SAE Aerospace
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# AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2768

Issued AUG 2005

## Heat Treatment of Magnesium Alloy Castings

1. SCOPE:

1.1 Purpose:

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

1.2 Application:

This specification is applicable to castings of the following magnesium alloys:

| | | | | |
|---|---|---|---|---|
| AM100A | AZ63A | AZ81A | AZ91C | AZ91E |
| AZ92A | EQ21A | EZ33A | QE22A | ZE41A |
| WE43A | WE54A | ZK51A | ZK61A | |

1.3 When AMS 2768 is specified and specific heat treat processing instructions are included in the material specification, the equipment and control requirements of AMS 2768 shall apply. For alloys not specifically covered, the applicable provisions of this specification shall be invoked but temperatures, times, and quench procedures shall be as specified by the purchaser.

1.4 It is permissible, for specific parts, to use equipment, practices and test methods which conformed to AMS-H-6857 or MIL-H-6857 and were previously acceptable to the purchaser.

2. 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 superceding document has been specified, the last published issue of that document shall apply.





**TO PLACE A DOCUMENT ORDER:**
**Tel: 877-606-7323 (inside USA and Canada)**
**Tel: 724-776-4970 (outside USA)**
**Fax: 724-776-0790**
**Email: custsvc@sae.org**
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2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

| | |
|---|---|
| AMS 2750 | Pyrometry |
| AMS 3025 | Polyalkylene Glycol Heat Treat Quenchant |
| ARP 1962 | Training and Approval of Heat Treating Personnel |

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 or www.astm.org.

| | |
|---|---|
| ASTM B 557 | Methods of Tension Testing Wrought and Cast Aluminum and Magnesium Alloy Products |

3. TECHNICAL REQUIREMENTS:

3.1 Equipment:

Equipment used for thermal processing shall conform to the requirements of this specification and AMS 2750, except (1) requirements for working zone controls, instruments and sensors shall apply to all heating zones and (2) recordings from instruments may be stored on magnetic or optical media providing a hard copy is available on request.

3.1.1 Pyrometry: Shall meet the requirements of AMS 2750.

3.1.2 Furnaces:

3.1.2.1 Heating Media: Shall be air, protective atmosphere, combustible gases, or fluidized bed. Electrical heating elements and radiant tubes shall be shielded to prevent direct radiation from striking any part. The furnace products of combustion in the furnace, and the composition and maintenance of fluidized beds shall be such as to prevent attack or contamination of the parts, or impingement of the flame on the work.

3.1.2.2 Temperature Uniformity: The design and construction of the furnaces shall be such that the temperature in the working zone is capable of being maintained within ±10 °F (6 °C) of the desired heat treating temperature after the charge has been brought up to temperature. At no time shall the temperature in any part of the working zone exceed the maximum permissible temperature for the alloy being heat treated (See Table 1).

3.1.3 Quenching: Unless otherwise approved by the cognizant engineering organization, the following provisions apply. Equipment shall be provided for quenching in water, air blast, oil, or in polymer quenchants and for measuring quenchant temperature. Provisions shall be made for mechanical, hydraulic, or air agitation of the quenching medium, or agitation of the parts, or both and for heating or cooling of the quenchant, as required. Air agitation shall be allowed provided the air doesn't come in contact with the parts being quenched. The volume of quenching medium for immersion quenching shall be sufficient so that its temperature rise due to quenching meets the requirements of 3.2.8.3.1. 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 and provided that the parts are not damaged by dumping. Exceptions to the use of agitation is permitted provided that it has been demonstrated that the parts meet the required specified properties in the final heat treated condition.

3.1.3.1 Polymer Quenchants: Polyalkalene glycol shall meet the requirements of AMS 3025. Other synthetics may be used provided that they have demonstrated not to be detrimental to the material and that the parts meet the required specified properties in the final heat treated condition. Polymer concentration shall be established for the particular casting configuration prior to use.

3.1.4 Cleaning: Equipment shall be provided to clean castings before heat treatment, and to remove residual film from parts quenched in a polymer quenchant or oil from parts quenched or aged in oil baths.

