SAE Aerospace
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# AEROSPACE MATERIAL SPECIFICATION

SAE MAM2771B

Issued 1992-07
Noncurrent 2003-09
Cancelled 2008-12

Superseding MAM2771A

## Heat Treatment of Aluminum Alloy Castings

RATIONALE

MAM2771A has been designated Cancelled and Superseded because equivalent technical requirements are provided in AMS2771.

CANCELLATION NOTICE

This specification has been declared "CANCELLED" by the Aerospace Materials Division, SAE, as of December 2008 and has been superseded by AMS2771. The requirements of the latest issue of AMS2771 shall be fulfilled whenever reference is made to the cancelled MAM2771. By this action, this document will remain listed in the Numerical Section of the Index of Aerospace Material Specifications, noting that it has been superseded by AMS2771.

Cancelled specifications are available from SAE.

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# AEROSPACE MATERIAL SPECIFICATION

SAE® MAM 2771A

Issued JUL 1992
Noncurrent SEP 2003

Superseding MAM 2771

## HEAT TREATMENT OF ALUMINUM ALLOY CASTINGS

### NONCURRENCY NOTICE

This specification has been declared “NONCURRENT” by the Aerospace Materials Division, SAE, as of September, 2003. It is recommended, therefore, that this specification not be specified for new designs.

AMS 2771 covers the same requirements.

“NONCURRENT” refers to those materials which have been widely used and which may be required on some existing designs in the future. The Aerospace Materials Division, however, does not recommend these as standard materials for future use in new designs.

“NONCURRENT” specifications are available from SAE.

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1. SCOPE:

1.1 Purpose:

This specification covers the engineering requirements for heat treatment of aluminum alloy castings and for parts machined from castings.

1.1.1 AMS 2771 is the inch/pound version of this specification.

1.2 Application:

This specification is applicable to cast parts using the following aluminum alloy families (See 8.1.10):

| | | | | |
|---|---|---|---|---|
| 201.0 | 243.0 | 333.0 | 357.0 | 707.0 |
| 203.0 | 295.0 | 336.0 | 358.0 | 712.0 |
| 206.0 | 296.0 | 354.0 | 359.0 | 713.0 |
| 222.0 | 319.0 | 355.0 | 520.0 | 850.0 |
| 242.0 | 328.0 | 356.0 | 705.0 | 851.0 |
| | | | | 852.0 |

1.3 When MAM 2771 is specified, heat treatment procedures for castings by foundries shall be in accordance with the material procurement specification when a specified heat treatment is required. However, requirements for equipment and controls shall be in accordance with MAM 2771.

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.

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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 Aluminum Alloy Parts
AMS 3025 Polyalkylene Glycol Heat Treat Quenchant

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM E 10 Brinell Hardness of Metallic Materials
ASTM B 557M Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)

3. TECHNICAL REQUIREMENTS:

3.1 Equipment:

Equipment used for thermal processing shall conform to the requirements of this specification and AMS 2750.

3.1.1 Pyrometry: Shall meet the requirements of AMS 2750.

3.1.2 Furnaces:

3.1.2.1 Heating Media: Shall be air, molten salt bath, oil bath, or fluidized bed. The products of combustion and other materials which could attack or contaminate parts shall not contact part. Electrical heating elements and radiant tubes shall be shielded to prevent direct radiation from striking any part. Composition and maintenance of salt baths and fluidized beds shall be such as to prevent attack of the parts.

3.1.2.2 Temperature Uniformity Surveys:

3.1.2.2.1 Solution Heat Treating and Aging Furnaces: The stabilization time between recovery of the first furnace thermocouple to the set temperature and recovery of the last test thermocouple to within 5 °C of the set temperature shall not exceed 20 minutes with an empty furnace. After stabilization, the temperature of all test thermocouples shall be within 5 °C of the set temperature.

3.1.2.2.2 Annealing Furnaces: After stabilization, the temperature of all test thermocouples shall be within 15 °C.

3.1.3 Quenching: Equipment shall be provided for quenching in water or in synthetic solutions and for measuring quenchant temperature. Provisions shall be made for mechanical or hydraulic agitation of the quenching medium or agitation of the parts or both and for heating and cooling of the quenchant, as required. Air agitation shall not be used. The volume of quenching medium shall be sufficient so that its temperature rise due to quenching is not more than 10 °C.

