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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2772

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Submitted for recognition as an American National Standard

HEAT TREATMENT OF ALUMINUM ALLOY RAW MATERIALS

1. SCOPE:

1.1 Purpose:

This specification covers requirements and recommendations for the heat treatment of wrought aluminum alloy raw materials (See 8.1.1 and 8.1.8). It is intended to replace MIL-H-6088.

1.1.1 Tempers: Aluminum alloy tempers are described in SAE AS1990 and ANSI H35.1.

1.1.2 Other Alloys: This specification may be used for alloys other than those specified herein providing temperatures, times, and quenchant are specified.

1.1.3 Other Heat Treatment:

1.1.3.1 Parts (See 8.1.2): Made from wrought raw material shall be heat treated in accordance with AMS 2770.

1.1.3.2 Castings and Parts Made from Castings: Although castings are not specifically covered within this specification, heat treatment of castings is covered by AMS 2771.

1.1.3.3 Samples for Response to Heat Treatment Tests: Should be heat treated by material producers, warehouses/distributors, and forge shops (e.g., heat treatment of -0 or -F temper material to -T42 or -T62 temper) should be performed in accordance with the temperatures, soaking times, and cooling rates specified in AMS 2770.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2750	Pyrometry
AMS 2770	Heat Treatment of Wrought Aluminum Alloy Parts
AMS 2771	Heat Treatment of Aluminum Alloy Castings
AS1990	Aluminum Alloy Tempers

2.2 ASTM Publications:

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

ASTM B 557	Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
ASTM B 557M	Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)
ASTM E 1004	Electromagnetic (Eddy-Current) Measurements of Electrical Conductivity
ASTM G 110	Evaluating Intergranular Corrosion Resistance of Heat Treatable Aluminum Alloys by Immersion in Sodium Chloride + Hydrogen Peroxide Solution

2.3 U.S. Government Publications:

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

MIL-H-6088	Heat Treatment of Aluminum Alloys
MIL-STD-1537	Electrical Conductivity Test for Verification of Heat Treatment of Aluminum Alloys, Eddy Current Method

2.4 ANSI Publications:

Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI H35.1	American National Standard Alloy and Temper Designation Systems for Aluminum

3. TECHNICAL REQUIREMENTS:

3.1 Equipment:

3.1.1 Pyrometry: Shall conform to AMS 2750 except that (1) requirements for working zone controls, instruments, and sensors shall apply in heating zones of continuous and semi-continuous furnaces and (2) recordings from instruments may be stored on magnetic or optical media providing a hard copy is available upon request.

3.1.1.1 Temperature Uniformity Tests:

3.1.1.1.1 Batch Furnaces: During the heat-up portion of tests performed with a load, the temperature of the heating medium may exceed the maximum of the range being surveyed provided that the metal temperature does not exceed that maximum.

3.1.1.1.2 Continuous and Semi-Continuous Furnaces: In the heating zone(s), the temperature of the heating medium may exceed the maximum of the range being surveyed provided that the metal temperature does not exceed that maximum.

3.1.1.1.3 Metal Temperature: Shall be determined by load sensors in contact with the metal distributed around the periphery of the load. The minimum number of load sensors shall be one-half the required number of test sensors.

3.1.1.1.4 The following temperature tolerances take precedence over those of AMS 2750:

3.1.1.1.4.1 ±50 F (±28 C) degrees for furnaces used only for annealing and stress relieving.

3.1.1.1.4.2 ±30 F (±17 C) degrees for furnaces used only for solution heat treatment of those 6XXX alloys for which Table 1 specifies a range of ±30 F (±17 C) degrees or more.

3.1.1.1.4.3 ±20 F (±11 C) degrees for furnaces used for other solution heat treatment, any aging treatment, and processing to the 01 temper at the temperature shown in Table 1.

