AEROSPACE MATERIAL SPECIFICATION

AMS2772™	REV. H
Issued 1997-01 Revised 2023-03 Superseding AMS2772G	

Heat Treatment of Aluminum Alloy Raw Materials

RATIONALE

AMS2772H results from a Five-Year Review and update of this specification with changes to update and clarify purpose (1.1), definitions (2.2), equipment qualification (3.1, 3.1.3), pyrometry (3.2, 3.2.1.2, 3.2.1.3, 3.2.1.4, 3.2.1.4.1), heating media for solution heat treatment (3.3.2), cleanliness (3.4.1), racking and spacing (3.4.2.2, 3.4.2.2.1, 3.4.2.2.2), temperatures (3.5.1.1), solution heat treatment (3.6.1), soaking (3.6.2.3, 3.6.2.4), quenching (3.6.3, 3.6.3.2, 3.6.3.3, 3.6.3.5.1. 3.6.3.7), temper conversion (3.8.1.2), procedure for response-to-heat-treatment tests (3.9), processing to -O1 temper (3.11), procedure for electrical conductivity testing (4.3.2.6), and acceptance criteria (4.3.2.7).

1. SCOPE

1.1 Purpose

This specification covers requirements and recommendations for the heat treatment of wrought aluminum alloy raw materials (see 2.2.1) by producers. It supersedes AMS-H-6088 and replaces MIL-H-6088.

1.1.1 Tempers

Aluminum alloy tempers are described in 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.

1.1.2.1 For those material specifications that specify proprietary heat treat and/or aging practices, all other requirements of AMS2772 apply.

1.1.3 Other Heat Treatment

1.1.3.1 Parts (see 2.2.2)

Are made from wrought raw material but are not being heat treated by or for the original raw material producer. These shall be heat treated in accordance with AMS2770.

1.1.3.2 Castings and Parts Made from Castings

Are not covered by this specification; heat treatment of aluminum castings and parts made from such castings is covered by AMS2771.

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For more information on this standard, visit
https://www.sae.org/standards/content/AMS2772H/

1.1.3.3 Temper Conversion

Warehouses, distributors, etc., shall be in conformance with 3.8 and AS6279 when required by the raw material specification.

1.1.3.4 Procedure for Response-to-Heat-Treatment Tests

Shall be in accordance with 3.9.

2. REFERENCES

2.1 APPLICABLE DOCUMENTS

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2750	Pyrometry
AMS2770	Heat Treatment of Wrought Aluminum Alloy Parts
AMS2771	Heat Treatment of Aluminum Alloy Castings
AMS-H-6088	Heat Treatment of Aluminum Alloys
ARP1962	Training and Approval of Heat-Treating Personnel
ARP7500	Minimization of High Temperature Oxidation, Aluminum Alloy Heat Treatment
AS6279	Standard Practice for Production, Distribution, and Procurement of Metal Stock
AS7766	Terms Used in Aerospace Metals Specifications

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B557	Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
ASTM B557M	Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)
ASTM B666/B666M	Identification Marking of Aluminum and Magnesium Products
ASTM G110	Evaluating Intergranular Corrosion Resistance of Heat Treatable Aluminum Alloys by Immersion in Sodium Chloride + Hydrogen Peroxide Solution
ASTM STP15D	Manual on Presentation of Data and Control Chart Analysis

2.1.3 U.S. Government Publications

Copies of these documents are available online at https://quicksearch.dla.mil.

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

2.1.4 ANSI Accredited Publications

Copies of these documents are available online at https://webstore.ansi.org/.

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

2.1.5 MMPDS Publications

Available from MMPDS, Tel 614-424-6557, www.mmpds.org, bcommpds@battelle.org.

MMPDS Metallic Materials Properties Development and Standardization (MMPDS)

2.2 Definitions

Terms used in AMS2772 are defined in AS7766 and as follows:

2.2.1 RAW MATERIAL (e.g., Sheet, Plate, Wire, Rod and Bar, Tubing, Forging, Extrusion)

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.

2.2.2 PARTS

Usually are identified by a part number and 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.

2.2.3 THICKNESS

For forgings and extrusions, thickness is the minimum dimension of the heaviest section.

2.2.4 MANDATORY AND NON-MANDATORY PROVISIONS

The word “shall” identifies mandatory provisions; “should,” “may,” and “recommended” identify non-mandatory provisions.

2.2.5 PRODUCT FORMS

“Forging” includes die and hand forgings and rolled or forged rings. “Extrusion” includes wire, rod, bar, profiles (shapes), and tube. When “wire,” “bar,” and “rod” are specified, they refer to cold finished or rolled products.

2.2.6 HEAVY LOAD

A load is heavy if the volume of the metal in the load is more than 10% of the volume of the qualified work (soaking) zones.

2.2.7 LIGHT LOAD

A load is light if the volume of the metal in the load is less than 10% of the volume of the qualified work (soaking) zones.

2.2.8 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.

3. TECHNICAL REQUIREMENTS

3.1 Equipment Qualification

Before production heat treatment, each solution heat treating furnace/quench facility and each aging furnace shall be qualified by tensile and metallurgical testing (see 4.4) of heat-treated samples representative of the most quench-sensitive (see 4.3.2.5.1) product to be heat treated. In addition, qualification of quench facilities shall include conformance to 4.3.

If load sensors are used to monitor and control all production loads, and if tensile testing is required and performed on each solution heat treatment and age load as part of normal production, then those results may be used for requalification purposes in lieu of the special production testing specified in 4.3.1.