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3.1.3.1 Synthetic Solution: Polyalkalene glycol shall meet the requirements of AMS 3025. Other synthetics may be used if approved by the cognizant engineering organization. Solution concentration shall be established for the particular casting configuration prior to solution use.

3.1.3.2 Salt Contamination of Synthetic Solutions: Shall not exceed 6% by weight.

3.1.4 Cleaning: Equipment shall be provided to clean castings before heat treatment and to remove the film from parts quenched in a synthetic solution, oil from parts aged in oil baths, and salt residue from the surfaces of parts heated in salt baths unless the quench bath is equipped with fresh water overflow.

3.1.5 Refrigeration: Refrigeration or liquid baths shall be provided for cold storage of parts, when retention of the as-quenched (AQ) temper is necessary.

3.2 Procedures:

3.2.1 General: Cast parts that require heat treatment to a T4X, T6X, or T7X temper shall be solution heat treated (including quenching), refrigerated when necessary, and aged, when required, as specified herein. Heat treatment shall be performed only on entire parts, never on a portion of a part, except a section of a casting may be heat treated for test coupons as permitted in 4.4.2.2.

3.2.2 Racking and Spacing: Parts shall be racked or supported to permit free access of the heating and quenching media to all surfaces of parts in all portions of the load with minimal distortion.

3.2.2.1 Solution Heat Treating: All parts shall be separated by not less than 13.0 mm. Complex parts and parts of large plan form may require greater separation to permit free access.

3.2.2.2 Aging and Annealing: Parts shall be separated by not less than 13.0 mm.

3.2.2.3 Small parts may be heated and soaked in baskets or continuous furnaces. Care must be used to provide access for heating and quench media and to prevent damage during loading and quenching.

3.2.2.4 Exceptions to the above requirements shall be approved by the cognizant engineering organization (See 8.1.7).

3.2.3 Loading: Furnace shall not be loaded when the furnace temperature exceeds the solution treating temperature of the parts being heat treated.

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|---|---|---|

3.2.4 Soaking: For air furnace loads containing load thermocouples, fluidized beds, and salt baths, soaking time starts when all thermocouples are within 5 °C of the set or offset temperature. For other air furnace loads, soaking time starts when control thermocouples reach the temperature required. During solution heat treatment, after recovery, soaking shall be performed, without interruption, for the required time (See 8.1.6). Interruptions during solution treatment are permitted provided the minimum soak time is met and at least a two-hour soak time occurs after the interruption. During aging and annealing treatments, a maximum of four interruptions, with door(s) open for not more than two minutes during each, are permissible for removal or loading of parts.

3.2.4.1 Load thermocouples shall be used when needed to determine and control metal temperature and heating time or when required by the cognizant engineering organization (See 8.1.7).

3.2.5 Logs: A log (record), traceable to temperature recording chart(s), shall be kept for each furnace load. The information on the log/chart combination shall include the equipment identification, qualified operator's identification, date, part number(s), number of parts, alloy, minimum and maximum thickness, lot identification, times and temperatures used, quench delay, and type and temperature of quenchant. The minimum thickness recorded shall be the minimum dimensions of the lightest section of the part; the maximum thickness recorded shall be the minimum dimension of the heaviest section of the part.

3.2.6 Cleaning: Prior to heat treatment, parts shall be cleaned and shall be visually free of contaminants such as dirt, metal residues, and lubricants. Residual foundry sand and binders shall not be considered contaminants. Residue from heating and quenching media shall be removed from parts after heat treatment.

3.2.7 Solution Heat Treating:

3.2.7.1 Temperature: Cast parts that require solution heat treatment shall be soaked at the temperature specified in Table 1 (See 3.2.7.3), and shall not be loaded when the temperature exceeds that specified. Control instrument(s) shall be set either at the temperature specified in Table 1 or at an offset temperature based on the last temperature uniformity survey. The offset temperature shall be within 3 °C of the specified set temperature and shall be posted on the instrument. The offset temperature shall be selected to optimize temperature distribution within the furnace so that the highest and lowest temperatures are equidistant from the specified set temperature.