3.2 Procedures:

3.2.1 General: Cast parts that require heat treatment to a T4X, T5X, or T6X temper shall be heat treated in accordance with Tables 1 and 2 (See 3.2.4). Heat treatment shall be performed only on entire parts, never on a portion of a part. The process used to generate the necessary requirements shall be established and controlled for each part number to ensure that each lot of castings is treated in the same manner.

3.2.2 Racking and Spacing: Product shall be supported or hung and spaced to permit flow of the heating and cooling media over all surfaces to ensure that the castings will meet the specified requirements. Written instructions, drawings, photographs, etc. shall be used as necessary to ensure proper spacing.

3.2.2.1 Water Entrapment: Racks and fixtures used for solution heat treatment shall be constructed to preclude entrapment of water.

3.2.3 Loading: The furnaces shall be at or below the maximum solution treating temperature when the parts are loaded.

3.2.4 Control instrument(s) shall be set within the temperature range specified in Table 1 for solution treating and should be set at the recommended temperature specified in Table 2 for aging. Sensor/control offsets, if used, shall comply with AMS 2750.

3.2.5 Soaking: Soaking time starts when all temperature control sensing elements are within 10 °F (6 °C) of the set or offset temperature.

3.2.5.1 Interruptions during solution treatment are permitted provided the minimum soak time is met and at least a 2-hour soak time occurs after the interruption. During aging treatments a maximum of four interruptions are permitted for removal or loading of parts. The time between door opening and furnace or load thermocouple recovery is not to be counted as part of the total aging time.

3.2.6 Logs: A record (written or electronic storage media), traceable to temperature recording information (chart(s) or electronic storage media) and to shop travelers or other documentation, shall be kept for each furnace and load. The information on the combination of documents shall include: equipment identification, approved personnel's identification, date, part number or product identification, number of parts, alloy, lot identification, AMS 2768 or other applicable specification, actual thermal processing times and temperatures used. When applicable, atmosphere control parameters, quench delay, quenchant type, polymer concentration and quenchant temperature shall also be recorded. The maximum thickness, when process parameters are based on thickness, shall be recorded and shall be taken as the minimum dimension of the heaviest section of the part. The log data shall be recorded in accordance with the heat treater's documented procedures.

3.2.7 Cleaning: Prior to heat treatment, parts shall be cleaned to assure that there will be no adverse effects to the surfaces following heat treatment. Residue from heating and quenching media shall be removed from parts after heat treatment.

3.2.8 Solution Heat Treating:

3.2.8.1 Temperature: Cast parts that require solution heat treatment shall be soaked within the temperature ranges specified in Table 1.

3.2.8.1.1 For solution heat treating AZ63A (type 1 and 2), AZ81A, AZ91C, AZ91E, AZ92A (type 1), AM100A, and ZK61A, the castings shall be heated slowly to prevent eutectic melting which is cause for rejection. Incremental steps or a uniform heating rate, which requires at least 2 hours to raise the temperature from 640 °F (338 °C) to the heat treating temperature, shall be used (See 8.5).

3.2.8.1.2 AZ92A (type 2) and QE22A may be charged into the furnace which is at the heat treating temperature.

3.2.8.1.3 Evidence of high temperature oxidation shall be cause for rejection (See 3.4.3.1). A protective atmosphere containing sufficient sulfur dioxide, carbon dioxide, or satisfactory oxidation inhibitor shall be used when solution heat treating at or above 750 °F (399 °C) (See 8.2).

3.2.8.2 Soaking Time: The castings shall be held at temperature for a sufficient time to secure adequate solution heat treatment. Recommended soaking times at temperature for castings up to 1 inch (25.4 mm) thickness are provided in Table 1. A longer soaking time may be required for castings with heavier sections.

3.2.8.3 Quenching: Parts, after being soaked at the solution heat treating temperature for the required time, shall be quenched.

