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AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2772B

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Superseding AMS 2772A

Submitted for recognition as an American National Standard

(R) 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 8.2.1). It is intended to replace AMS-H-6088 and 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 8.2.2): Made from wrought raw material shall be heat treated in accordance with AMS 2770.

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

1.1.3.3 Response-to-Heat-Treatment Tests: Procedure for heat treatment of samples by material producers and forge shops (for example, heat treatment of -0 or -F temper material to -T42 or -T62 temper) shall include conformance, for the alloys and forms listed, with the mandatory solution heat treatment temperatures in Table 1, Note 6, and the mandatory aging temperatures and times in Table 4, Note 5.

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.

QUESTIONS REGARDING THIS DOCUMENT: (724) 772-7154 FAX: (724) 776-0243
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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
AMS-H-6088	Heat Treatment of Aluminum Alloys
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 (1) it is not applicable to furnaces used only for stress relieving or full annealing below 825 °F (441 °C), (2) recordings from instruments may be stored on magnetic or optical media providing a hard copy is available on request, (3) in continuous and semi-continuous furnaces, the requirements applicable to controls, instruments, and sensors in the working (soaking) zone shall also be applicable to the heating (heat-up) zone and (4) temperature uniformity test requirements of AMS 2750 shall be modified as follows:

3.1.1.1 Load Condition: Initial tests shall be performed with a typical load. For in-production furnaces not previously so tested, such a test shall be performed within six months of AMS 2772B publication.

3.1.1.2 Load Sensors: When all production loads are heavy (See 8.2.8) and a temperature uniformity test load is heavy, load sensors may be used at the specified locations, in lieu of the required uniformity test sensors.

3.1.1.3 Loaded Furnaces: During the heat-up portion of uniformity tests performed on a loaded batch furnace and during the period that a load is in the heating (heat-up) zone(s) of continuous and semi-continuous furnaces, the temperature of the heating medium may exceed the maximum of the range being surveyed providing that the metal temperature does not exceed that maximum.

3.1.1.4 Uniformity Requirements: After establishment of thermal equilibrium or a recurrent temperature pattern, the temperature of all working and test sensors in the working (soaking) zone shall be within the following allowable ranges (these ranges supersede the ± temperature tolerances specified in AMS 2750):

3.1.1.4.1 50 F (28 C) degrees for furnaces used only for full annealing at 825 °F (441 °C) and higher except 20 F (11 C) degrees if within 15 F (8 C) degrees of the middle of the solution heat treating temperature range.

3.1.1.4.2 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.

3.1.1.4.3 20 F (11 C) degrees for furnaces used for other solution heat treatment, any aging heat treatment and processing to the -01 temper within the Table 1 temperature range.

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 or the protective atmosphere. 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 all product will meet the specified requirements. Load arrangement shall be validated by heat treatment of a similarly arranged load (See 8.2.9) containing one or more appropriately placed load sensors which showed that all product will be soaked within the specified range for a time which has been previously shown, by tensile tests, to produce the specified properties (not required for load arrangements which have been previously validated in accordance with MIL-H-6088). Written instructions, drawings, photographs, etc. shall be used to ensure proper load arrangements.

3.2.2.1 Thin Forgings: Random racking or layering of forgings, 1-inch (25-mm) and under in thickness (See 8.1.3), 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 three inches (76 mm) and distance between layers shall be at least three inches (76 mm) (not required for load arrangements which have been previously validated in accordance with MIL-H-6088).

3.3 Furnace Temperature:

Shall be controlled so as to ensure that the metal temperature does not exceed the maximum of the range.

3.3.1 When a load is charged into a batch furnace whose indicated temperature is higher than the maximum of the specified range, a recording load sensor, in contact with the thinnest material on the outside of the load, shall be used to verify that the metal temperature did not exceed the maximum of the range.

3.4 Solution Heat Treatment:

Product shall be soaked within the temperature range specified in Table 1 and quenched as specified in 3.4.2.

3.4.1 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.