3.2.7.2 Soaking Time: Shall conform to Table 1 (See 8.1.6).

3.2.7.3 Variations: Solution treating temperatures may vary from the requirements of Table 1 to obtain required properties for a specific casting configuration. Departure from the required set temperature of more than 5 °C shall require approval of the cognizant engineering organization (See 8.1.7).

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3.2.7.4 Water Entrapment: Racks and fixtures used shall be constructed to preclude entrapment of water. Ammonium fluoborate, or equivalent, may be used in air furnaces as necessary.

3.2.7.5 Salt Entrapment: Parts that will entrap salt shall not be heated in a salt bath.

3.2.7.6 Quenching: Parts, after being soaked at the solution heat treating temperature for the required time, shall be quenched by immersion in water or in a synthetic solution.

3.2.7.6.1 Quenchant Temperature: To prevent excessive warpage and possible cracking, castings may be quenched in water with temperature varying from cold to hot (100 °C) or a synthetic solution at room temperature providing it is substantiated that the combination of quench and solution temperature will produce mechanical properties meeting the material specification without impairing corrosion resistance. During the quench, the quenchant temperature shall not rise more than 10 °C.

3.2.7.6.2 Quench Delay Time: The quench delay time shall not exceed 15 seconds. The delay shall be measured from the time the furnace door of an air furnace starts to open, or the first portion of the load emerges from a fluidized bed or salt bath, to complete immersion of the load in the quenchant. This delay time may be exceeded providing the temperature of the part(s) does not fall below 415 °C before immersion.

3.2.7.6.3 Agitation: Parts, quenchant, or both shall be vigorously agitated during quenching. Small parts heated and soaked in baskets may be quenched by dumping when basket loads are too heavy to allow adequate quenching by immersion of the full basket.

3.2.7.6.4 Immersion Time: Parts shall be kept immersed in the quenchant until parts are the same temperature as the quenchant.

3.2.7.7 Temper After Treatment: All alloys are in the AQ (as-quenched) temper immediately after quenching. After maximum delay time at room temperature or maximum refrigerated storage time has elapsed they are in the W temper which is unstable, i.e., their properties are continuously changing. After a delay of 96 hours at room temperature, unless otherwise noted herein, the tempers shall be as shown in Table 1.

3.2.8 Refrigeration: Cast parts requiring retention of the as-quenched (AQ) condition after solution treatment shall, after quenching, be refrigerated. The maximum delay time between quench and refrigeration shall not exceed 45 minutes. The maximum refrigeration storage time shall not exceed seven days at -12 °C, 30 days at -18 °C, or 90 days at -23 °C maximum temperatures. (See 8.2)

3.2.9 Aging: Cast parts requiring aging shall be aged as specified in Table 2 (See 3.2.9.1) to obtain the final temper and required mechanical properties.

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3.2.9.1 Delay at Room Temperature: The aging treatment shall not be initiated until at least 16 hours at room temperature have elapsed after quenching, unless otherwise allowed by the cognizant engineering organization.

3.2.9.2 Variations: Aging temperature may vary from the requirements of Table 2 to obtain required properties for a specific casting configuration. Departure from the required set temperature of more than 15 °C shall require approval of the cognizant engineering organization.

3.2.10 Annealing: Cast parts requiring annealing shall be heated, soaked, and cooled as specified in Table 3. If a partial anneal (stress relief) is required, it shall be as specified by the cognizant engineering organization.

3.2.11 Straightening After Final Heat Treatment: Shall be performed in conformance with the requirements of the cognizant engineering organization.

3.3 Qualification:

3.3.1 Suppliers: Facilities performing heat treatment in accordance with this specification shall be approved as specified in 4.5.1 by the cognizant quality assurance organization (See 8.1.8).

3.3.2 Personnel: All responsible heat treating personnel at leadman and foreman levels performing heat treatment in accordance with this specification shall be qualified as specified in 4.5.2 by the cognizant quality assurance organization.