3.1.2 Heating Media: Shall be air, protective atmosphere, combusted gases, molten salt bath, oil bath, or fluidized bed. Use of solution heat treating furnaces in which the products of combustion or protective atmosphere contact the product is limited to alloys and forms which have been demonstrated by test, in accordance with 4.5.1, to be free from porosity caused by the products of combustion. Composition and maintenance of salt baths and fluidized beds shall be maintained to prevent attack of the product.

3.2 Preparation for Heat Treatment:

3.2.1 Cleanliness: Prior to heat treating, product shall be free from surface contaminants which might have a detrimental effect.

3.2.2 Racking and Spacing: Product shall be supported or hung and spaced to permit flow of the heating and cooling media over all surfaces to ensure that the product will meet the specified requirements. Alternate racking methods are acceptable if tests have been performed to demonstrate that all product so racked will meet specified requirements. Written instructions, drawings, photographs, etc shall be used to ensure proper racking.

3.2.2.1 Thin Forgings: Random racking or layering of forgings, 1-inch (25-mm) and under in thickness (See 8.1.4), is permissible for solution heat treating which includes immersion quenching, aging, and annealing providing product so racked has been demonstrated by test to meet the specified requirements. Layer thickness shall not exceed 3-inches (76-mm) and distance between layers shall be at least three inches (76 mm).

3.3 Solution Heat Treatment:

Product shall be soaked within the temperature range specified in Table 1 and quenched as specified in 3.3.2.

3.3.1 Soaking Time: After furnace instrument(s) (or the load if load sensors are used) has reached the minimum of the required solution heat treating temperature range, the product shall be soaked within that temperature range for sufficient time to ensure development of specified properties after aging. Recommended soaking times are listed in Table 2.

3.3.1.1 During soaking in a continuous or semi-continuous air furnace, a drop in temperature indicated by furnace instrument(s) is permissible provided (1) that temperature does not drop more than 20 F (11 C) degrees below the minimum of the specified range, (2) time below the minimum of the specified range does not exceed five minutes, and (3) soaking is continued for not less than of 10 minutes after recovery before quenching.

3.3.1.1.1 If furnace temperature does not drop more than 20 F (11 C) degrees below the minimum of the specified range, but does not recover to the minimum of the specified range within five minutes, the total soaking time, if less than one hour was required, shall be increased by one-half hour. If one hour or more was required the total soaking time shall be increased by one hour.

3.3.2 Quenching: 2XXX and 7XXX alloy forgings shall be quenched by immersion. Quenching of other forms of 2XXX and 7XXX alloys and all forms of other alloys shall be by immersion, spray (See 4.3) or, in a suitable chamber, by air blast. Quenchant for immersion and spray quenching shall be water, aqueous polymer solution, or other quenchant approved by the cognizant engineering organization (See 8.1.3). Agitation of quenchant and/or product, quenchant temperature, velocity, and distribution shall be sufficient to ensure that all product will meet specified requirements after aging.

3.3.2.1 Quench Delay for Immersion Quenching: Shall conform to Table 3.

3.3.2.2 Quenchant Control:

3.3.2.2.1 Forgings and Impact Extrusions: If water is used for quenching, water temperature should be 140 to 180 °F (60 to 82 °C) for 2014 and 2024 alloys and 140 to 160 °F (60 to 71 °C) for other alloys except that when final temper is T41 or T61, quenching shall be by immersion in boiling water. If aqueous polymer solution is used for quenching, the quenchant temperature shall not exceed 130 °F (54 °C) at the completion of the quench.

3.3.2.2.2 Other Forms of 2XXX and 7XXX Alloys: If water immersion quenching is used, the water temperature shall not exceed 100 °F (38 °C) at the start of quench and 110 °F (43 °C) at the completion of the quench (3.3.2.2.4). If aqueous polymer immersion quenching is used, the quenchant temperature shall not exceed 130 °F (54 °C) at the completion of the quench (3.3.2.2.4).