3.1.1 Sample Thickness

Tensile tests shall be representative of the thinnest and the thickest material to be heat treated; intermediate thickness samples shall be included when necessary to ensure proper production heat treatment. Thickness of samples for metallurgical tests shall conform to 4.4.

3.1.2 Sample Locations

Samples shall be randomly positioned in simulated production loads except at least one of the tensile test samples shall be positioned at a location which exhibited a conductivity within 03% of the highest conductivity in a quench uniformity test.

3.1.3 Equipment Re-Qualification

Whenever any qualified equipment is changed or reworked, it shall be re-qualified unless it is known that the change, modification, or repair will not have a detrimental effect upon the properties of products. Re-qualification of quench facilities shall include conformance to 4.3.

3.2 Pyrometry

Shall be in accordance with AMS2750 except as follows:

- It is not applicable to furnaces used only for stress relieving or full annealing below 825 °F (441 °C).
- Recordings from instruments may be stored as an electronic record providing a hard copy is producible on request.
- In continuous and semi-continuous furnaces, the requirements applicable to controls, instruments, and sensors in the qualified work (soaking) zone shall also be applicable to the heating (heat-up) zone.

3.2.1 The temperature uniformity test requirements of AMS2750 shall be modified as follows:

3.2.1.1 Load Condition

The initial Temperature Uniformity Survey (TUS) shall be performed with a typical load. Subsequent TUSs may be performed with any load or no load. Furnaces which have only been surveyed with a heavy load (in anticipation of only heat treating heavy loads) (see 2.2.6) shall not be used to heat treat light loads (see 2.2.7) unless load sensors and recording instruments are employed to (1) preclude any portion of the load exceeding the maximum specified temperature on heat-up and (2) ensure soaking within the specified temperature range for the required time.

3.2.1.2 Load Sensors

When all production loads are heavy (see 2.2.6) and a TUS load is heavy, load sensors may be used in addition to TUS sensors.

3.2.1.3 Loaded Furnaces

During the heat-up portion of the TUS when 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 temperature range being surveyed providing that the metal temperature measured with load sensors does not exceed the maximum temperature allowed.

3.2.1.4 Uniformity Requirements

During the TUS hold period, the temperature of all process and TUS sensors in the qualified work (soaking) zone shall be within the following allowable ranges (these ranges supersede the ± temperature tolerances specified in AMS2750):

3.2.1.4.1 50 °F (28 °C) range for furnaces used only for full annealing at temperatures higher than 825 °F (441 °C). Annealing temperatures shall be controlled so as to preclude any material exceeding the lowest solution heat treating temperature for the alloy being annealed.

3.2.1.4.2 30 °F (17 °C) range 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 greater.

3.2.1.4.3 20 °F (11 °C) range for furnaces used for solution heat treatment of 6xxx alloys for which Table 1 specifies a range of less than 30 °F (17 °C).

3.2.1.4.4 20 °F (11 °C) range for furnaces used for solution heat treatment of other alloys except 10 °F (6 °C) range for furnaces used for solution heat treatment of 8090 sheet.

3.2.1.4.5 20 °F (11 °C) range for furnaces used for aging treatments.

3.2.1.4.6 20 °F (11 °C) range for furnaces used for processing to the -O1 temper.

3.3 Heating Media for Solution Heat Treatment

3.3.1 Shall be air, protective atmosphere, combusted gases, molten salt bath, or fluidized bed. However, no protective atmosphere, combusted gas, or fluidized bed environment shall be used unless it has been shown by testing (in accordance with 4.4.1.1), on the alloy/form to be heat treated, to yield product which is free from heat treat induced porosity. Composition of salt baths and fluidized beds shall be maintained to prevent attack of the product.

3.3.2 ARP7500 provides recommendations for minimizing high temperature oxidation (HTO) during the heat treatment of aluminum alloy products and parts. HTO leads to deterioration of properties.

3.4 Preparation for Heat Treatment

3.4.1 Cleanliness

Prior to heat treating, product shall be free from surface contaminants which could have a detrimental effect on the material. It is the responsibility of the heat-treating processor to ensure that the surface cleanliness of the product is satisfactory prior to being solution heat treated, artificially aged, and/or annealed.

3.4.2 Racking and Spacing

During solution heat treatment, 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. During aging, product shall be supported or hung and spaced so that it will be heated and soaked as required to meet the specified requirements.

3.4.2.1 Load arrangement shall be validated by heat treatment of a similarly arranged load (see 2.2.8) containing one or more appropriately placed load sensors which show that all product 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 load arrangements which have been previously validated in accordance with MIL-H-6088, AMS-H-6088, or a previous issue of AMS2772). Written instructions, drawings, photographs, or other illustrations shall be used to ensure proper load arrangements.

3.4.2.2 Spacing of Forgings

Except as specified in 3.4.2, each forging shall be separated from the nearest piece in any direction by a distance greater than its thickest section, or as provided by special racking procedures for which it has been demonstrated that the specific product receives sufficient heating and/or quenching to achieve the required mechanical properties and corrosion resistance.

3.4.2.2.1 Fixtures

Fixtures shall be designed so as to have a minimum effect on the heating and quench rates. Orientation shall be such as to avoid entrapment of steam, allow free circulation of quenchant along all surfaces of the product, and to preclude steam from harmfully degrading the quench. Contact areas between the product and the fixture shall be minimized and verified to allow adequate flow and produce no detrimental effects on product characteristics.