3.4 Acceptance: Procedures given in 4.4.2 shall be used to confirm that parts have been heat treated as specified.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

Except as specified in 4.1.1, the supplier shall be responsible for the performance of all tests and inspections specified herein. The supplier may use his own facilities or any commercial laboratory acceptable to the cognizant quality assurance organization. The procuring activity reserves the right to sample and to perform any tests or inspections to confirm that parts have been heat treated properly.

4.1.1 Responsibility for Inspection for Direct U.S. Government Orders: Unless otherwise specified in the contract, the contractor shall be responsible for the performance of all inspection requirements as specified herein. The contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the government. The government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure supplies and services conform to specified requirements.

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4.2 Inspection:

The cognizant quality assurance organization shall review heat treating records and the results of tests and inspections to verify that heat treatment conformed to all requirements of this specification.

4.3 Records:

Records shall be kept available to purchaser for five years after heat treatment. The records shall contain all data necessary to verify conformance to the requirements of this specification.

4.4 Heat Treatment Control:

4.4.1 Equipment Control:

4.4.1.1 Heat treating equipment and test instrumentation shall be controlled, calibrated, tested, and maintained in accordance with AMS 2750.

4.4.1.2 Heat treating equipment used for solution heat treating and for aging shall be qualified initially, and after any rework which could affect its thermal characteristics, by performing temperature uniformity surveys in accordance with AMS 2750. Equipment qualified in accordance with AMS 2770 shall be considered qualified for this specification.

4.4.2 Parts Control:

4.4.2.1 Each part shall be hardness tested in accordance with ASTM E 10 when specified by the material procurement specification or the cognizant engineering organization. Acceptance criteria shall be established for each configuration based on test of "cast-to-size" tensile specimens or specimens attached to the cast part. In lieu of testing each part, a random sampling plan of each lot may be used when such sampling is approved by the cognizant quality assurance organization.

4.4.2.2 Tensile testing, when required, shall be in accordance with ASTM B 557M. The tensile specimen shall be made from a part selected at random, or a prolongation thereof, or a section of a part, or separately "cast-to-size" tensile specimens cast from the same casting alloy as the parts.

4.4.2.3 If any specimen fails to meet the specified requirements, disposition of the castings may be based on the results of testing two additional specimens for each original nonconforming specimen. Failure of any retest specimen shall be cause for rejection and disposition by the cognizant engineering organization.

4.4.3 Process Control: The cognizant quality assurance organization shall perform any inspections, surveillances, tests, and statistical process control analyses necessary to ensure that parts are heat treated in accordance with this specification.

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4.5 Qualification:

4.5.1 Vendors (Subcontractors): The approval of a facility shall be based upon meeting the following requirements:

4.5.1.1 The heat treating vendor shall submit a copy of its shop procedure, consisting of a full description of all equipment and procedures that will be used to meet the requirements of this specification. The equipment and procedures shall be approved by the cognizant quality assurance organization.

4.5.1.2 The equipment shall meet the requirements of this specification and AMS 2750.

4.5.2 Personnel: Qualification of personnel shall be based upon meeting the requirements of 4.5.2.1, 4.5.2.2, and 4.5.2.3. These requirements may be waived if a person has experience acceptable to the cognizant quality assurance organization.

4.5.2.1 Completion of an apprenticeship program approved by the cognizant quality assurance organization.

4.5.2.2 Passing a written examination prepared by the cognizant quality assurance organization.

4.5.2.3 Demonstration of capability of heat treating parts in their company's facilities.

4.6 Reports:

The vendor shall furnish with each shipment a report showing the heat treatment log reference, the results of tests to determine conformance to this specification, and a statement that the parts were processed in accordance with the requirements of this specification. This report shall include the purchase order number, MAM 2771, alloy designation and material specification number, part number, quantity, and the soaking times and set temperatures used.

4.6.1 If the heat treating procedure is considered proprietary, the vendor may certify that the information is proprietary and is on file. The procedures shall be available for review by personnel representing the purchaser or the cognizant quality control organization.

5. PREPARATION FOR DELIVERY:

All parts shall be preserved and wrapped or packaged to ensure protection from corrosion and damage during handling, transportation, and storage.