3.3.2.2.3 Salt Contamination in Aqueous Polymer Solutions: When an aqueous polymer solution is used for quenching product heated in a salt bath furnace, salt contamination shall not exceed 6.0% by weight.

3.3.2.2.4 Immersion Quench Completion: Product under 0.250 inch (6.35 mm) in thickness shall remain in the quenchant until boiling ceases. Shorter immersion periods are permissible provided that statistical analysis of data ensures that specified properties are achieved after aging. Product 0.250 inch (6.35 mm) and over in thickness shall remain in the quenchant for not less than two minutes per inch (25 mm) of thickness, or fraction thereof or for not less than two minutes after boiling ceases.

3.3.2.2.5 Other Quench Completion: Product quenched by spray or air blast shall remain in contact with the quenchant until surface temperature of the product is below the boiling point of water.

3.3.3 Restrictions on Alclad Products:

3.3.3.1 Heat-Up Time: The time required for sheet material to reach the minimum of the specified temperature range shall not exceed 30 minutes for thicknesses up to 0.049 inch (1.24 mm), 60 minutes for thicknesses from 0.050 to 0.101 inch (1.27 to 2.57 mm), and 120 minutes for thicker sheet.

3.3.3.2 The soaking time required, to ensure all lots will develop specified properties after aging, shall be established for each alloy/form/thickness. The total soaking time used for any lot (single or multiple solution heat treatments) shall be limited; the limit shall ensure that alclad thickness will meet the requirements of the material specification.

3.3.3.3 Re-solution Heat Treatment: The number of re-solution heat treatments of alclad 2XXX and 7XXX alloy products shall be restricted to not more than one re-solution heat treatment for thicknesses from 0.020 to 0.125 inch (0.51 to 3.18 mm) and not more than two re-solution heat treatments for thicknesses over 0.125 inch (3.18 mm); product thinner than 0.020 inch (0.51 mm) shall not be reheat treated.

3.3.3.4 The restrictions of 3.3.3.1, 3.3.3.2, and 3.3.3.3 are not applicable to any lot of product which is tested to ensure conformance to the alclad thickness requirement of the material specification.

3.4 Aging:

Recommended aging times/temperatures are shown in Table 4. Alternate times/temperatures may be used provided the aged material meets specified requirements.

3.5 Conversion:

When an organization other than the producer (i.e., warehouse/distributor, etc) specifies heat treatment of raw material to convert it to a different temper in accordance with this specification, the heat treatment shall conform to AMS 2770 and the heat treated product shall be tested for conformance to requirements of the material specification. The report to purchaser shall include the heat treatment procedure, test results, and a copy of the original mill certification.

3.6 Annealing:

Recommended times, temperatures, and cooling procedures are as follows:

3.6.1 1XXX, 3XXX, and 5XXX Series Alloys Except 3003: Heat to 650 °F (343 °C); cooling rate optional.

3.6.2 3003 Alloy: Heat to 775 °F (413 °C); cooling rate optional.

3.6.3 2XXX and 6XXX Series Alloys Except 2036 and 6013: Soak for two to three hours at 760 °F (404 °C); cool at rate of 50 F (28 C) degrees per hour or slower to 500 °F (260 °C); further cooling rate optional.

3.6.4 2036 Alloy: Soak for two to three hours at 725 °F (385 °C); cool at rate of 50 F (28 C) degrees per hour or slower to 500 °F (260 °C); further cooling rate optional.

3.6.5 6013 Alloy: Soak for two to three hours at 775 °F (413 °C); cool at rate of 50 F (28 C) degrees per hour or slower to 500 °F (260 °C); further cooling rate optional.

3.6.6 7XXX Series Alloys: Soak for two to three hours at 760 °F (404 °C); cool to 400 °F (204 °C) or lower, reheat to 450 °F (232 °C), and soak for four hours; cooling rate optional.

