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AEROSPACE MATERIAL SPECIFICATION

SAE AMS-M-6857

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Magnesium Alloy Castings, Heat Treatment of

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1. SCOPE:

1.1 This specification covers the requirements for the heat treatment of magnesium alloy castings. This specification covers furnace equipment requirements, and general information for heat treating procedures and heat treating temperatures for magnesium alloys.

1.2 Alloys:

The following magnesium alloys are covered by this specification (see Table 1):

AM100A
AZ63A
AZ81A
AZ91C
AZ91E
AZ92A
ZK51A
ZK61A
ZE41A
ZE63A
EZ33A
HK31A
HZ32A
ZH62A
EQ21A
QH21A
QE22A
WE54A

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2. APPLICABLE DOCUMENTS:

The following publications, of the issues in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

2.1 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-45662 Calibration System Requirements

2.2 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2750 Pyrometry

2.3 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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

2.4 Order of precedence:

In the event of a conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. TECHNICAL REQUIREMENTS:

3.1 Furnaces:

Furnaces used for the solution heat treatment and aging of magnesium alloys shall be of the closed chamber type with forced air or protective atmosphere circulation. These furnaces shall be designed to preclude direct radiation from the heating elements or impingement of the flame on the work.

3.1.1 Temperature uniformity: The design and construction of the furnaces shall be such that the temperature in the working zone, for any charge, 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 II). Each furnace used shall be equipped with a separate manual reset safety cutout which will turn off the heat source in the event of any malfunctioning or failure of the regular control equipment. These safety cutouts shall be set as close as practicable above the maximum solution heat treating temperature for the alloy being heat treated. Protective devices shall also be installed to turn off the heat source in case of stoppage of circulation of air.

3.2 Heat control equipment:

3.2.1 Pyrometry and furnace temperature control: The requirements and procedures for control and testing of furnaces, ovens, and allied pyrometric equipment used for heat treatment shall be in accordance with AMS 2750.

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3.2.1.1 Temperature-measuring and recording equipment: Location of temperature-measuring and recording instruments shall be in accordance with AMS 2750. The exact location of the temperature-sensing elements will be dependent upon the furnace design. However, they shall be in such a location as to give accurate measurement of the working or soaking, or both, zone temperature.

3.2.1.2 Accuracy: Temperatures shall be adjusted to within ±5°F (±3°C) of true temperature by applying corrections established by calibrating equipment as specified in 4.3.3.

3.3 Quenching:

Rapid cooling from the solution heat treated condition is required to obtain optimum properties in the castings. The arrangements should be such that the cooling on the various parts of a furnace charge or casting is as uniform as possible.

3.3.1 Air quenching by means of fan cooling can be used if the quench rate is sufficiently rapid to obtain the desired properties.

3.3.2 Water quenching requires the use of a sufficient volume of water in the quench tank to insure that proper quenching rates are attained. Means shall be provided for circulation of the water to give violent agitation during the quench cycle in order to reduce the incidence of steam pockets. Means for heating or cooling to provide the desired water temperature are required.

3.3.2.1 Quenching equipment shall be located in such a manner and handling facilities shall be so arranged and equipped to permit rapid transfer of the load from the furnace to the quenching medium.

3.4 Miscellaneous equipment:

Suitable jigs, fixtures, trays, hangers, racks, ventilators, etc., shall be provided as necessary for the proper handling of the work and for the maintenance of the equipment.

3.5 Approval:

The equipment, methods, and processes shall be subject to the approval of the procuring activity.

3.6 Procedure and operations:

3.6.1 Heat Treatment: Magnesium alloy castings shall be solution heat treated to the T4 temper properties of the applicable material specification within the temperature ranges specified in Table II. When unusual circumstances make strict compliance with Table II impractical, request for deviation approval with substantiating test data should be addressed to the procuring activity.

3.6.1.1 The furnace shall be loaded in such a manner as to permit adequate circulation of the furnace atmosphere. Attention shall be given to providing necessary support to minimize warpage.

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3.6.2 The charge shall be held at temperature for a sufficient time to secure adequate solution heat treatment. Suggested soaking times at temperature for castings up to 1 inch (25.4 mm) thickness are given in Table II. A longer soaking time may be required for castings with heavier sections.

3.6.2.1 In solution heat treating AZ63A (type 1 and type 2), AZ81A, AZ91C, AZ92A (type 1), AM100A and ZK61A, the castings shall be heated slowly to prevent eutectic melting which is cause for rejection. 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.

3.6.2.2 AZ92A (type 2), HK31A and QE22A may be charged into the furnace which is at the heat treating temperature.

3.6.2.3 Evidence of high temperature oxidation shall be cause for rejection (See 6.4.1). A protective atmosphere containing sufficient sulfur dioxide, carbon dioxide, or other satisfactory oxidation inhibitor shall be used when solution heat treating at or above 750°F (339°C).

