitudinal center line of the forgings, and the specimen representing a transverse direction shall be taken so that the midpoint of its axis shall lie on the longitudinal center line of the forging. For any specimen, the midpoint of its axis shall be at least one-half of the forging thickness from any surface of the forgings. Tests will regularly be made only in the long transverse direction, but when required by the procuring activity, tests shall also be made in the longitudinal direction or short transverse direction.