3.7 Processing to -01 Temper:

Should consist of heating product to the temperature shown in Table 1 followed by an air cool.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The producer is responsible for the performance of all inspections and specified tests.

4.2 Records:

4.2.1 Inspections and Tests: Records of all inspections and tests shall be kept available for review for five years after the inspection or test.

4.2.2 Production: Records of all applicable production parameters, e.g., racking, time, temperature, quenchant temperature and pressure, and quench delay shall be kept available for review for five years after heat treatment.

4.3 Testing and Inspection - Air Blast and Spray Quenching Equipment:

4.3.1 Tests and Frequency: The following tests of each furnace/quench unit combination shall be performed initially (not required for equipment previously qualified in accordance with MIL-H-6088) and as specified below, and after any modification of the equipment which could affect the quenching characteristics, e.g., nozzle size change, manifold size change, pump size change.

4.3.1.1 Quench Procedure: A load of sheet, plate, extrusions, rod, or bar shall be quenched in the equipment and tested in accordance with 4.3.1.2 and 4.3.1.3.

4.3.1.1.1 Alloy Selection - Order of Preference:

Weekly Test: (1) 7X75 or 2X24, (2) other 7XXX

Annual Test: 7X75, 2XXX, other 7XXX, other

4.3.1.1.2 Thickness for the weekly test (4.3.1.2) shall be the maximum thickness (of the alloy selected) available on the day of selection for test, subject to the following: at least once during each calendar quarter, the thickest material of each alloy/form used for the weekly test shall be tested.

4.3.1.1.3 Thickness for the annual test (4.3.1.3) shall be the maximum (of the alloy selected) available during the week of selection for test.

4.3.1.2 Initial and Weekly Uniformity (Not Applicable to Sheet and 6XXX Alloys): The electrical conductivity of the product, in the W or -T4 temper, shall be measured in accordance with ASTM E 1004 using equipment calibrated in accordance with MIL-STD-1537; measurement of conductivity of 7075 alloy shall not be started until 10 hours of room temperature aging have elapsed.

4.3.1.2.1 Location of Measurements - Plate: Measurements shall be made on both sides (faces) at four-inch (102-mm) maximum intervals across the width and 24-inch (610-mm) maximum intervals along the length. For continuously quenched product, a minimum length of 12 feet (3.7 m) shall be tested. For non-continuously quenched product the entire product shall be tested. Measurement locations for each successive traverse across the width shall be offset by one inch (25 mm) so as to test one inch (25 mm) increments across the width over each 48 inches (1.2 m) of length.

4.3.1.2.2 Location of Measurements - Extrusion, Rod, and Bar: Measurements shall be made at 12-inch (305-mm) maximum intervals across the width of the load, two-inch (51-mm) maximum intervals around the product section perimeter, and 24-inch (610-mm) maximum intervals along the length. For continuously quenched product, a minimum length of 12 feet (3.7 m) shall be tested; for non-continuously quenched product, the entire product shall be tested.

4.3.1.2.3 Acceptance Criteria: The range of the conductivity on one side (face) of any plate shall not exceed 2.5% International Annealed Copper Standard (1.45 MS/m IACS). The range of conductivity of any extrusion, rod, or bar shall not exceed 4% IACS (2.32 MS/m IACS) overall, but shall not exceed 3% IACS (1.74 MS/m IACS) on any one element (flange, web, etc). In addition, the conductivity of any 7075 alloy product shall not exceed the following: 31% IACS (17.98 MS/m IACS) for plate; 32% IACS (18.56 MS/m IACS) for extrusion, rod, or bar.

4.3.1.3 Initial and Annual Quench Effectiveness Test: Tensile specimens, oriented in accordance with specified requirements and aged to the final temper, shall be excised from the product and tested in accordance with ASTM B 557 or ASTM B 557M. The specimen locations shall be:

4.3.1.3.1 Thickness: At the center of the thickness (T/2) or halfway between the center and the surface (T/4) or full thickness in accordance with specification requirements.