3.6.2.4 Heat treating operations shall be performed on the whole of a casting (never on a part only) and shall be applied in a manner that will produce the utmost uniformity.

3.6.3 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 III. No protective atmosphere is required.

3.6.4 Reheat treatment: Reheat treatment and resubmission of material rejected for improper heat treatment is permitted. Full information concerning the cause of all previous rejections of the lot shall accompany any resubmitted material (see 4.4.4).

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for inspection:

Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, 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 this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

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4.1.1 Responsibility for compliance: All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.2 General:

All heat treating and cooling equipment, temperature control devices, and all details of the heat treating procedure shall be subject to inspection by representatives of the procuring activity.

4.2.1 Acceptance or approval of the equipment shall in no case be construed as a guarantee of the acceptance of the heat treated product.

4.2.2 The supplier shall maintain on file test reports showing results of the temperature survey required by this specification and make them available to representatives of the procuring activity.

4.3 Equipment:

4.3.1 Furnace temperature survey: A temperature survey shall be made for each furnace to be used on the contract or order. This survey may be waived at the discretion of the procuring activity provided that the results from previous tests with the same furnace and same type of load show that the uniformity is within the specified limits.

4.3.1.1 A new survey shall be made after changes are made in the furnace construction.

4.3.2 Temperature uniformity: The temperature uniformity shall be determined while the furnace contains a typical charge.

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4.3.2.1 The initial temperature survey shall be made at the maximum and minimum temperature of solution heat treatments and precipitation heat treatments for which each furnace is to be used. The number and location of the test temperature-sensing elements shall meet the requirements of AMS 2750. After the initial survey, each furnace shall be surveyed monthly, except as provided in 4.3.1 and 4.3.2.2. The monthly survey shall be at one operating temperature for solution heat treatment and one for precipitation heat treatment. The surveys shall be performed in such a manner as to reflect the normal operating characteristics of the furnace. If the furnace is normally charged after being stabilized at the correct operating temperature, the temperature-sensing elements shall be similarly charged. If the furnace is normally charged cold, the temperature-sensing elements shall be charged cold. After insertion of the temperature-sensing elements, readings should be taken frequently enough to determine when the temperature of the test region of the furnace approached the bottom of the temperature range being surveyed. From the time until thermal equilibrium is reached, the temperature of all test locations shall be determined at 2-minute intervals in order to detect any overshooting. After thermal equilibrium is reached, readings should be taken at 5-minute intervals for sufficient time to determine the recurrent temperature pattern, but not less than 30 minutes. Before thermal equilibrium is reached, none of the temperature readings should exceed the maximum temperature of the range being surveyed. After thermal equilibrium is reached, the maximum temperature variation of all elements shall not exceed 20°F (11°C) and shall not vary outside the range being surveyed.

4.3.2.2 Monthly surveys may not be necessary when the furnace is equipped with a permanent multipoint recording system with at least two sensing thermocouples in each zone or when at least two load thermocouples are employed to measure actual metal temperature, providing that uniformity surveys show a history of satisfactory performance for a period of at least 6 months.

4.3.2.3 Furnace control temperature measuring instruments shall not be used to read the temperature of the test temperature sensing elements.

4.3.3 Accuracy of furnace pyrometer systems: The accuracy of temperature-measuring systems shall be checked under operating conditions weekly. Checks should be made by inserting a calibrated test temperature-sensing element adjacent to the furnace temperature-sensing element and reading the test temperature-sensing element with a calibrated test potentiometer. When the furnace is equipped with dual potentiometer measuring systems which are checked daily against each other, the above checks may be conducted every 3 months, rather than every week. The test temperature-sensing element, potentiometer, and cold junction compensation combination shall have been calibrated against Bureau of Standards' primary or secondary certified temperature-sensing elements within the previous 3 months, to an accuracy of ±2°C (±1°C).

4.3.3.1 Calibration: Calibration of equipment as specified in 3.2.1.2 shall be carried out in accordance with MIL-STD-45662.

4.4 Test methods:

4.4.1 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.

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4.4.2 The tensile test results of the separately cast test bars or of test bars sectioned from the heat treated castings shall be used to judge the adequacy of the heat treatment to produce acceptable properties. The number of tensile tests shall be as specified in the applicable material specification.

4.4.3 Microscopic examination: The tensile test shall be supplemented by a microscopic examination of the test bars or selected castings at the discretion of the procuring activity. A single 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 nonhomogeneity as to type of alloy, and when the recommended heat treatments for the respective alloys differ, additional samples shall be prepared.

