Society of Automotive Engineers, Inc.
TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001

AEROSPACE MATERIAL SPECIFICATION

AMS 2770

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Revised

HEAT TREATMENT OF ALUMINUM AND ALUMINUM-BASE ALLOYS

1. SCOPE:

1.1 Purpose: This specification covers the engineering requirements for the thermal treatment of aluminum-base alloy parts.

1.2 Application: To produce conditions favorable to the forming of parts by annealing or by solution heat treating, quenching, and refrigerating; or to strengthen parts by solution and precipitation heat treatment.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., Two Pennsylvania Plaza, New York, New York 10001.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

ASTM B557 - Tension Testing Wrought and Cast Aluminum and Magnesium Alloy Products

3. TECHNICAL REQUIREMENTS:

3.1 Equipment:

3.1.1 Furnaces:

3.1.1.1 General: Furnaces shall be of an acceptable type such as air, molten salt bath, oil bath, or fluidized bed. Temperature in the furnace shall be controlled as in 3.1.1.2. The products of combustion or superheated steam should be excluded from contact with the material in the charge. Electrical heating elements and radiant tubes shall be shielded to prevent direct radiation from striking any part of the furnace charge. Salt baths shall be of a composition and maintained in such condition as to prevent attack of the alloys in the charge.

CAUTION: Salt baths containing mixtures of nitrates are hazardous under certain conditions. Explosive reactions with magnesium may occur if alloys such as 5056, 5456, and 520.0 (220), containing appreciable amounts of magnesium, are placed in the molten bath. Aluminum-base alloy parts lost or allowed to remain in the sludge in the bottom of the tank may start a thermit reaction and overheat the bath. Above 1100° F (593° C), either at locally overheated points or throughout the bath, the salt begins to decompose with emission of corrosive and toxic fumes and at higher temperatures may detonate. Contamination with soot, graphite, cyanide, oil, and other oxidizable substances may cause similar reactions. Therefore, salt baths shall be operated below 1050° F (566° C) and sludge accumulation shall be removed frequently to keep the bath free of contamination and loose parts.

3.1.1.2 Thermocouples: At least one thermocouple shall be located in each control zone. Each furnace shall have a minimum of two load thermocouples, one each at the hottest and coldest locations in the work zone as determined by furnace survey. Each container of rivets or small parts shall have a thermocouple buried in the center of the load. Load thermocouples shall be attached to the heaviest section in the load, or peened into a load test block of the same thickness. Other thermocouples shall be located as required to control uniformity of heating.

3.1.2 Temperature Controllers: Furnace temperature shall be controlled by potentiometric control and recording instruments accurate to ±2° F (± 1.1° C). Multipoint recorders shall show the temperature of each thermocouple by clearly legible indications at least once each 5 min., or six times during each heating period, whichever requires the faster printing speed. Control thermocouples shall be located as close as practicable to the work zone. The controls shall maintain all points in the work zone within the specified temperature range after recovery of the coldest thermocouple to the minimum of the specified range following charging of the work load, without overshooting the maximum specified temperature during the heat-up period. For repetitive loads qualified in accordance with 3.4.1.5, load thermocouples may be omitted.

3.1.3 Quenching Tanks: Shall be of sufficient capacity and adequate circulation so that the temperature of the water is not raised above the allowable range specified in 3.4.3.7. Means shall be provided for circulation, heating, and cooling as necessary. A concentration of dissolved salts above a level that leaves a visible deposit on parts after drying shall be reduced by inflow of fresh water during use. Tanks shall be located as near as practical to the furnace and facilities arranged to allow a rapid transfer of heated parts. Each tank shall be equipped with a temperature indicator accurate to ±2° F (±1.1° C). Racks and containers shall be of light and open construction to afford minimum heat transfer to the work load and quench water.

3.1.4 Refrigeration Units: Shall be equipped with temperature recording instruments having an accuracy of ±2° F (±1.1° C).

3.2 Qualification and Calibration of Equipment: Facilities and equipment shall be qualified to the requirements of this specification prior to processing of parts. Alteration of equipment or procedures shall require requalification.

