



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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Documents

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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 0.3% 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 $\pm$ 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.