3.2.8.3.1 Quenchant Temperature: During the quench, the quenchant temperature shall not rise more than 25 °F (14 °C). To prevent excessive warpage and possible cracking, castings may be quenched in oil or water with temperature varying from cold to hot (212 °F (100 °C)) or in a polymer quenchant at room temperature providing it is substantiated that the combination of quench and solution temperature will produce mechanical properties meeting the material specification. Exceptions to the temperature rise are permitted provided that it has been demonstrated by testing and documentation that the parts meet the required specified properties in the final heat treated condition.

3.2.8.3.2 Quench Delay Time: The quench delay time shall not exceed 30 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, to complete immersion of the load in the quenchant. This delay time may be exceeded providing that the cooling rate does not result in a loss of any mechanical property typically obtained by the established process for that casting configuration.

3.2.8.3.3 Quenchant Contact Time: Castings which are quenched by immersion shall be kept immersed in the quenchant for not less than 2 minutes per inch of thickness, or fraction thereof in the thickest section. Alternatively, castings shall be kept immersed in the quenchant for not less than 2 minutes after boiling ceases. Parts quenched in boiling water shall remain immersed for not less than 2 minutes. Castings quenched in an air blast shall remain in contact with the air blast until surface temperatures are reduced to 212 °F (100 °C).

3.2.9 Aging: Precipitation heat treatment or artificial aging, when T5 or T6 tempers are specified, shall be performed at the temperature and times required to develop the specified properties. Aging conditions which have been used satisfactorily are shown in Table 2. No protective atmosphere is required.

3.2.10 Straightening after final aging is prohibited unless otherwise specified by the cognizant engineering organization.

3.3 Qualification:

3.3.1 Suppliers: Facilities performing heat treatment in accordance with this specification shall be subject to approval by the cognizant quality assurance organization (See 8.1.7).

3.3.2 Personnel: All responsible heat treating personnel at leadsman and foreman levels performing heat treatment in accordance with this specification shall be qualified as specified in 4.5.

3.4 Acceptance:

3.4.1 The routine operation of the equipment and heat treating procedure shall be judged by the mechanical properties obtained on the test bars heat treated with every furnace charge and tested in accordance with ASTM B 557.

3.4.2 Microscopic Examination: The tensile test may be supplemented by a microscopic examination of the test bars or selected castings at the discretion of the cognizant engineering organization. At least one representative sample for each of the specified tests shall be taken. If the furnace selected for routine inspection contains a load which is homogeneous as to alloy, form and size of part, two specimens shall be selected to represent the least massive and the most massive portions of the charge. In the event of nonhomogeneous as to type of alloy, and when the recommended heat treatments for the respective alloys differ, additional samples shall be prepared.

3.4.2.1 Eutectic melting and high temperature oxidation: Specimens from the heat treated samples shall be prepared for microscopic examination. The unetched surface shall be examined at 500X minimum magnification with a metallurgical microscope. The presence of eutectic melting or high temperature oxidation shall be considered evidence of improper heat treatment (See 3.4.3.3). Porosity should not be confused with eutectic melting.

3.4.3 Improper Heat Treatment:

3.4.3.1 Improper Equipment: If any of the tests indicate that the heat treatment was improper (3.4.2.1) and was caused by poor performance of the furnace (and not improper settings or insufficient time in the furnace), the furnace shall not be used for further heat treating until it is demonstrated that all equipment and operating requirements of this specification are being met.

3.4.3.2 Status of Materials: Materials heat treated in the furnace since the time of the previous tests and found unsatisfactory shall be rejected or reheat treated (beginning with the solution heat treatment) in an acceptable furnace, depending on the character of the failed tests.

3.4.3.3 If the test samples show eutectic melting or high temperature oxidation, the casting lot(s) shall be rejected and no reheat treatment permitted.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The supplier shall be responsible for the performance of all tests and inspections specified herein. The procuring activity reserves the right to sample and to perform any tests or inspections to confirm that parts have been heat treated properly.

4.2 Inspection:

The cognizant quality assurance organization may 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 performance of heat treatment. The records shall contain all data necessary to verify conformance to the requirements of this specification.

4.3.1 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 cognizant engineering or quality organizations.