3.2.1 Recovery Time: The interval between the closing of the furnace door, or immersion of the load in the heating medium, and the first indication that all thermocouples have reached the specified temperature range shall be defined as recovery time. Loads shall be arranged in the furnace in such a manner that the combined characteristics of furnace heating and load arrangement allow recovery within the time shown in Table I for the thinnest material in the load.

TABLE I

Material Thickness		Recovery Time
Inch	(Millimetres)	minutes max
Up to 0.021, excl	(Up to 0.53, excl)	15
0.021 to 0.063, incl	(0.53 to 1.60, incl)	20
Over 0.063 to 0.125, incl	(Over 1.60 to 3.18, incl)	25
Over 0.125 to 0.500, incl	(Over 3.18 to 12.70, incl)	30
Over 0.500	(Over 12.70)	30 + 10 min. for each additional 0.5 in. (13 mm)

3.2.2 Qualification of Equipment:

3.2.2.1 Furnace Temperature Survey: The temperature distribution in each furnace shall be surveyed for uniformity in compliance with applicable technical requirements prior to initial production use, after any changes that might affect operational characteristics prior to further use, and at not longer than six month intervals thereafter.

3.2.2.1.1 Test Locations: There shall be at least one test location for each 25 cu ft (0.70 m^3) of air furnace working zone or for each 40 cu ft (1.12 m^3) of salt bath volume. Each furnace shall have a minimum of nine test locations but the total number need be no more than 40. Test positions for rectangular furnaces shall be at the corners and the center of the working zone with the balance spaced at regular intervals through the remaining space. Test positions for cylindrical furnaces shall be at three locations each, spaced regularly around the top and bottom circumferences of the working zone, and one each at the top, center, and bottom of the furnace axis, with the balance distributed uniformly through the remaining space.

3.2.2.1.2 Soak Test: Temperature distribution shall be surveyed at one solution heat treating range and one precipitation heat treating range for which each furnace is to be used and at the highest annealing temperature range at which the furnace will be used. Test thermocouples shall be installed in all of the test locations in the same manner that a load is charged in the furnace so as to reflect the normal operating characteristics of the furnace. Readings of each thermocouple shall be taken at intervals of not longer than 2 min. until the temperature stabilizes and at no longer than 5 min. intervals thereafter until the recurrent temperature pattern is established, but not less than 30 min. after stabilization.

3.2.2.1.3 Radiation Test: In addition to the soak test, air furnaces shall have three or more radiation panels located near the center and the ends of the long dimension of the working zone. The panels shall be made of 6061-T4 or -T6 bare alloy sheet nominally 0.050 in. (1.27 mm) thick by at least 12 in. (305 mm) square with a thermocouple peened into the center. The radiation test may be performed as a part of the soak test with the radiation panels used in the place of thermocouples at three of the required test locations. The rolled surfaces of the sheet shall be placed normal to the direction of the nearest heating element or heated wall.

3.2.3 Accuracy of Furnace Pyrometer Systems: The accuracy of temperature measuring systems shall be determined weekly by comparison with a calibrated probe unless the furnace is operating with two or more potentiometer measuring systems checked daily against each other. Test thermocouple potentiometer instrumentation shall be calibrated against a Bureau of Standards primary or secondary standard system at intervals of not longer than three months to an accuracy of ±2° F (±1.1° C). All furnace systems shall be checked at least once each three months.

3.3 Preparation: Dirt, welding flux, shot peening residues, die pick-up, and similar contamination shall be removed from parts before placing in the furnace charge. Cleaners shall be compatible with the alloy and surface condition. Organic residues such as cutting oils and rubber mallet marks that burn off cleanly do not require cleaning. Salt bath residues shall be removed by thorough washing in water.

3.4 Procedure:

3.4.1 General Requirements:

3.4.1.1 Solution treatment is permissible only for parts which -T42, -T6, -T61, -T62 or -T7X tempers are specified as the final temper. Solution heat treated parts that yield the unstable "W" condition (Table V) shall be precipitation heat treated.