3.4.2.2.2 Load Size

The size of the load shall be limited so as to produce no more than a 20 °F (11 °C) rise in water temperature, or a 25 °F (14 °C) rise in aqueous polymer temperature as a result of quenching. Exceptions to the temperature rise are acceptable if the product has been demonstrated by testing and documentation to meet the applicable requirements.

3.4.2.2.3 Thin Forgings

Random racking (not nested) or layering of forgings, 1 inch (25 mm) and under in thickness is permissible for (1) solution heat treating (providing quenching is by immersion), (2) aging, and (3) annealing, providing product so racked has been demonstrated by test to meet the material specification requirements. Layer thickness shall not exceed 3 inches (76 mm) and distance between layers shall be at least 3 inches (76 mm) (not required for load arrangements which have been previously validated in accordance with MIL-H-6088, AMS-H-6088, or a previous issue of AMS2772).

3.5 Temperatures

3.5.1 Furnace temperatures shall be controlled so as to ensure that the metal temperature does not exceed the maximum of the range.

3.5.1.1 When a load is charged into a batch furnace whose indicated temperature is higher than the maximum of the specified range, recording hot load sensor(s) shall be used to verify that the metal temperature did not exceed the maximum of the specified range. Load sensors will be put in direct contact with the load in sufficient number and appropriate placement throughout the load and control zones in such a way as to accurately identify and monitor the hottest locations in the load and the hottest spots in the qualified work zone(s) – e.g., such as on the thinnest material on the outside of the load or the hottest parts of the control zone based on TUS uniformity surveys.

3.6 Solution Heat Treatment

3.6.1 Product shall be soaked, in accordance with 3.6.2, within the temperature range specified in Table 1 and quenched as specified in 3.6.3. Quenching directly from a furnace or salt bath is required. Extrusion press quenching (see 3.6.3) and rolling mill quenching (see 3.6.3) are not allowed to be certified as being in accordance with AMS2772.

3.6.2 Soaking

3.6.2.1 Start

Soaking time shall start when the temperature readings of all load sensors indicate that the temperature of the load has reached the minimum of the required temperature range. Alternatively, determination that the temperature of the load has reached the minimum of the required temperature range (start of soaking time) may be based on readings of furnace instruments providing the lag between their readings and load sensor temperature readings has been determined in a similarly arranged load.

3.6.2.2 Duration

The load shall be maintained within the required 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, AMS-H-6088, or a previous issue of AMS2772). Recommended soaking times are listed in Table 2.

3.6.2.3 Semi-Continuous Air Furnace

During soaking in a semi-continuous air furnace, a drop in temperature is permissible providing that:

3.6.2.3.1 The temperature indicated by any instrument does not drop more than 20 °F (11 °C) below the minimum of the specified range.

3.6.2.3.2 Time below the minimum of the specified range does not exceed 5 minutes.

3.6.2.3.3 Soaking is continued for not less than 10 minutes after recovery to the minimum of the solution heat treatment temperature range before quenching.

3.6.2.3.4 If furnace temperature does not drop more than 20 °F (11 °C) below the minimum of the specified range but does not recover to the minimum of the specified temperature range within 5 minutes, the total soaking time within the specified range shall be increased; if less than 1 hour was required, it shall be increased by 1/2 hour; if 1 hour or more was required, it shall be increased by 1 hour.

3.6.2.4 Batch Air Furnace

During soaking, a drop in temperature below the specified minimum is permissible providing that:

3.6.2.4.1 Recording load sensors are used to:

- Detect and monitor the actual minimum metal temperature(s) reached in the entire load or loads if more than one is in the furnace,

and

- To determine the time at which the minimum metal temperatures regain the minimum specified temperature so that soaking can be resumed.

3.6.2.4.2 There is a minimum of one load sensor in each control zone which contains all or part of the load(s) and the load sensor(s) must be positioned to detect the lowest metal temperature in the load(s) or zone(s).

3.6.2.4.3 The temperature indicated by any load sensor does not drop more than 30 °F (16 °C) below the minimum of the specified range.

3.6.2.4.4 The total specified soak time will be increased by the length of time equal to how long the coldest load sensor was below the specified minimum soak temperature.

3.6.3 Quenching (see 4.3)

2xxx and 7xxx series alloy forgings and impact extrusions shall be quenched by immersion. Quenching of other forms of 2xxx and 7xxx series alloys and all forms of other alloys shall be by immersion, spray or, in a suitable chamber, by air blast.

Extrusion press quenching (directly quenching from the extrusion press without a subsequent furnace solution heat treating operation) may not be used as a substitute for the furnace heating and quenching specified herein. Extrusion press quenching is not covered by this specification.

Rolling mill quenching (directly quenching from the rolling mill without a subsequent furnace solution heat treating operation) may not be used as a substitute for the furnace heating and quenching specified herein. Rolling mill quenching is not covered by this specification.

3.6.3.1 Quenchant

For immersion and spray quenching shall be water or an aqueous solution of a residual stress/distortion reducing additive such as polymer.

3.6.3.2 Quench Conditions

Quenchant volume, velocity, distribution, and agitation (of quenchant and/or product) shall be sufficient to ensure that all products will meet specified requirements after aging. Quenchant temperature shall conform to 3.6.3.5. The additive, concentration and specific temperature used for each load shall be supported by analysis of data verifying that the specified properties are achieved after aging (not required for additives/concentrations/temperatures previously valid in accordance with AMS-H-6088, MIL-H-6088, AMS2770, or a previous issue of AMS2772). Polymer concentration measurement methods are defined in AMS2770.