3.4.1.1 Soaking time shall be based on tests, of the load arrangement, or a similar load arrangement, (See 8.2.9) containing one or more appropriately placed load sensors, which showed that all product in the load will be soaked within the specified temperature range for a time which has been previously shown, by tensile tests, to produce the specified properties (not required for soaking times which have been previously validated in accordance with MIL-H-6088).

3.4.1.2 During soaking in a semi-continuous air furnace, a drop in temperature indicated by furnace instrument(s) is permissible providing that:

3.4.1.2.1 Temperature does not drop more than 20 F (11 C) degrees below the minimum of the specified range.

3.4.1.2.2 Time below the minimum of the specified range does not exceed five minutes.

3.4.1.2.3 Soaking is continued for not less than 10 minutes after recovery before quenching.

3.4.1.2.4 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.

3.4.2 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. (See 8.2.6.) Quenchant for immersion and spray quenching shall be water or an aqueous solution of a residual stress/distortion reducing additive, e.g., polymer. The additive, concentrations and temperatures used shall be supported by analysis of data verifying that the specified properties are achieved after aging (not required for concentrations/temperatures/times previously valid in accordance with MIL-H-6088 or AMS 2770). 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. Quench delay for immersion quenching shall conform to Table 3. For air blast and spray quenching, maximum allowable quench delays shall be established based on tests of tensile properties and, for 2xxx and 7xxx sheet, wire and extrusion under 0.250 inches (6.35 mm) thick, tests for susceptibility to intergranular corrosion (See 4.5.2).

3.4.2.1 Product heat treated in salt bath furnaces and product quenched in an aqueous solution of polymer shall be rinsed as necessary to ensure that it will be free from corrosion and detrimental foreign materials.

3.4.2.2 Quenchant Control:

3.4.2.2.1 Forgings and Impact Extrusions: If the quenchant is water or an aqueous solution of a non-polymer additive, the quenchant 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 the quenchant is a solution of polymer in water, the quenchant temperature shall not exceed 130 °F (54 °C) at the completion of the quench.

3.4.2.2.2 Immersion Quenching of Other Forms of 2xxx and 7xxx Alloys: If the quenchant is water or an aqueous solution of a non-polymer additive, the quenchant temperature shall not exceed 100 °F (38 °C) at the start of quench and 110 °F (43 °C) at the completion of the quench (See 3.4.2.2.4). If the quenchant is an aqueous solution of polymer, the quenchant temperature shall not exceed 130 °F (54 °C) at the completion of the quench.

3.4.2.2.3 Salt Contamination in Aqueous Solutions of Additives: When an aqueous solution of additive is used for quenching product heat treated in a salt bath furnace, salt contamination shall not exceed 6% by weight.

3.4.2.2.4 Immersion Quench Completion: Product under 0.250 inch (6.35 mm) in thickness shall remain in the quenchant until boiling emanating from the product (not the rack) ceases. 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.

3.4.2.2.5 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.

3.4.3 Restrictions on Alclad Products:

3.4.3.1 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.

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

3.4.3.3 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.

3.4.3.4 The restrictions of 3.4.3.1, 3.4.3.2 and 3.4.3.3 are not applicable to any lot of product which is tested to ensure conformance to the alclad thickness requirement of the material specification.

3.5 Aging:

Temperatures and times are shown in Table 4. Alternate temperatures and times may be used provided the aged material meets the specified requirements.

3.6 Temper Conversion:

3.6.1 When a warehouse, distributor or similar organization converts raw material to a different temper in accordance with this specification or AMS-H-6088 or MIL-H-6088, the following provisions shall apply:

3.6.1.1 The heat treatment shall conform to the technical requirements and quality assurance provisions of AMS 2770.

3.6.1.2 The converted product shall be tested in accordance with the requirements of the applicable material specification.

3.6.1.3 Any original mill marks shall be removed and the product shall be re-identified in accordance with ASTM B666/B666M; the new identification shall ensure traceability to the warehouse/distributor's records showing the original producer, the lot number and the converting organization.

3.6.1.4 The report to the purchaser shall include certification of conversion to the new temper, the conversion heat treatment procedure, the test results for the converted product and the original mill certification.