6. ACKNOWLEDGMENT:

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

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7. REJECTIONS:

Castings and parts not heat treated in accordance with this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES:

8.1 Definitions:

8.1.1 Solution Heat Treatment: Soaking parts at an elevated temperature for a sufficient time to put alloying elements into solid solution followed by quenching to retain the condition until the parts are aged.

8.1.2 Aging (Precipitation Heat Treatment): Soaking solution heat treated parts at a moderately elevated temperature or, for some alloys and tempers, at room temperature to precipitate alloying elements from solid solution to develop strength and corrosion resistance properties.

8.1.3 Annealing: A full anneal will soften material to develop maximum formability and ductility. A partial anneal is used when grain growth is a problem or when less formability or ductility is required.

8.1.4 Synthetic Quench: A water solution of polyalkylene glycol or other synthetic material used when minimum distortion or low residual stresses are desired.

8.1.5 Parts: The words "parts", "casting", and "cast parts" as used in this specification have the same meaning and are used interchangeably.

8.1.6 Recovery and Soaking Time: Recovery time is elapsed time between insertion of parts in a heating medium and start of soaking time. For air furnace loads containing load thermocouples, fluidized beds, and oil and salt baths, soaking time starts when all thermocouples are within 5 °C of the specified set or offset temperature. For other air furnace loads, except as specified in 3.2.4.1, soaking time starts when all thermocouples return to the temperature indicated before insertion of parts,

8.1.7 Cognizant Engineering Organization: A term applied to the engineering organization responsible for the design of the parts or a designee of that organization.

8.1.8 Cognizant Quality Assurance Organization: A term applied to the quality assurance organization which is allied to the cognizant engineering organization or its designee.

8.1.9 Lot: A group of parts of the same part number and at the same stage of fabrication which have been either heat treated in the same load or, in the case of continuous furnaces, hand-loaded salt baths, etc, have been heat treated continuously during the same eight-hour shift.

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8.1.10 Alloy Family: A term which refers to variations within a single alloy designation. The variations normally only amount to closer control on certain elements in the composition or tighter tolerances on allowable interstitials while maintaining the basic chemistry. An example being 357.0 with variations designated A357.0, B357.0, D357.0, etc. Different heat treat procedures may be necessary due to composition variations as noted in Table 1 and Table 2.

8.2 Prechilling: Prior to refrigeration, parts may be prechilled in a suitable cooled bath if necessary to accelerate cooling for compliance with requirement of 3.2.8.

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

8.4 Key Words:

Heat treatment, aluminum alloy, castings, parts from castings

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PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE “D”.

TABLE 1 - Solution Heat Treatment Temperature and Soak Time

| Alloy | Set Temperature (1) °C | Soak Time (2) (3) Hours | Temper After Solution Treatment and Delay at RT |
|---|---|---|---|
| 201.0 | 525 (4) | 14 | T4 |
| A201.0 | 525 | 14 | T4 |
| 203.0 | 545 | 5 | T4 |
| A206.0 | 525 (4) | 12 | T4 |
| 222.0 | 505 | 6 | T4 |
| 242.0 | 520 | 2 | T41 |
| 243.0 | 520 | 2 | T41 |
| 295.0 | 515 | 6 | T4 |
| 296.0 | 510 | 4 | T4 |
| 310.0 | 500 | 6 | T4 |
| 319.0 | 500 | 6 | T4 |
| 328.0 | 515 | 12 | T4 |
| 333.0 | 505 | 2 | T4 |
| 336.0 | 515 | 6 | T45 |
| 354.0 | 525 | 10 | T41 |
| 355.0 | 525 | 6 | T4 |
| C355.0 | 525 | 6 | T4 |
| 356.0 | 540 | 6 | T4 |
| A356.0 | 540 | 6 | T4 |
| A357.0 | 545 | 8 | T4 |
| D357.0 | 545 | 8 | T4 |
| 358.0 (5) | 540 | 20 | T4 |
| 359.0 | 540 | 10 | T4 |
| 520.0 | 430 | 12 | T4 |
| 712.0 | 535 | 2 | T4 |

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