3.6.3.3 Quench Delay

Immersion quench delay shall conform to Table 3. For air blast and spray quenching, maximum allowable quench delays shall be established based on tests for tensile properties. In addition, tests for susceptibility to intergranular corrosion shall be required for 2xxx and 7xxx sheet, wire, and extrusion under 0.250 inch (6.35 mm) thick (see 4.4.1.2).

3.6.3.4 Rinsing

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.

3.6.3.5 Quenchant Temperature

3.6.3.5.1 Immersion Quenching of Forgings and Impact Extrusions

3.6.3.5.1.1 Quenchant - Water, with or without a Non-Polymer Additive

Recommended quenchant temperature ranges are 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, when final temper of T41 or T61 temper is specified, immersion quenching in boiling water is required. The overall temperature of the quenchant bath should not increase by more than 20 °F (11 °C) except as noted in 3.4.2.2.

3.6.3.5.1.2 Quenchant - Water with a Polymer Additive

Quenchant temperature shall not exceed 130 °F (54 °C) at the completion of the quench. Additionally, it should not increase by more than 25 °F (14 °C) except as noted in 3.4.2.2.

3.6.3.5.2 Immersion Quenching of Other Product Forms

If the quenchant is water or an aqueous solution of a non-polymer additive, 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 3.6.3.7). If the quenchant is an aqueous solution of polymer, quenchant temperature shall not exceed 130 °F (54 °C) at the completion of the quench.

3.6.3.5.3 Spray Quenching of Other Product Forms

The quenchant temperature is not restricted but the quenchant temperature used shall be supported by analysis of data in accordance with 3.6.3.2.

3.6.3.6 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 in the quenchant shall not exceed 6% by weight.

3.6.3.7 Immersion Quench Completion

Product under 0.250 inch (6.35 mm) in thickness shall remain in the quenchant at least 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 2 minutes per inch (25 mm) of thickness, or fraction thereof, or for not less than 2 minutes after boiling of the quenchant around the product ceases.

3.6.3.8 Other Quench Completion

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

3.6.4 Restrictions on Alclad Products

3.6.4.1 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 or for plate.

3.6.4.2 Soaking Time

To ensure all lots will develop specified properties after aging, soaking time shall be established in accordance with 3.6.2. However, 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 specified requirements.

3.6.4.3 Re-Solution Heat Treatment of Alclad 2xxx and 7xxx Sheet and Plate

Product thinner than 0.020 inch (0.51 mm) shall not be re-solution heat treated. Sheet thicknesses from 0.020 to 0.125 inch (0.51 to 3.18 mm), inclusive, shall not be re-solution heat treated more than once. Product thicker than 0.125 inch (3.18 mm) shall not be re-solution heat treated more than twice.

3.6.4.4 The restrictions of 3.6.4.1 and 3.6.4.3 are not applicable to any lot of product which is tested to ensure conformance to the alclad thickness requirement of the material specification.

3.7 Aging

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

3.8 Temper Conversion

3.8.1 When a warehouse, distributor or similar organization, or its vendor, 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:

3.8.1.1 The heat treatment of the raw material and any heat treatment of samples for heat-treatment- response tests shall conform to the technical requirements and quality assurance provisions of AMS2770. For products not included in the tables in AMS2770, the temperatures and times of Table 5 or 6 shall be used.

3.8.1.2 The converted product shall be tested in accordance with the requirements for the heat-treated temper of the applicable raw material specification which the material was originally produced to.

3.8.1.3 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.

3.8.1.4 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.

3.9 Procedure for Response-to-Heat-Treatment Tests

When a material specification or other procurement document requires heat treatment of samples to demonstrate response to user heat treatment (e.g., heat treatment of -O, -O1, or -F temper material to -T42 or -T62 temper), the procedure used by producers, forge shops, or warehouses/distributors and their vendors shall include conformance to the mandatory set temperatures and times in Tables 5 and 6.

3.10 Recommended Annealing Times, Temperatures, and Cooling Rates

3.10.1 1xxx, 3xxx, and 5xxx Series Alloys Except 3003

Heat to 650 °F (343 °C); cooling rate optional.

3.10.2 3003 Alloy

Heat to 775 °F (413 °C); cooling rate optional.

3.10.3 2xxx and 6xxx Series Alloys Except 6013

Soak for 2 to 3 hours at 760 °F (404 °C); cool at rate of 50 °F (28 °C) per hour or slower to 500 °F (260 °C); further cooling rate optional.

3.10.4 6013 Alloy

Soak for 2 to 3 hours at 775 °F (413 °C); cool at rate of 50 °F (28 °C) per hour or slower to 500 °F (260 °C); further cooling rate optional.

3.10.5 7xxx Series Alloys

Soak for 2 to 3 hours at 760 °F (404 °C); cool to 400 °F (204 °C) or lower, reheat to 450 °F (232 °C), and soak for 4 hours; cooling rate optional.

3.11 Processing to -O1 Temper

Shall consist of heating product up to at least 10 °F below the low limit of the temperature range shown in Table 1 followed by an air cool.

3.12 Personnel Training

A company performing heat treating shall have a verifiable program (either company-created or conforming to ARP1962) of initial and periodic training and evaluation of its personnel. The training program shall consist of one or more of the following: on-the-job training, classroom instruction, and/or academic instruction. The evaluation shall be based on education, experience, and training results.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

4.1.1 The entity performing the heat treatment, or its designee is responsible for the performance of all inspections and specified tests.