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

4.4.4 Improper heat treatment:

4.4.4.1 Improper equipment: In case any of the tests indicate that the heat treatment was improper (4.4.3.1) 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.

4.4.4.2 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. Alloys in which eutectic melting and high temperature oxidation is found shall be rejected and no reheat treatment permitted.

5. PACKAGING:

This section is not applicable to this document.

6. NOTES:

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use:

This specification is intended for development and control of heat treating procedures applied to magnesium alloy castings.

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6.2 Acquisition requirements:

Acquisition documents must specify the following:

a. Title, number and date of the specification.
b. Issue of DODISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.1)

6.3 Consideration of data requirements:

The following data requirements should be considered when this specification is applied on a contract. The applicable Data Item Description (DID) should be reviewed in conjunction with the specific acquisition to ensure that only essential data are requested/provided and that the DID is tailored to reflect the requirements of the specific acquisition. To ensure correct contractual application of the data requirements, a Contract Data Requirements List (DD Form 1423) must be prepared to obtain the data, except where DOD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
4.2.2	DI-MISC-80653	Test Reports	

The above DID is that cleared as of the date of this specification. The current issue of DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current cleared DID's are cited on the DD Form 1423.

6.4 General Information:

6.4.1 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 0.5-1.0 percent sulfur dioxide or 3.0-3.5 percent carbon dioxide for protection at temperatures as low as 600°F (316°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 off the power 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°F) 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.

6.4.1.1 When protective atmosphere referred to in section 6.4.1 are used, the concentration in the furnace atmosphere should be checked at periodic intervals.

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6.4.2 An effective method of extinguishing 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.

6.4.3 The temperatures for solution treatment shown in Table II are the maximum temperatures to which the alloys may be heated without danger of high temperature deterioration or fusion of the eutectic. Magnesium alloy castings may be heat treated at lower temperatures but in such cases a longer time at temperature than that shown in Table II would be necessary in order to develop satisfactory mechanical properties.

6.4.4 AS63A (type 1 and type 2), AZ81A, AZ91C, (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.

6.4.4.1 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.

6.4.5 The aging treatments recommended in Table III for "as cast" materials are used to improve mechanical properties, to provide 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 application, where "as cast" mechanical properties suffice, and dimensional stability is essential.

6.5 Subject term (key word) listing:

Aging
Eutectic
Permanent mold
Quench
Sand casting
Temper

6.6 Metrication:

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.

PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE "D"

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TABLE I
MAGNESIUM BASE CASTING ALLOYS COVERED BY THIS SPECIFICATION

Alloy	Form	Other Specifications		
AM100A	Permanent Mold	ASTM B 199	AMS 4483	MIL-M-46062
AM100A	Sand Casting	ASTM B 80		MIL-M-46062
AZ63A	Sand Casting	ASTM B 80	AMS 4420, 4422, 4424	
AZ81A	Permanent Mold	ASTM B 199		
AZ81A	Sand Casting	ASTM B 80		
AZ91C	Permanent Mold	ASTM B 199		MIL-M-46062
AZ91C	Sand Casting	ASTM B 80	AMS 4437	MIL-M-46062
AZ91E	Sand Casting	ASTM B 80	AMS 4446	
AZ91E	Permanent Mold	ASTM B 199		
AZ92A	Permanent Mold	ASTM B 199	AMS 4484	MIL-M-46062
AZ92A	Sand Casting	ASTM B 80	AMS 4434	MIL-M-46062
ZK51A	Sand Casting	ASTM B 80	AMS 4443	MIL-M-46062
ZK61A	Sand Casting	ASTM B 80	AMS 4444	MIL-M-46062
ZE41A	Sand Casting	ASTM B 80	AMS 4439	MIL-M-46062
ZE63A	Sand Casting	ASTM B 80	AMS 4425	MIL-M-46062
EZ33A	Permanent Mold	ASTM B 199		
EZ33A	Sand Casting	ASTM B 80	AMS 4442	
HK31A	Permanent Mold	ASTM B 199		MIL-M-46062
HK31A	Sand Casting	ASTM B 80	AMS 4445	MIL-M-46062
HZ32A	Sand Casting	ASTM B 80	AMS 4447	
ZH62A	Sand Casting	ASTM B 80	AMS 4438	MIL-M-46062
EQ21A	Permanent Mold	ASTM B 199		
EQ21A	Sand Casting	ASTM B 80	AMS 4417	
QE22A	Permanent Mold	ASTM B 199		MIL-M-46062
QE 22A	Sand Casting	ASTM B 80	AMS 4418	MIL-M-46062
QH21A	Sand Casting	ASTM B 80	AMS 4419	
WE54A	Sand Casting		AMS 4426	

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