3.4.1.2 Parts either made from material as supplied by the producer or as solution heat treated in accordance with this specification may be precipitation heat treated, but shall be so treated only in the starting temper corresponding to the final temper shown in Table VI. Solution heat treated parts in the "W" condition may require two precipitation heat treatment steps to obtain the final temper specified for the parts. The interval between solution heat treatment and precipitation heat treatment or between precipitation heat treat steps is not restricted except that 5 days shall elapse between solution heat treatment of 7079 alloy and precipitation heat treatment, and 2 days for 7049 alloy.

3.4.1.3 Annealing, where permissible, shall be followed by solution heat treatment and aging or precipitation heat treatment, unless the "O" temper is specified as the final condition.

3.4.1.4 Heat treating operations shall be performed on the whole part, never on a portion only, and in a manner that will produce maximum uniformity.

3.4.1.5 Heating Time: Shall be based on bath temperatures or load thermocouple readings. Heating, or soaking, time encompasses the time all thermocouples are within the specified temperature range. For identical or nearly identical loads, the heating time for solution heat treating or precipitation heat treating is required to be determined by load thermocouples only for the first load of each identical group after each furnace survey. Subsequent loads in a group may be accepted on the basis of similarity of controller records provided both the indicated recovery time and total of recovery plus heating time are within ±5 min. of the time indicated by the controller record of the first of the identical loads conforming to load thermocouple control requirements.

3.4.1.6 Load Arrangement: Material and parts shall be racked or supported so as to permit free access of the heating and quenching media to all portions of the work load. Very small parts such as washers and spacers may be handled like rivets. It is recommended that other parts be separated by at least 2 in. (51 mm) for solution treating and 1 in. (25 mm) for precipitation heat treatment, and at greater distances as necessary to prevent blocking of heat flow to other parts or to decrease recovery time. Only aluminim alloy wire and rod shall be used to support parts on the racks. Load arrangement and heating time control for identical loads shall be verified before charging the load.

3.4.1.7 Solution and Precipitation Heat Treatments: The work load shall be charged into furnaces that have been stabilized at the specified temperature. After recovery in conformance with 3.2.1 the charge shall be heated within the specified temperature range without interruption for the required time as defined in 3.4.1.5. The part numbers, material sizes, alloy, quantity of parts or pieces in the work load, furnace number, and date of heat treatment shall be recorded on the controller chart.

3.4.2 Annealing: Loads may be charged into furnaces at any temperature below the maximum permissible annealing temperature (3.4.2.1). Control of recovery in accordance with 3.2.1 shall apply only to clad products annealed at temperatures above 700° F (371° C). Heating time begins when the controller recorder reaches the control setting.

3.4.2.1 Only material or parts in the "O" or "F" condition, or which will subsequently be reheat treated, may be annealed. Parts shall be annealed as specified in Table II. Annealing of clad sheet under 0.125 in. (3.18 mm) thick above 700° F (371° C) is not permitted. Clad sheet and plate 0.125 in. (3.18 mm) thick and over may be annealed above 700° F (371° C) once.

TABLE II

ANNEALING OF WROUGHT ALUMINUM ALLOYS

For Removal of Work-Hardening from Non-Heat Treatable Alloys and Heat Treatable Alloy Sheet and Thin Sections	Full Anneal for Removal of Work Hardening and Previous Heat Treatment from Heat Treatable Alloys
Option 1: Heat to 650° F ± 25 (343.3° C ± 14) and air cool. For 3003 alloy heat to 750° F ± 25 (398.9° C ± 14). 2024 alloy may be heated to 700° F ± 25 (371.1° C ± 14) and water quenched.	Option 1: Heat to 775° F ± 25 (412.8° C ± 14) then cool in furnace at uniform rate not to exceed 50 F (28 C) deg per hour to below 500° F (260° C).
Option 2: Quick dip (not to exceed 30 sec) in salt bath at 920° F ± 10 (493.3° C ± 5.8).	Option 2: For maximum formability, heat to 775° F ± 25 (412.8° C ± 14) and hold 1 hr for each 0.5 in. (13 mm) of thickness of the heaviest section in the load, furnace cool to 450° F ± 25 (232.2° C ± 14) and hold at 450° F ± 25 (232.2° C ± 14) for not less than 6 hr, and cool in air.