4.2 Records

4.2.1 Retention

Records of all inspections and tests shall be kept available for review for 5 years after the inspection or test. 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 5 years after heat treatment.

4.3 Equipment Used for Air Blast, Spray, and Immersion Quenching of 2xxx and 7xxx Series Alloys

4.3.1 Effectiveness of Quench (see 4.3.3)

Shall be demonstrated by tensile tests upon initial installation (not required for equipment previously qualified in accordance with AMS-H-6088, MIL-H-6088, or a previous issue of AMS2772). 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 or arrangement, reduction of spacing between pieces, manifold size change, pump size change, and change of quenchant type or manufacturer. Tensile properties shall meet the requirements of the material specification or the drawing.

4.3.1.1 Load Selection and Configuration

A load of sheet(s), plate(s), forgings, extrusions, rods, or bars (see 4.3.3), conforming to the following, shall be selected, and quenched in the equipment:

4.3.1.1.1 Alloy Selection

Shall be in accordance with the following order of preference: (1) 7x75, (2) 7xxx, (3) 2xxx.

4.3.1.1.2 Load Size

Shall be representative of the maximum thickness of product (of the alloy selected) to be heat treated. Load size shall be sufficiently large to evaluate the entire quench facility, without exceeding the equipment handling capabilities.

4.3.1.2 Procedure for Tensile Testing Required for Assessment of Quench Effectiveness

Tensile specimens shall be full thickness or located and oriented as required by the material specification or the forging/extrusion drawing. They shall be excised from the product or sample (see 4.3.3) before or after aging to the final temper and shall be tested in accordance with ASTM B557 or ASTM B557M. The number of specimens and locations shall be as follows:

4.3.1.2.1 Immersion Quenched Loads

Specimens shall be taken from one piece, or 10% of the pieces, whichever is greater, from random locations in the load.

4.3.1.2.1.1 Sheet(s) or Plate(s)

Specimens shall be taken at both ends and the mid-length, from four locations across the width of the load. The centers of the outer specimens shall be between 6 inches (152 mm) and 9 inches (229 mm) from the edge of the load and the spaces between the specimens shall be approximately equal.

4.3.1.2.1.2 Extrusions, Rods, or Bars

Specimens shall be taken at both ends of the pieces selected.

4.3.1.2.1.3 Forgings

Specimens shall be taken from each of the pieces selected.

4.3.1.2.1.4 Additional Specimen

At least one of the above specimens shall represent a location which exhibited a conductivity within 0.3% of the highest conductivity in the most recent quench uniformity test or an additional specimen shall be taken to represent such a location.

4.3.1.2.2 Air Blast and Spray Quenched Loads

4.3.1.2.2.1 Continuously Quenched Sheet or Plate (see 8.5)

Specimens shall be taken at both ends from four locations across the width of the load. The centers of the outer specimens shall be between 6 inches (152 mm) and 9 inches (229 mm) from the edge of the load and the spaces between the specimens shall be approximately equal.

4.3.1.2.2.2 Non-Continuously Quenched Sheet or Plate (see 8.5)

Specimens shall be taken at both ends and the mid-length, from four locations across the width of the load. The centers of the outer specimens shall be between 6 inches (152 mm) and 9 inches (229 mm) from the edge of the load and the spaces between the specimens shall be approximately equal.

4.3.1.2.2.3 Extrusions, Rod, or Bar

Specimens shall be taken from product located at both ends of the load, at 6 to 12 inches (152 to 305 mm) intervals across the width of the load.

4.3.2 Uniformity of quench of product shall be demonstrated by conductivity tests upon initial installation (not required for equipment previously qualified in accordance with MIL-H-6088, AMS-H-6088, or a previous issue of AMS2772). The uniformity of quench 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 or arrangement, reduction of spacing between pieces, manifold size change, pump size change, and quenchant change.

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

4.3.2.2 Uniformity of quench 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.

4.3.2.3 Pressure or Flow

Shall be inspected and recorded daily during production to ensure proper operation.

4.3.2.4 Alternate Inspection

In lieu of the periodic uniformity of quench test (4.3.2.1) and the daily pressure or flow inspection (4.3.2.3), it is permissible to substitute the following:

4.3.2.4.1 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 quench 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.

4.3.2.5 Load Selection and Configuration

For the periodic uniformity of quench test (4.3.2.1), a load of sheet(s), plate(s), forgings, extrusions, rods, or bars (see 4.3.3) shall be selected and quenched in the equipment. The preference for the load selection shall conform to the following requirements:

4.3.2.5.1 Alloy Selection

Order of preference shall be in accordance with the order of quench sensitivity as follows: (1) 7x75 or 2x24, (2) other 7xxx, (3) other 2xxx, (4) other.

4.3.2.5.2 Load Size

Sheet, forgings, extrusions, rods, or bars shall be the maximum thickness (of the alloy selected) available at the time of selection. Plate shall be the maximum thickness or a thickness of at least 2 inches (of the alloy selected) available at the time of selection. Load size shall be sufficiently large to evaluate the entire quench facility, without exceeding the equipment handling capabilities.

Each calendar quarter, testing shall include the thickest material of the most quench-sensitive alloy (see 4.3.2.5.1) of sheet, forgings, extrusions, rods, or bars solution heat treated during that quarter, and plate shall be the maximum thickness or a thickness of at least 2 inches (51 mm). Load size shall be sufficiently large to evaluate the entire quench facility, without exceeding the equipment handling capabilities.