3.7 Annealing:

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

3.7.1 1xxx, 3xxx, and 5xxx Series Alloys Except 3003: Heat to 650 °F (343 °C); cooling rate optional.

3.7.2 3003 Alloy: Heat to 775 °F (413 °C); cooling rate optional.

3.7.3 2xxx and 6xxx Series Alloys Except 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.

3.7.4 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.

3.7.5 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.

3.8 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 of Air Blast, Spray and Immersion Quenching Equipment:

4.3.1 Effectiveness of Quench (See 4.3.7 and 8.4): Shall be demonstrated by tensile tests upon initial installation (not required for equipment previously qualified in accordance with MIL-H-6088). The effectiveness of quench shall also be demonstrated by tensile tests after any modification which could reduce the quenching effectiveness. Some examples of modifications for which the need for testing should be evaluated are nozzle size change, reduction of spacing between pieces, manifold size change, pump size change, and quenchant change.

4.3.2 Uniformity of Conductivity of Production Material (See 4.3.6 and 8.4): Shall be demonstrated by conductivity tests upon initial installation (not required for equipment previously qualified in accordance with MIL-H-6088). The uniformity of conductivity shall also be demonstrated by conductivity tests after any modification which could reduce the quenching uniformity. Some examples of modifications for which the need for testing should be evaluated are nozzle size change, reduction of spacing between pieces, manifold size change, pump size change, and quenchant change.

4.3.2.1 In addition, the uniformity of conductivity shall be tested (1) weekly for spray and air blast quenching and (2) monthly for immersion quenching.

4.3.2.2 Uniformity of conductivity tests are not required for equipment used exclusively for quenching of (1) sheet, (2) wire, rod and round tube under 0.750 inch (19 mm) diameter or (3) all forms of 6xxx alloys.

4.3.3 Pressure or Flow: Shall be inspected and recorded daily during production to ensure proper operation.

4.3.4 Alternate Inspection: In lieu of the periodic uniformity of conductivity test (4.3.2.1) and the daily pressure or flow inspection (4.3.3), it is permissible to substitute the following:

4.3.4.1 Daily Inspection: During production, quenchant flow rate, plus flow direction if variable, shall be inspected daily to ensure that they remain consistent with those conditions at the time of a previous uniformity of conductivity test. A daily record of the observed values shall be maintained. Flow rate for air blast quenching shall be measured by fan rpm or equivalent; flow rate for spray quenching shall be accomplished by direct or remote visual inspection of nozzle spray or by measurement of nozzle output pressure or equivalent; flow rate for immersion quenching shall be measured by flow meters, pump or propeller rpm or equivalent. Flow direction shall be inspected visually.

4.3.5 Load Selection and Configuration: A load of sheet(s), plate(s), forgings, extrusions, rods, or bars (See 8.4), sufficiently large to evaluate the entire quench facility and conforming to the following, shall be selected and quenched in the equipment:

4.3.5.1 Alloy Selection for Conductivity Test Loads: Order of preference shall be in accordance with the order of quench sensitivity as follows: (1) 7x75 or 2x24, (2) other 7xxx.

4.3.5.2 Alloy Selection for Tensile Test Loads: Shall be in accordance with the following order of preference: (1) 7x75, (2) 7xxx, (3) 2xxx, (4) other.

4.3.5.3 Thickness for Conductivity Test Loads: Shall be the maximum thickness (of the alloy selected) available on the day of selection for test, except that testing during each calendar quarter, shall include the thickest material of the most quench-sensitive alloy (See 4.3.5.1) of each form solution heat treated during that quarter.

4.3.5.4 Thickness for Tensile Test Loads: Shall be the maximum (of the alloy selected) available during the week of selection for test.

4.3.6 Procedure for Conductivity Tests: The electrical conductivity of the product or sample (See 8.4) in the -W, -T3, or -T4 temper shall be measured, before or after stretching, compressing, forming or straightening 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.

4.3.6.1 Immersion Quenched Loads: Measurements shall be made on one piece, selected at random, or 10% of the pieces, selected at random, whichever is greater. In lieu of 10%, the number of pieces selected at random may be equal to the following:

(a) If the load arrangement is equiaxed, the number of pieces in a plane at, or adjacent to, the center of the load, e.g., 12 pieces from a load arrangement of 12 x 12.