3.4.3 Solution Heat Treatment: The charge shall be heated within the temperature range specified in Table V for the applicable alloy, held at temperature for the soak time specified in Table IV for the applicable thickness, and quenched into water in accordance with 3.4.3.7. The controlling thickness shall be the smallest dimension of the largest section in the load.

3.4.3.1 Maximum Thickness: Unless otherwise specified, the thickness at the time of heat treatment of the materials listed in Table III shall not exceed the maximum shown. Parts made from plate over 2 in. (51 mm), forgings over 3 in. (76 mm), and extrusions over 4 in. (102 mm), shall be machined to within 0.5 in. (13 mm) of final thickness before heat treatment. No thickness limits apply to materials not listed in Table III.

TABLE III

MAXIMUM THICKNESS AT TIME OF SOLUTION HEAT TREATMENT

Alloy	Final Temper	Maximum Thickness	
		Inch	(Millimetres)
2014, 2024, 2219	All	4	(102)
2017, 6061	All	8	(203)
7075	T6, T62, T76, T762	3	(76)
7049, 7075	T73	6	(152)
7178	T62	2	(51)
7178	T76	3	(76)
7079	T6, T62	7	(178)

3.4.3.2 Salt Baths: Shall not be used for parts in which molten salt could be retained. Rivets shall be placed in a tube closed at one end to prevent contact with the salt and the salt level maintained at least 6 in. (152 mm) above the level of the rivets during heating.

3.4.3.3 Clad Material: The maximum time of heating clad material shall not exceed 2 min. longer than the minimum time at temperature for thicknesses under 0.017 in. (0.43 mm), 5 min. longer than the minimum time for thicknesses 0.017 in. (0.43 mm) to 0.019 in. (0.48 mm), incl, or 10 min. longer than the minimum time for thicker material. Clad material that has been heat treated in accordance with this specification shall not be reheat treated unless authorized by the purchaser.

3.4.3.4 Rivets: Recovery time for rivet loads shall not exceed 30 min. and in no case shall the maximum effective thickness of the load exceed 3 in. (76 mm).

3.4.3.5 T411 Temper: When specified as a conditioning treatment for machining or nondestructive testing, material in "F" or "O" temper may be put in the T411 temper by heating to the solution treating temperature and then cooling in air. Material in this condition is considered to be equivalent to "O" temper for the purpose of determining the applicability of subsequent heat treatments.

3.4.3.6 Air Furnace Atmosphere: Fluorborate compounds may be used to prevent high temperature oxidation or blisters. Discoloration resulting from heat treatment is acceptable.

3.4.3.7 Quenching: The solution heat treated load shall be transferred from the working zone of the furnace while the load is still at the soaking temperature into the quench water with the least possible delay. The maximum time of delay permissible for the thinnest material in the load shall be as shown in Table IV. The delay period shall be the time from complete opening of a furnace door or the start of removal of the charge from a salt bath to complete immersion in the quenching water. Regardless of time, however, the transfer operation is acceptable if it is determined that the temperature of the thinnest part in the load, when measured at the instant of quenching, is above 775° F (413° C). Rivets, fasteners, fastener components, washers, spacers, and other small parts heated in tubes shall be quenched by dumping into water. The quench water temperature shall be maintained below 100° F (38° C) during the entire quenching operation, except for forgings and castings and for product to be heat treated to the T61 temper. Castings shall be quenched into water maintained between 150° - 212° F (65.6° - 100° C), except that alloy 242.0 (142) castings shall be cooled in still air for T77 temper. Forgings of 2000 series alloys shall be quenched in water maintained at 150° - 180° F (65.6° - 82.2° C), and all other forgings in water maintained at 140° - 160° F (60° - 71.1° C). Products to be heat treated to the T61 temper shall be quenched in boiling water.