4.3.2.6 Procedure for Electrical Conductivity Testing

The electrical conductivity of the product or sample (see 4.3.3) in the -W, -T3, or -T4 temper shall be tested (before or after stretching, compressing, forming, or straightening) using equipment calibrated in accordance with MIL-STD-1537. Tests of 7075 product should not be started until a minimum of 10 hours of room temperature aging has elapsed so as to allow natural aging to stabilize the readings. Readings taken before 10 hours will be less stable and will vary by larger amounts but will be considered to be acceptable if they meet the requirements of the 4.3.2.7 acceptance criteria.

4.3.2.6.1 Sampling (see 4.3.3)

4.3.2.6.1.1 Immersion Quenched Loads

The sample shall consist of one piece, or 10% of the pieces, selected at random, whichever is greater.

4.3.2.6.1.2 Air Blast and Spray Quenched Loads

The sample shall consist of all pieces in the load. For extrusion, rod, and bar; the sample pieces shall be arranged in a single plane.

4.3.2.6.2 Test Location Spacing

4.3.2.6.2.1 Plate

Maximum distance between test locations shall be 4 inches (102 mm) on a line across the width; maximum distance between the lines shall be 24 inches (610 mm) along the length.

4.3.2.6.2.2 Extrusion, Rod, and Bar

Maximum distance between test locations shall be 12 inches (305 mm) on a line across the width and 2 inches (51 mm) around the product section perimeter; maximum distance between the lines shall be 24 inches (610 mm) if air blast or spray quenched and 48 inches (1219 mm) if immersion quenched.

4.3.2.6.2.3 Forgings

When possible, distance between test locations on 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.

4.3.2.6.3 Minimum Length/Quantity of Product to be Tested

4.3.2.6.3.1 Immersion and Continuously Quenched (see 8.5) Loads

For initial and equipment modification tests (see 4.3.2), the entire load shall be tested. For periodic tests, if the load is longer than 24 feet (7.4 m), a minimum of 12 feet (3.7 m) shall be tested at each end; if the load is 24 feet (7.4 m) long or less, the entire load shall be tested.

4.3.2.6.3.2 Non-Continuously Quenched (see 8.5) Loads

The entire load shall be tested.

4.3.2.7 Acceptance Criteria

4.3.2.7.1 Plate

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). Additionally, the conductivity of any 4-inch (102-mm) or thinner 7075 alloy non-alclad plate shall not exceed 31% IACS (17.98 MS/m IACS).

4.3.2.7.2 Forging, Extrusion, Rod, and Bar

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) on any one element (flange, web, etc.). Additionally, the conductivity of any 4-inch (102-mm) or thinner 7075 forging, extrusion, rod, or bar shall not exceed 32% IACS (17.98 MS/m IACS).

4.3.3 Sample Material

It is permissible to perform quench effectiveness tensile tests and quench uniformity conductivity tests on sample material, of the same alloy/form/thickness, inserted in the load at the appropriate locations. When samples are used for quench effectiveness tests, their length and width shall be at least three times their thickness.

4.4 Metallurgical Testing

4.4.1 The tests in 4.4.1.1 and 4.4.1.2 shall be performed on production material from each solution heat treating furnace initially and periodically thereafter. The frequency of testing shall be (1) monthly until a total of six successful tests have been performed; then the frequency may be reduced to quarterly. However, if a failure occurs, the frequency shall revert to monthly and shall not be reduced again until a total of six successive successful tests have been performed. The above initial and periodic test requirements shall be applied after any modification of the equipment which could affect the metallurgical properties of the product.

4.4.1.1 Heat Treat Induced Porosity and Eutectic Melting

A sample of 2xxx or 7xxx sheet (non-alclad shall be used for heat treat induced porosity testing) heat treated during the previous calendar month (see 8.2) shall be tested in accordance with 4.4.2.1. If sheet was not heat treated, a sample of product of an alternate form (order of preference: tube, extrusion, wire, rod, bar, plate, forging) shall be tested. The thickness of the sample shall be not more than twice the thickness of the thinnest product heat treated during the previous month.

4.4.1.2 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) shall be tested in accordance with 4.4.2.2. 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.

4.4.2 Test Methods and Acceptance Criteria

4.4.2.1 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.

4.4.2.2 Intergranular Corrosion Susceptibility

The sample shall be prepared and tested in accordance with ASTM G110 modified as follows:

4.4.2.2.1 Specimen surface area shall be not less than 4 square inches (25.8 cm^2) (sum of both sides) except, for wire, a minimum length of 4 inches (102 mm) shall suffice.

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

4.4.2.2.3 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.

4.4.2.2.4 The immersion period in the test solution shall be 6 to 7 hours.

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

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

4.4.2.2.7 The severity of inter-granular corrosion exhibited by the major surfaces of the sample (end-grain attack shall be disregarded) shall be no greater than that normally experienced by producers when heat treating under production conditions in accordance with the requirements and recommendations of this specification. Intentional or inadvertent process changes shall not cause increased severity.

4.5 Test Failures

4.5.1 Equipment Deficiency

If any valid test fails to meet any requirement specified herein, or if any valid test (after retesting, if permitted) fails to meet a requirement of the material specification or the drawing, and the cause of the failure was a deficiency of the heat treating equipment (not the test procedure or test apparatus), the following measures shall be taken:

4.5.1.1 The equipment shall not be used for production until the cause of the failure has been corrected and the test has been performed successfully.