4.3.1.3.2 Length: For extrusions, rod, bar, and continuously quenched sheet or plate - both ends. For non-continuously quenched sheet or plate - both ends and center.

4.3.1.3.3 Width: For sheet and plate, four equally-spaced locations but not closer than 6 inches (152 mm) nor more than 9 inches (229 mm) from each edge. For extrusions, rod, and bar, at 6 to 12-inch (152 to 305-mm) intervals across the width of the load.

4.3.1.3.4 Tensile Properties: Shall meet specified requirements.

4.3.2 Periodic Inspection:

4.3.2.1 Pressure and Flow: Shall be inspected and recorded daily during production to ensure proper operation at the specified pressure.

4.3.2.2 If inspection of pressure and flow reveals improper operation, the equipment shall not be used for production until the cause has been corrected and a successful weekly test (4.3.1.1) has been performed.

4.4 Metallurgical Testing:

The following tests shall be performed on production product from each solution heat treating furnace initially and monthly thereafter and after any modification of the equipment which could affect the metallurgical properties of the product.

4.4.1 Porosity and Eutectic Melting: A sample of the thinnest 2XXX or 7XXX sheet (non-clad for porosity testing) heat treated during the previous calendar month (See 8.1.5) shall be tested in accordance with 4.5.1. If sheet was not heat treated, a sample of the thinnest product of an alternate form (order of preference: tube, extrusion, wire, rod, bar, plate, forging) shall be tested.

4.4.2 Intergranular Corrosion Susceptibility of Sheet, Wire, or Extrusion: A sample of the thickest (under 0.250 inch (6.35 mm)) product solution heat treated during the previous calendar month (See 8.5) shall be tested in accordance with 4.5.2. Primary order of preference shall be based on alloy/temper as follows: (1) 2XXX in -T3 or -T4 temper, (2) 7XXX in -T6 temper. Secondary order of preference shall be based on form as follows: (1) sheet, (2) extrusion, (3) wire. No test is required if 2XXX-T3 or -T4 or 7XXX-T6 in the above categories was not solution heat treated.

4.5 Test Methods and Acceptance Criteria:

4.5.1 Porosity and Eutectic Melting: One or more specimens taken from the solution heat treated sample(s) shall be sectioned, polished, and examined at 500X magnification before and after etching. The specimen(s) shall be free from eutectic melting and heat treat induced porosity, i.e., a greater concentration of porosity at grain boundaries near the surface than at the center.

4.5.2 Intergranular Corrosion Susceptibility: The sample shall be prepared and tested in accordance with ASTM G 110 modified as follows:

4.5.2.1 Specimen surface area shall be not less than 4 square inches (25.8 sq cm) (sum of both sides) except, for wire, a minimum length of 4 inches (102 mm) shall suffice.

4.5.2.2 Removal of cladding may be confirmed by either examination of specimen surfaces or microscopic examination of metallographic cross sections.

4.5.2.3 After immersion in the etching cleaner and nitric acid, the specimen shall be rinsed in water and either (1) air dried or (2) immersed in the test solution.

4.5.2.4 The immersion period in the test solution shall be six to seven hours.

4.5.2.5 After exposure in the test solution, corrosion products shall be removed by simultaneously rinsing in tap water and brushing with a soft bristle brush.

4.5.2.6 Metallographic examination shall be between 200 and 500X magnification.

4.5.2.7 The degree of susceptibility to intergranular corrosion exhibited by the major surfaces of the sample (end-grain attack shall be disregarded) shall be no greater than that normally experienced when following the requirements and recommendations of this specification.

4.6 Test Failures:

If, due to a deficiency of heat treatment equipment, (1) any valid test fails to meet specified requirements, or (2) any valid test (after retesting, if permitted) fails to meet a requirement of the material specification, the equipment shall not be used for production until the cause has been corrected and the test has been performed successfully.