TABLE IV

SOLUTION HEAT TREAT SOAK TIME AND PERMISSIBLE QUENCH DELAY

Minimum Soak Time, Minutes	Thickness		Maximum Quench Delay, sec
	Inches	(Millimetres)	
10	0.010 - 0.012, incl	(0.25 - 0.30 incl)	4
10	Over 0.012 - 0.015, incl	(Over 0.30 - 0.38 incl)	5
10	Over 0.015 - 0.019, incl	(Over 0.38 - 0.48 incl)	6
15	Over 0.019 - 0.030, incl	(Over 0.48 - 0.76 incl)	7
20	Over 0.030 - 0.063, incl	(Over 0.76 - 1.60 incl)	10
25	Over 0.063 - 0.090, incl	(Over 1.60 - 2.29 incl)	10
30	Over 0.090 - 0.125, incl	(Over 2.29 - 3.18 incl)	15
35	Over 0.125 - 0.250, incl	(Over 3.18 - 6.35 incl)	15
45	Over 0.250 - 0.500, incl	(Over 6.35 - 12.70 incl)	25
△1	Over 0.500	(Over 12.70)	25

△1 - 45 min. plus 20 min. for each 0.5 in. (13 mm) over 0.5 in. (13 mm) thickness or fraction thereof.

3.4.3.8 Refrigeration of Freshly Quenched Parts: The fresh "W" condition may be preserved up to 170 hr by cooling below 0° F (-18° C), or up to 30 days by cooling below -10° F (-23° C). When material or parts are specified to be refrigerated, cool below 0° F (18° C) within 1 hr and maintain refrigeration such that excursions above 0° F (-18° C) to a maximum of 30° F (-1° C) are limited to 100 F deg-hr (56 C deg-hr) per day, until required for further processing. Parts or material may be immersed in liquified gas or refrigerant to aid cooling of thick sections. All 2024 rivets shall be refrigerated, and 3/32 in. (2.38 mm) diameter 2117 rivets may be refrigerated when specified by the purchaser, until driven. Other 2117 and 2017 rivets shall be aged 96 hr at ambient temperature before driving.

3.4.4 Aging and Precipitation Heat Treatment:

3.4.4.1 Room Temperature Aging: After quenching, the 2000 and 6000 series alloys attain the T42 temper in about 4 days at ambient temperature. No further heat treatment is permissible for parts for which T42 temper is specified as the final condition, except reheat treatment of bare material and parts. Reheat treatment shall consist of optional annealing and then re-solution heat treating.

TABLE V

SOLUTION HEAT TREATMENT

Alloy (Any temper and product)	Solution Heat Treating Temperature °F	(°C)	Temper After Heat Treatment
2014	925 - 945	(496.1 - 507.2)	T42
2017	925 - 950	(496.1 - 510)	T42
2018	940 - 970	(504.4 - 521.1)	T4
2117	925 - 950	(496.1 - 510)	T42
2024	910 - 930	(487.8 - 498.9)	T42
2025	950 - 970	(510 - 521.1)	T4
2218	940 - 960	(504.4 - 515.6)	T4 & T41
2219	985 - 1005	(529.4 - 540.6)	T42
2618	975 - 995	(523.9 - 535)	T4
4032	940 - 960	(504.4 - 515.6)	T4
6061	960 - 1000	(515.6 - 537.8)	T42
6063	960 - 980	(515.6 - 526.7)	T42
7049	865 - 885	(462.8 - 473.9)	W
7075 Up to 0.050 in. (12.7 mm), incl	910 - 930	(487.8 - 498.9)	W
7075 Over 0.050 in. (12.7 mm) to 1.000 in. (25.4 mm) incl.	865 - 930	(462.8 - 498.9)	W
7075 Over 1.000 in. (25.4 mm)	865 - 885	(462.8 - 473.9)	W
7079	820 - 870	(437.8 - 465.6)	W
7178 (sheet)	860 - 930	(460 - 498.9)	W
7178 (plate)	860 - 910	(460 - 487.8)	W
7178 (extrusions)	860 - 880	(460 - 471.1)	W
A201.0 (KO-1) ⚠1	930 - 950	(498.9 - 510)	
	+950 - 970	(510 - 521.1)	
	+970 - 990	(521.1 - 532.2)	T4
242.0 (142) ⚠2	950 - 980	(510 - 526.7)	T4
295.0 (195)	940 - 970	(504.4 - 521.1)	T4
355.0 (355)	960 - 990	(515.6 - 532.2)	T4
356.0 (356)	980 - 1010	(526.7 - 543.3)	T4
A356.0 (A356)	980 - 1010	(526.7 - 543.3)	T4
A357.0 (A357)	980 - 1010	(526.7 - 543.3)	T4