4.5.1.2 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 Revision Indicator

A 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 document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

8.2 Samples for Metallurgical Tests

May be taken from remnants of samples taken in accordance with material specification requirements.

8.3 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

8.4 Most of the mandatory set temperatures and aging times specified for response-to-heat-treatment tests (in Tables 5 and 6) are based on those of AMS2770. For alloys/tempers not covered by AMS2770, Tables 5 and 6 temperatures/times are based on Tables 1 and 4 herein. These tests are intended to demonstrate that the material, in the as-produced condition (prior to any additional processing) has the capability to respond to a heat treatment which duplicates, as closely as possible, user's test and production heat treating conditions.

8.5 Continuously quenched product traverses through a quench chamber without a pause or change of direction. Non-continuously quenched product pauses or changes direction during its traverse through a quench chamber.

Table 1 - Solution heat treating temperatures[9]

Alloy	Product Form (see 2.2.5)	Temperature (1)(2)(3) °F	Temperature (1)(2)(3) °C	Alloy	Product Form (see 2.2.5)	Temperature (1)(2)(3) °F	Temperature (1)(2)(3) °C
2011	Wire, Rod, Bar	945- 995	507-535	6156	Sheet	1010-1025	543-552
2013	Extrusion	1003-1023	539-551	6262	All	960-1050	516-566
2014	All	925- 945	496-507	6951	Sheet	975- 995	524-535
2017	Wire, Rod, Bar	925- 950	496-510	7001	Extrusion	860- 880	460-471
2018	Forging	940- 970	504-521	7010	Plate, Forging	880- 900	471-482
				7019	Plate	855- 875	458-468
2024	All[4]	910- 930	488-499	7036	Extrusion	870- 890	466-477
2025	Forgings	950- 970	510-521				
2026	Extrusion	910- 930	488-499	7039	Plate	700- 880	371-471
2027	Plate, Extrusion	915- 935	491-502	7039	Other	840- 860	449-460
2048	Sheet, Plate	910- 930	488-499	7040	Plate	880- 910	471-488
2056	Sheet	915- 935	491-502				
2090	Extrusion	990-1010	532-543	7049	All	860- 900	460-482
2090	Sheet	975-1000	524-538	7050	All	880- 900	471-482
2098	All	960- 980	516-527	7055	Extrusion	870- 890	466-477
2099	Extrusion	990-1030	532-554	7055	Plate	860- 900	460-482
				7056	Plate	860- 890	460-477
2117	Wire, Rod, Bar	925- 950	496-510	7068	Extrusion	860- 885	460-474
2124	Plate	910- 930	488-499	7075	Forging	860- 900	460-482
2195	Plate	940- 960	504-516	7075	Other	860- 930[5][6]	460-499
				7076	Forging	850- 910	454-488
2198	Sheet	930- 950	500-510	7136	Extrusion	870- 890	466-477
2218	Forging	940- 960	504-516	7140	Plate	880- 900	471-482
2219	All	985-1005	529-541				
2297	Plate	980-1000	527-538	7149	All	860- 900	460-482
2397	Plate	960- 980	516-527	7150	Plate, Extrusion	880- 900	471-482
2524	Sheet, Plate	910- 930	488-499	7175[7]	Plate, Extrusion	880- 910	471-488
2618	Forging	975- 995	524-535	7178	Sheet	860- 930	460-499
4032	Forging	940- 970	504-521	7249	Extrusion	865- 895	463-479
6013	Sheet	1045-1065	563-574	7349	Extrusion	870- 890	466-477
6013	Rod, Bar	1040-1060	560-571	7449	Plate	860- 890	460-477
6020	Rod, Bar	1010-1050	543-566	7449	Extrusion	860- 890	460-477
6053	Forging	960- 980	516-527				
6056	Extrusions	1012-1032	544-557	7475	Sheet[8], Plate	880- 970	471-521
6061	All	960-1075	516-579	8090	Sheet	990-1000	532-538
6063	Extrusion	960-1010	516-543	8090	Plate	990-1025	532-552
6066	All	960-1010	516-543				
6151	Forging	950- 980	510-527				

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) Solution heat treatment set temperatures for response-to-heat-treatment tests are mandatory and shall conform to Table 5A or 6A (see 8.4).

(4) 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 MMPDS or ASTM STP15D, shows, with a 95% confidence level, that 99% of the material meets specification requirements.

(5) 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).

(6) Temperatures higher than 900 °F (482 °C) should not be used unless manufacturing controls, production experience and/or tests ensure freedom from eutectic melting. For products thicker than 4 inches (102 mm), temperatures higher than 910 °F (488 °C) are not recommended.

(7) Procedures for solution heat treatment of forgings are proprietary.

(8) Alclad sheet, maximum temperature shall be 945 °F (507 °C).

(9) AMS2772 is not applicable to extrusion press quenched nor rolling mill quenched products. See 3.6.1 and 3.6.3.

Table 2 - Recommended minimum soaking time for solution heat treatment of wrought products

Thickness (see 2.2.3) Inches	Thickness (see 2.2.3) Millimeters[1]	Minimum Soaking Time Minutes[1] Salt Bath or Fluidized Bed	Minimum Soaking Time Minutes[1][2] Air Furnace
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)

Notes:
(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 3.6.4).
(2) The recommended minimum soaking time is based on load sensor readings. If soak start is based on furnace instrument readings, the lag between the furnace and load sensor readings is to be added to soak time shown in the table (see 3.6.2.1).