4.6.1 In addition, the quality assurance organization responsible for the equipment shall evaluate possible effects of the failure on product processed since the last successful test. The evaluation shall be documented and, where necessary, shall include consultation with metallurgists, engineers, and purchasers. Appropriate corrective action shall be taken and documented.

5. PREPARATION FOR DELIVERY:

Not applicable.

6. ACKNOWLEDGMENT:

Not applicable.

7. REJECTIONS:

Not applicable.

8. NOTES:

8.1 Clarification of terms used in AMS is presented in ARP1917 and as follows:

8.1.1 Raw Material (e.g., sheet, plate, wire, rod, bar, forgings, extrusions): Usually is identified by a heat treat or inspection lot number and is usually tested destructively for acceptance. It is heat treated, by or for a material producer, in accordance with a material specification which may require, by reference, conformance to a heat treating specification.

8.1.2 Parts: Usually identified by a part number, are produced from raw material in accordance with requirements of a drawing, and are usually tested by nondestructive techniques only. They are heat treated, by or for a fabricator, in accordance with a drawing, purchase order, fabrication order, or heat treatment specification. At time of heat treatment, they may resemble raw material.

8.1.3 Cognizant Engineering Organization: The engineering organization responsible for the design of the parts to be fabricated from the product, or its designee.

8.1.4 Thickness: Thickness of forgings and extrusions is the minimum dimension of the heaviest section.

8.1.5 Samples for Metallurgical Tests: May be taken from remnants of samples taken in accordance with material specification requirements.

8.1.6 Mandatory and Non-Mandatory Provisions: The word "shall" identifies mandatory provisions; "should", "may", and "recommended" identify non-mandatory provisions.

8.1.7 Press Quenching: As a substitute for the quenching specified herein, is not covered by this specification.

8.1.8 Forms: "Forgings" includes die and hand forgings and rolled rings. "Extrusions" includes wire, rod, bar, profiles (shapes), and tubes.

8.2 Processes meeting the requirements of this specification are classified under Federal Supply Classification (FSC) 95GP.

PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE "D" AND "AMEC"

TABLE 1 - Solution Heat Treating Temperatures

Alloy	Product Form (See 8.1.8)	Temperature (1)(2) °F	Temperature (1)(2) °C	Alloy	Product Form (See 8.1.8)	Temperature (1)(2) °F	Temperature (1)(2) °C
2011	wire, rod, bar	945-995	507-535	6063	extrusion	960-985	516-529
2014	all	925-945	496-507	6066	all	960-1010	516-543
2017	wire, rod, bar	925-950	496-510	6151	forgings	950-980	510-527
2018	forgings	940-970	504-521	6262	all	960-1050	516-566
2024	all (3)	910-930	488-499	6951	sheet	975-995	524-535
2025	forgings	950-970	510-521	7001	extrusion	860-880	460-471
2048	sheet, plate	910-930	488-499	7010	plate, forgings	880-900	471-482
2117	wire, rod, bar	925-950	496-510	7039	plate	750-880	399-471
2124	plate	910-930	488-499	7039	other	840-860	449-460
2218	forgings	940-960	504-516				
2219	all	985-1005	529-541	7049/7149	all	860-900	460-482
2324/2424	all	910-930	488-499	7050	all	880-900	471-482
2419	plate	990-1010	532-543	7075	forgings	860-900	460-482
2524	sheet, plate	910-930	488-499	7075	other (4)	860-930	460-499
2618	forgings	975-995	524-535	7076	forgings	850-910	454-488
4032	forgings	940-970	504-521	7150	plate, extrusion	880-900	471-482
6010	sheet	1045-1065	563-574	7175	plate, extrusion	880-910	471-488
6013	sheet	1045-1065	563-574	7178	sheet	860-930	460-499
6013	rod, bar	990-1045	532-563	7475	sheet (5), plate	880-970	471-521
6053	forgings	960-980	516-527	8090	sheet	990-1000	532-538
6061	all	960-1075	516-579	8090	plate	990-1025	532-552

NOTES:

(1) Set temperature shall be selected so as to ensure, based on temperature uniformity tests and/or load sensors, the product is soaked within the selected range.