⚠1 Three step operation: soak at each temperature 8 - 9 hr starting with lowest range.
⚠2 For 242.0-T77, air cool and precipitation heat treat.

3.4.4.2 Precipitation Heat Treatment: Parts to be precipitation heat treated shall be heated to the temperature and for the time specified in Table VI for the applicable starting condition and final temper, followed by cooling in air. Segregated lots of alloys or tempers requiring different heating times at the same temperature may be processed together if the furnace door is opened for not longer than 2 min. to remove the lot requiring the shorter heating time. Under no circumstances shall cold material be introduced to a furnace containing other material being precipitation heat treated. After precipitation heat treatment, no further heating of parts is permissible except for reheat treating of bare material or parts or overaging to the T7X tempers. Reheat treatment shall consist of optional annealing and then both re-solution heat treatment and precipitation heat treatment.

3.4.4.3 Stress Relief of 5000 Series: When specified, 5083, 5086, and 5456 alloy parts shall be heated for at least 30 min. at 450° F ± 10 (232.2° C ± 5.6) and cooled in air. Welded assemblies shall be heated for at least 15 min. at 550° F ± 10 (287.8° C ± 5.6).

3.5 Properties: Heat treatment shall produce properties in the parts conforming to the values specified for the final heat treated temper of the parts by the specification for the material from which the parts were made, including conductivity and corrosion resistance for the T7X tempers, unless otherwise specified by the drawing or purchase order.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of heat treated products shall supply all samples and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.6. Purchaser reserves the right to perform such confirmatory testing as he deems necessary to assure that the product conforms to the requirements of this specification.

4.2 Classification of Tests: Tests to determine conformance to all technical requirements of this specification are classified as acceptance or routine control tests.

4.3 Sampling: Shall be in accordance with the following; material used as test specimens shall conform to applicable material specifications.

4.3.1 Qualification: For qualification of equipment, not less than nine 7075 or 2024 alloy tensile test specimens shall be solution and precipitation heat treated in accordance with the use of each furnace at the test locations specified in 3.2.2.1.1. The specimens may be heat treated concurrent with the temperature uniformity survey, separately, or with a production load. Tensile tests shall be performed in accordance with ASTM B557.

4.3.2 Production: When specified, one or more specimens representing the thickest and thinnest sections of the parts and of the same alloy and product as the parts, shall be distributed through the load and processed with the parts.

4.4 Approval: Processor shall submit results of qualification tests and surveys for approval of the purchaser before parts for production use are supplied, unless such approval be waived. If necessary to make any change or repair for which requalification is required, no production parts shall be processed prior to receipt of reapproval.

4.5 Heat Treatment Log: A log for each heat treat load shall be maintained to verify conformance to the requirements of this specification of the following: qualification of equipment, alloy and temper, arrangement of load, recovery time, furnace temperature control, time at temperature, quench delay time, and temperature of quench water for solution heat treatment, and the date of heat treatment. The log shall be traceable to all furnace records and recorder charts and shall be retained for inspection for at least two years.

4.6 Reports: The vendor of heat treated products shall furnish with each shipment three copies of a report showing the heat treat log entry reference for each furnace charge of heat treated parts, the results of tests to determine conformance to the requirements of this specification, and a statement that the charge was processed in conformance to the requirements of this specification. This report shall include the purchase order number, this specification number, material specification number, part numbers, alloy, and quantity.

4.7 Resampling and Retesting: Shall be as agreed upon by purchaser and vendor.

5. PREPARATION FOR DELIVERY:

5.1 Identification: When specified, parts shall be identified as agreed upon by purchaser and vendor.

5.2 Packaging: Parts shall be handled and transported so as to preserve the required physical characteristics and properties.