Table 3 - Maximum quench delay (for immersion quenching)[1]

Nominal Thickness Inches	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 to 0.25, incl	Over 2.29 to 6.35, incl	15
Over 0.25 to 1.0, incl	Over 6.35 to 25.4, incl	20
Over 1.0	Over 25.4	30

Notes:
(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.

Table 4 - Recommended aging treatments[5][6]

Alloy	Product Form (see 2.2.5)	Temper[1] Before Aging[2]	Temper[1] After Aging[2]	Aging[3] Temperature[4] (°F)	Aging[3] Temperature[4] (°C)	Aging[3] Time (Hours)
2011	All	T3	T8	320	160	14
2013	Extrusion	T3511	T6511	374	190	7-9
2014	Sheet	T4	T6	320	160	18
2014	All	T4	T6	350	177	9
2018	Forging	T41	T61	340	171	10
2024	Forging	T3	T8	375	191	11
2024	All Other	T3	T81	375	191	12
2024	Sheet, Wire	T36	T86	375	191	8
2024	Wire, Rod, Bar	T4	T6	375	191	12
2025	Forging	T4	T6	350	177	9
2048	All	T3	T8	375	191	12
2090	Extrusion	T3	T86	305	151	30
2090	Sheet	T3	T83	325	163	20-26
2098	All	T32P	T82P	320	160	17-19
2099	Extrusion	T33	T83	250 Followed by 305	121 151	10-14 42-54
2124	Plate	T3	T8	375	191	12
2124	Plate	T31	T8151	370	188	9-12
2124	Plate	T4	T6	375	191	9
2195	Plate	T34	T82	300-320	149-160	24-40
2218	Forging	T4	T6	340	171	10
2218	Forging	T4	T7	460	238	6
2219	Rod, Bar, Extrusion	T3	T8	375	191	18
2219	Sheet, Plate	T37	T87	325	163	24
2219	Forging	T4	T6	375	191	26
2219	All Other	T3	T8	350	177	18
2297	Plate	T37	T87	320	160	20-48
2397	Plate	T37	T87	320	160	59-61
2618	Forging	T4	T6	390	199	20
4032	Forging	T4	T6	340	171	10
6013	All	T4	T6	375	191	4
6013	Sheet, Alternate	T4	T6	345	174	8
6020	Rod, Bar, Extrusion	W	T6511	355	176	8-10
6020	Wire, Rod, Bar	T3	T8	355	176	8-10
6053	Forging	T4	T6	340	171	10
6061	Forging, Extrusion	T4	T6	350	177	8
6061	All Other	T4	T6	320	160	18
6063	All	T4	T6	350	177	8
6063	All, Alternate	T4	T6	360	182	6
6066	All	T4	T6	350	177	8
6151	All	T4	T6	340	171	10
6156	Sheet	T4	T62	375	190	4-6
6262	Extrusion	T4	T6	350	177	12
6262	All Other	T4	T6	340	171	8
6951	Sheet	T4	T6	320	160	18
7001	Extrusion	W	T6	250	121	24
7010	Plate, Forging	W	T73	250 Followed by 340	121 171	6-24 20
7010	Plate, Forging	W	T74	250 Followed by 340	121 171	6-24 14
7010	Plate, Forging	W	T76	250 Followed by 340	121 171	6-24 11

Table 4 - Recommended aging treatments (continued) [5][6]

Alloy	Product Form (see 2.2.5)	Temper[1] Before Aging[2]	Temper[1] After Aging[2]	Aging[3] Temperature[4] (°F)	Aging[3] Temperature[4] (°C)	Aging[3] Time (Hours)
7039	Plate	W	T64	Room Followed by 225 Followed by 300	Room 107 149	72 8 16
7040	Plate	W	T7451	250 Followed by 329	121 165	4-28 10-16
7039	Forgings	W	T73	Room Followed by 250 Followed by 325	Room 121 163	48 24 12
7140	Plate	W	T7451	250 Followed by 310	121 154	6-12 20-30
7049 & 7149	Extrusion	W	T73	Room Followed by 250 Followed by 330	Room 121 166	48 24 17
7049 & 7149	Extrusion	W	T76	Room Followed by 250 Followed by 325	Room 121 163	48 24 13
7049 & 7149	Forging	W	T73	Room Followed by 250 Followed by 340	Room 121 171	48 8-24 6-16
7049 & 7149	Forging	W52	T7352	Room Followed by 250 Followed by 335	Room 121 168	24 8-24 6-16
7049	Plate	W51	T7351	Room Followed by 250 Followed by 335	Room 121 168	8-16 8-24 6-16
7050	Forging	W	T6	Room Followed by 250	Room 121	72 48
7050	Wire, Rod, Bar	W	T73	250 Followed by 350	121 177	4-24 6-12
7050	Plate	W	T73	250 Followed by 350	121 177	4-24 8-16
7050	Plate	W	T74	250 Followed by 325	121 163	3-6 24-30
7050	Forging	W	T74	250 Followed by 350	121 177	3-6 6-12
7050	Forging	W51, 52	T7451, 52	250 Followed by 350	121 177	3-6 6-10
7050	Plate	W	T76	250 Followed by 325	121 163	3-6 12-15
7050	Extrusion	W	T76	250 Followed by 325	121 163	3-8 15-18
7050	Extrusion	W	T6	250	121	23-25
7055	Extrusion	W	T74511	250 Followed by 320	121 160	4-6 11-12
7055	Extrusion	W	T76511	250 Followed by 320	121 160	4-6 6.5-7.5