(2) During heating of a load, until it reaches the selected range, the temperature of the heating medium may exceed maximum temperature providing that the temperature of the metal in the load does not exceed the maximum.

(3) For wire, rod, and bar, minimum temperature of 900 °F (482 °C) is permissible provided that statistical analysis of the test results, in accordance with MIL-HDBK-5 or ASTM STP 15D, shows, with a 95% confidence level, that 99% of the material meets specification requirements.

(4) For alclad sheet, 0.020 inch (0.51 mm) and under in thickness, minimum temperature of 850 °F (454 °C) is permissible; for alclad sheet over 0.020 inch (0.51 mm) in thickness, temperature should not exceed 900 °F (482 °C).

(5) For alclad sheet, maximum temperature shall be 945 °F (507 °C).

TABLE 2 - Recommended Minimum Soaking Time for Solution Heat Treatment of Wrought Products

Thickness (See 8.1.4) Inches	Thickness (See 8.1.4) Millimeters	Minimum Soaking Time Minutes (1) Salt Bath	Minimum Soaking Time Minutes (1) Air Furnace or Fluidized Bed
Up to 0.020, incl	Up to 0.51, incl	10	20
Over 0.020 to 0.032, incl	Over 0.51 to 0.81, incl	15	25
Over 0.032 to 0.063, incl	Over 0.81 to 1.60, incl	20	30
Over 0.063 to 0.090, incl	Over 1.60 to 2.29, incl	25	35
Over 0.090 to 0.124, incl	Over 2.29 to 3.15, incl	30	40
Over 0.124 to 0.250, incl	Over 3.15 to 6.35, incl	35	50
Over 0.250 to 0.500, incl	Over 6.35 to 12.70, incl	45	60
Over 0.500 to 1.000, incl	Over 12.70 to 25.40, incl	60	90
Over 1.000 to 1.500, incl	Over 25.40 to 38.10, incl	90	120
Over 1.500 to 2.000, incl	Over 38.10 to 50.80, incl	105	150
Over 2.000 to 2.500, incl	Over 50.80 to 63.50, incl	120	180
Over 2.500 to 3.000, incl	Over 63.50 to 76.20, incl	135	210
Over 3.000 to 3.500, incl	Over 76.20 to 88.90, incl	150	240
Over 3.500 to 4.000, incl	Over 88.90 to 101.60, incl	165	270
Over 4.000	Over 101.60	add 15 per 0.500 inch (12.70 mm)	add 30 per 0.500 inch (12.70 mm)

NOTE:

(1) Soaking time for alclad products should be minimized to preclude reduction of alclad thickness below the minimum thickness requirement of the material specification (See 3.3.3.2).

TABLE 3 - Maximum Quench Delay (for Immersion Quenching) (1)

Nominal Thickness Inch	Nominal Thickness Millimeters	Maximum Time (Seconds)
Up to 0.016, incl	Up to 0.41, incl	5
Over 0.016 to 0.031, incl	Over 0.41 to 0.79, incl	7
Over 0.031 to 0.090, incl	Over 0.79 to 2.29, incl	10
Over 0.090	Over 2.29	15

NOTE:

(1) Quench delay time begins when the furnace door starts to open or when the first corner of the load emerges from a salt bath and ends when the last corner of the load is immersed in the quenchant. With the exception of 2219 alloy, the maximum quench delay times may be exceeded if results of tests prove that all product in the load will be above 775 °F (413 °C) when quenched. For 2219 alloy, the maximum quench delay times may be exceeded if results of tests prove that all product in the load will be above 900 °F (482 °C) when quenched.