(b) If the load arrangement is not equiaxed, the average number of pieces in two perpendicular planes at or adjacent to the center of the load, e.g., 15 pieces from a load arrangement of 6 x 24.

4.3.6.2 Air Blast and Spray Quenched Loads: Measurements shall be made on all pieces in the load.

4.3.6.3 Plate - Location of Measurements: 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 72 inches (1.8 m) of length.

4.3.6.4 Extrusions, Rod and Bar - Location of Measurements: Randomly selected, immersion quenched pieces shall be arranged in a single plane. Measurements shall be made at 12-inch (305-mm) maximum intervals across the width of the load or plane, 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.

4.3.6.5 Forgings - Location of Measurements: When possible, spacing between test locations on the surfaces of forgings shall be 2 inches (51 mm) or less; when 2-inch (51-mm) spacing is precluded by the forging configuration, spacing shall be the minimum possible.

4.3.6.6 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 forging, 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 4-inch (102-mm) or thinner 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 forgings, extrusion, rod, or bar.

4.3.7 Procedure for Tensile Tests: Tensile specimens (full thickness or located at the T/2 or T/4 depth as required by the material specification), excised from the product or sample (See 8.4) before or after aging to the final temper, shall be tested in accordance with ASTM B 557 or ASTM B 557M. The specimen locations shall be:

4.3.7.1 Immersion Quenched Loads: Specimens shall be taken from one piece, from a random location in the load, or 10% of the pieces, from random locations in the load, whichever is greater. In lieu of 10%, the number of pieces may be equal to one of the following:

(a) If the load arrangement is equiaxed, the number of pieces in a plane at, or adjacent to, the center of the load, e.g., 12 pieces from a load arrangement of 12 x 12.

(b) If the load arrangement is not equiaxed, the average number of pieces in two perpendicular planes at or adjacent to the center of the load, e.g., 15 pieces from a load arrangement of 6 x 24.

4.3.7.1.1 Sheet(s) or Plate(s): Specimens shall be taken at both ends and the mid-length, from four equally-spaced locations across the width, of the load selected, but not closer than 6 inches (152 mm) nor more than 9 inches (229 mm) from the edge of the load.

4.3.7.1.2 Extrusions, Rods or Bars: Specimens shall be taken at both ends of the pieces selected.

4.3.7.1.3 Forgings: Specimens shall be taken from each of the pieces selected.

4.3.7.1.4 Additional Specimen: At least one of the above specimens shall represent a location which exhibited the highest conductivity in the most recent conductivity test or an additional specimen shall be taken to represent such a location.

4.3.7.2 Air Blast and Spray Quenched Loads:

4.3.7.2.1 Continuously Quenched Sheet(s) or Plate(s): Specimens shall be taken at both ends, from four equally-spaced locations across the width, of the load, but not closer than 6 inches (152 mm) nor more than 9 inches (229 mm) from the edge of the load.

4.3.7.2.2 Non-Continuously Quenched Sheet(s) or Plate(s): Specimens shall be taken at both ends and the mid-length, from four equally-spaced locations across the width, of the load, but not closer than 6 inches (152 mm) nor more than 9 inches (229 mm) from the edge of the load.

4.3.7.2.3 Extrusions, Rods or Bars: Specimens shall be taken at both ends, at 6 to 12-inch (152 to 305-mm) intervals across the width, of the load.

4.3.7.2.4 Forgings: Specimens shall be taken at both ends and the mid-length of the load, at 6 to 12-inch (152 to 305-mm) intervals across the width, of the load.

4.3.7.3 Tensile Properties: Shall meet specified requirements.

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 representative of the thinnest 2xxx or 7xxx sheet (non-clad shall be used for porosity testing) heat treated during the previous calendar month (See 8.2.4) shall be tested in accordance with 4.5.1. If sheet was not heat treated, a sample representative 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 representative of the thickest (under 0.250 inch (6.35 mm)) product solution heat treated during the previous calendar month (See 8.2.4) 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 Heat Treat Induced 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 (1) heat treat induced porosity, evidenced by multiple voids in grain boundaries near the surface which are visible in more than two fields of view, and (2) eutectic melting, evidenced by rosettes or eutectic structure at grain boundary triple points.