4.4 Process Control:

The cognizant quality assurance organization may perform any inspections, surveillance, tests, and statistical process control analyses necessary to ensure that parts are heat treated in accordance with this specification.

4.5 Personnel Qualification:

ARP1962 provides an example of a program for training and approval and lists the associated operations.

4.6 Reports:

The vendor shall furnish with each shipment a report referencing the heat treatment log number, 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, AMS 2768, alloy designation and material specification number, part number, and quantity.



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.

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

8.1.1 Solution Heat Treatment: Soaking parts at an elevated temperature for a sufficient time to put alloying constituents 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 to precipitate alloying constituents from solid solution to develop strength and corrosion resistance properties.

8.1.3 Polymer Quenchant: A water solution of polyalkylene glycol or other synthetic material used when minimum distortion or low residual stresses are desired.

8.1.4 Parts: The words "parts", "casting", and "cast parts" as used in this specification have the same meaning and are used interchangeably. Small parts are those that are under 0.250 inch (6.35 mm) in nominal thickness and weigh 2 pounds (0.9 kg) or less.

8.1.5 Recovery and Soaking Time: Recovery time is elapsed time between insertion of parts in a heating medium and start of soaking time. Soaking time starts when all temperature control sensing elements and load thermocouples (if used) are within 10 °F (6 °C) of the set or offset temperature.

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

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

8.2 A potential fire hazard exists in the heat treatment of magnesium alloys. If, through oversight or failure of the temperature control equipment, the temperature of the furnace appreciably exceeds the maximum solution heat treating temperature of the alloy, the castings may ignite and burn. A suitable sulfur dioxide or carbon dioxide atmosphere prevents the starting of a fire until the temperature limits have been exceeded by a considerable amount. Many heat treaters use an atmosphere of 0.5 to 1.0% sulfur dioxide, or carbon dioxide in a minimum concentration of 3% to 950 °F (510 °C) or 5% up to about 1000 °F (538 °C). Once a magnesium fire has started, the sulfur dioxide or carbon dioxide supply to the furnace should be shut off, since the burning magnesium unites with the oxygen of these materials. Each furnace used should be equipped with a safety cutout which will turn the power off to the heating elements and blowers in the event of any malfunctioning or failure of the temperature control equipment. These safety cutouts should be set at a temperature of no more than 10 °F (6 °C) above the maximum temperature permitted for the alloy being heat treated. Air flow switches should also be installed to guard against the stoppage of circulation of air and they should be interconnected with a manual reset control.

8.2.1 When protective atmospheres referred to in 8.2 are used, the concentration in the furnace atmosphere should be checked at periodic intervals.

8.3 An effective method of extinguishing a magnesium fire in a gas tight furnace is to introduce boron trifluoride gas ($BF_3$) through a small opening into the closed furnace. Details of this method may be found in NFPA Bulletin No. 480, “Storage, Handling, and Processing of Magnesium”, which is issued by the National Fire Protection Association. Argon, or other inert gases, can be used to flood a furnace to extinguish a magnesium fire.

8.4 AZ63A (type 1 and 2), AZ81A, AZ91C, AZ92A (type 1), AM100A, and ZK61A castings will be irreversibly damaged if not brought slowly to the solution heat treating temperature. Certain eutectic constituents in these alloys melt at a temperature lower than that required for the solution heat treatment, consequently, time should be allowed for the constituents to dissolve before their melting point is reached.

8.4.1 The presence of calcium in AZ92A (type 2) alloy greatly diminishes the danger of partial fusion and permits a more rapid rate of heating. The presence of calcium in AZ63A (type 2) does not eliminate the danger of partial fusion (eutectic melting) but it does allow a higher final temperature for solution heat treatment.

8.5 The aging treatments recommended in Table 2 for “as cast” materials are used to improve mechanical properties, to provide a stress relief, and to stabilize the alloys in order to prevent dimensional changes later, especially during machining. Both yield strength and hardness are increased somewhat by this treatment at the expense of a slight amount of ductility. This treatment is often recommended for those applications where “as cast” mechanical properties suffice, and dimensional stability is essential.