6. ACKNOWLEDGMENT: A vendor shall mention this specification number in all quotations and when acknowledging purchase orders.

7. REJECTIONS: Parts and material not heat treated in accordance with this specification or with authorized modifications will be subject to rejection. Evidence of eutectic melting, intergranular-corrosion susceptibility, or high-temperature oxidation, or failure of any test specimen to meet specified requirements shall be cause for rejection of parts and requalification of equipment.

8. NOTES:

8.1 Overaged (T7X) Material Properties: Each lot of 7000 series material intended to be heat treated to any of the T7X tempers as the final condition should be sampled for capability of meeting specified mechanical property and corrosion resistance requirements when processed in accordance with this specification, or the purchaser should require as a condition of acceptance the capability of the material to meet the specified properties when heat treated in accordance with the requirements of this specification to the T7X tempers.

8.2 Similar Specification: MIL-H-6088 is listed for information only and shall not be construed as an acceptable alternate unless all requirements of this specification are met.

TABLE VI

PRECIPITATION HEAT TREATMENT

Alloy	Product	Temper Before Treatment	Temperature °F	Temperature (°C)	Time Hours	Final Temper
2014	Sheet, Plate	T3 T4 T42 T451	310 - 330	(154.4 - 165.6)	18 - 20	T6 T6 T62 T651
	Wire, Rod Bar, Tube Extrusions	T4 T42 T451 T4510 T4511	340 - 360	(171.1 - 182.2)	8 - 10	T6 T62 T651 T6510 T6511
	Forgings Rolled Rings	T4 T42 T452	330 - 350	(165.6 - 176.6)	10 - 12	T6 T6 T652
2018	Forgings	T4	330 - 350	(165.6 - 176.7)	10 - 12	T6
2024	Sheet, Plate Wire, Rod Bar, Tube	T3 T351 T4 T42	370 - 380	(187.8 - 193.3)	9.5 - 10.5	T81 T851 T6 T62
	Sheet, Plate Wire, Rod Bar	T36 T361	370 - 380	(187.8 - 193.3)	5.5 - 6.5	T86 T861
	Sheet	T4 T42	370 - 380	(187.8 - 193.3)	15 - 17	T72 T72
	Extrusions Forgings	T4 T42 T3510 T3511	370 - 380	(187.7 - 193.3)	9.5 - 10.5	T81 T62 T8510 T8511
2025	Forgings	T4	330 - 350	(165.6 - 176.7)	10 - 12	T6

TABLE VI (Continued)