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 running 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 The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this specification. An (R) symbol to the left of the document title indicates a complete revision of the specification.

8.2 Terms used in AMS are clarified in ARP1917 and as follows:

8.2.1 Raw Material (e.g., sheet, plate, wire, rod and bar, forgings, extrusions): Usually is identified by a heat or 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.

8.2.2 Parts: Usually are 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 the time of heat treatment, they may resemble raw material.

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

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

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

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

8.2.7 Forms: “Forgings” includes die and hand forgings and rolled rings. “Extrusions” includes all forms, e.g., wire, rod and bar, profiles (shapes), and tubes.

8.2.8 Heavy Load: A load is heavy if the volume of the pieces in the load is more than 10% of the volume of all working (soaking) zones.

8.2.9 Similar Load Arrangement: A load arrangement in which all pieces will have heating and cooling rates similar to, or faster than, the pieces in the previously validated load arrangement may be considered similar. An example of a similar load arrangement is one in which the thickness of the pieces is similar to or less than, and the space between the pieces is similar to or greater than, the pieces in the previously validated load.

8.3 Mandatory solution heat treatment temperatures (Table 1, Note 6) and mandatory aging temperatures and times (Table 4, Note 5) for response-to-heat-treatment tests are the same as those of AMS 2770. These tests are intended to ensure that the material, in the as-produced condition (prior to any additional processing) has the capability to respond to a heat treatment using the temperatures and times specified.

8.4 To avoid destruction of production material for quench effectiveness tensile tests and to avoid production delays resulting from quench uniformity conductivity tests, it is permissible to insert sample material, of the same alloy/form/thickness, in the load. When samples are used for quench effectiveness tests, their length and width must be at least 3 times their thickness.

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)(6) °F	Temperature (1)(2)(6) °C	Alloy	Product Form (See 8.1.8)	Temperature (1)(2)(6) °F	Temperature (1)(2)(6) °C
2011	wire, rod, bar	945-995	507-535	6066	all	960-1010	516-543
2014	all	925-945	496-507	6151	forgings	950-980	510-527
2017	wire, rod, bar	925-950	496-510	6262	all	960-1050	516-566
2018	forgings	940-970	504-521	6951	sheet	975-995	524-535
2024	all (3)	910-930	488-499	7001	extrusion	860-880	460-471
2025	forgings	950-970	510-521	7010	plate, forgings	880-900	471-482
2048	sheet, plate	910-930	488-499	7039	plate	750-880	399-471
2117	wire, rod, bar	925-950	496-510	7039	other	840-860	449-460
2124	plate	910-930	488-499	7049/7149	all	860-900	460-482
2218	forgings	940-960	504-516	7050	all	880-900	471-482
2219	all	985-1005	529-541	7055	extrusions	870-890	466-477
2324/2424	all	910-930	488-499	7055	plate	860-900	460-482
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
6013	sheet	1045-1065	563-574	7175	plate, extrusion	880-910	471-488
6013	rod, bar	990-1045	532-563	7178	sheet	860-930	460-499
6053	forgings	960-980	516-527	7475	sheet (5), plate	880-970	471-521
6061	all	960-1075	516-579	8090	sheet	990-1000	532-538
6063	extrusion	960-985	516-529	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).

(6) Mandatory solution heat treatment temperatures, for the alloys and forms listed below, for response-to-heat-treatment tests shall be as follows (not applicable to other alloys and forms):

2004 Sheet - 985 °F (529 °C); * 2014 Sheet & plate - 935 °F (502 °C); * 2024 Sheet & plate - 920 °F (493 °C)
2219 Sheet & plate - 995 °F (535 °C); * 6061 All forms - 985 °F (529 °C); * 7049 Forgings - 875 °F (468 °C)
7075 Sheet, plate, rolled bars and rods - 870 °F (466 °C); * 7178 Sheet - 870 °F (466 °C) (See 8.2)