PRECIPITATION HEAT TREATMENT

Alloy	Product	Temper Before Treatment	Temperature °F	Temperature (°C)	Time Hours	Final Temper
2218	Forgings (1)	T4	330 - 350	(165.5 - 176.7)	10 - 12	T61
		T41	450 - 470	(232.2 - 243.3)	5.5 - 6.5	T72
	Sheet	T31	340 - 360	(171.1 - 182.2)	17 - 19	T81
		T37	315 - 335	(157.2 - 168.3)	23 - 25	T87
	Wire, Rod	T3510				T8510
2219	Bar Extrusions	T3511	340 - 360	(171.1 - 182.2)	17 - 19	T8511
		T37				T87
	All, Except Forgings	T42	365 - 385	(185 - 196.1)	35 - 37	T62
	Forgings	T4	365 - 385	(185 - 196.1)	25 - 27	T6
	Rolled Rings Hand Forgings	T352	340 - 360	(171.1 - 182.2)	17 - 19	T852
2618	Forgings (1)	T4	380 - 400	(193.3 - 204.4)	19 - 21	T61
4032	Forgings	T4	330 - 350	(165.6 - 176.7)	9 - 11	T6
	Sheet, Plate	T4				T6
	Rod, Bar	T42	310 - 330	(154.4 - 165.6)	18 - 20	T62
	Tube	T451				T651
6061	Extrusions	T4				T6
	Forgings	T42				T6, T61 (2)
	Rolled Rings	T4510	340 - 360	(171.1 - 182.2)	7.5 - 8.5	T6510
		T4511				T6511
		T452				T652
6063	All	T1	390 - 410	(198.9 - 210)	0.75 - 1.25	T5
		T4	340 - 360	(171.1 - 182.2)	7.5 - 8.5	T6
		T42				T62
7049	Forgings	W	240 - 260	(115.6 - 126.7)	24 - 25	T6
		T6	Ambient		48 minimum	
	Up to 4 in. (102 mm)		+330 - 340	(165.6 - 171.1)	12 - 14	T73
	Over 4 in. (102 mm)		+325 - 335	(162.8 - 168.3)	12 - 14	T73
	All Products	W	240 - 260	(115.6 - 126.7)	22 - 26	T6 (2)
7075	Sheet	T6	320 - 330	(160 - 165.6)	24 - 25	T73
	Plate	T651				T7351
	Extrusions	T6				T73
		T6510	345 - 355	(173.9 - 179.4)	7 - 7.5	T73510
		T6511				T73511
	Forgings	T6	345 - 355	(173.9 - 179.4)	8 - 8.5	T73
	Bar, Rod	T651	345 - 355	(173.9 - 179.4)	7 - 7.5	T7351
		T652				T7352
	Sheet	T6	320 - 330	(160 - 165.6)	16 - 17	T76
	Plate	T651				T7651
	Extrusions	T6				T76
		T6510	315 - 325	(157.2 - 162.8)	19 - 20	T76510
		T6511				T76511

(1) Boiling Water Quenched

(2) Forgings which were quenched in boiling water will be in the T61 temper after this treatment.

TABLE VI (Continued)

PRECIPITATION HEAT TREATMENT

Alloy	Product	Temper Before Treatment	Temperature °F	Temperature (°C)	Time Hours	Final Temper
7079	All	W	Ambient		120 minimum	
			+230 - 250	(110 - 121.1)	48 - 50	T6
7178	All	W	240 - 260	(115.6 - 126.7)	22 - 26	T6
	Sheet	T6	320 - 330	(160 - 165.6)	24 - 25	T73
	Plate	T651				T7351
	Extrusions	T65				T73
		T6510	345 - 355	(173.9 - 179.4)	7 - 7.5	T73510
		T6511				T73511
	Sheet	T6	320 - 330	(160 - 165.6)	16 - 17	T76
	Plate	T651				T7651
	Extrusions	T6510	315 - 325	(157.2 - 162.8)	19 - 20	T76510
		T6511				T76511
A201.0 (KO-1)	Castings	T4	Ambient		12 - 24	
			+300 - 320	(148.9 - 160)	18 - 20	T6
242.0 (142)	Castings	T4	640 - 660	(337.8 - 348.9)	1 - 3	T77
A242.0 (A142)	Castings	T4	540 - 560	(282.2 - 293.3)	2 - 5	T75
295.0 (195)	Castings	T4	300 - 320	(148.9 - 160)	12 - 20	T62
355.0 (355)	Castings	F	430 - 450	(221.1 - 232.2)	7 - 9	T51
		T4	300 - 320	(148.9 - 160)	3 - 5	T6
		T4	465 - 485	(240.6 - 251.7)	4 - 6	T71
C355.0 (C355)	Castings	T4	300 - 320	(148.9 - 160)	10 - 12	T61
356.0 (356)	Castings	F	430 - 450	(221.1 - 232.2)	7 - 9	T51
		T4	300 - 320	(148.9 - 160)	3 - 5	T6
		T4	390 - 410	(198.9 - 210)	3 - 5	T7
		T4	465 - 485	(240.6 - 251.7)	2 - 4	T71
A356.0 (A356)	Castings	T4	300 - 320	(148.9 - 160)	6 - 10	T61
A357.0 (A357)	Castings	T4	300 - 320	(148.9 - 160)	10 - 12	T61
		T4	330 - 350	(165.6 - 176.7)	6 - 10	T62
850.0 (750) A850.0 (A750) B850.0 (B750)	Castings	F	420 - 440	(215.6 - 226.7)	7 - 9	T5