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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 4446A

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Submitted for recognition as an American National Standard

Superseding AMS 4446

MAGNESIUM ALLOY, SAND CASTINGS
8.7Al - 0.70Zn - 0.26Mn (AZ91 E-T6)
Solution and Precipitation Heat Treated

UNS M11919

1. SCOPE:

1.1 Form:

This specification covers a magnesium alloy in the form of sand castings.

1.2 Application:

These castings have been used typically for parts operating up to 300 °F (149 °C), and requiring moderate strength and excellent corrosion resistance, but usage is not limited to such applications.

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.

2.1 SAE Publications:

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

AMS 2360 Room Temperature Tensile Properties of Castings
AMS 2475 Protective Treatments, Magnesium Alloys
AMS 2694 Repair Welding of Aerospace Castings
AMS 2804 Identification, Castings

2.2 ASTM Publications:

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

ASTM B 117 Operating Salt Spray (Fog) Testing Apparatus
ASTM B 557 Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
ASTM B 557M Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)
ASTM B 660 Packaging/Packing of Aluminum and Magnesium Products
ASTM E 10 Brinell Hardness of Metallic Materials
ASTM E 35 Chemical Analysis of Magnesium and Magnesium Alloys
ASTM E 155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings

2.3 U.S. Government Publications:

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

MIL-M-6857 Magnesium Alloy Castings, Heat Treatment of
MIL-STD-453 Inspection, Radiographic
MIL-STD-6866 Inspection, Liquid Penetrant

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

Shall conform to the percentages by weight shown in Table 1, determined by wet chemical methods in accordance with ASTM E 35, by spectrochemical methods, or by other analytical methods acceptable to purchaser.

TABLE 1 - Composition

Element	min	max
Aluminum	8.1	9.3
Zinc	0.40	1.0
Manganese	0.17	0.35
Iron (See 3.1.1)	--	0.005
Silicon	--	0.30
Copper	--	0.030
Nickel	--	0.0010
Other Impurities, Each	--	0.01
Magnesium	remainder	

3.1.1 If iron exceeds 0.005, iron to manganese ratio shall not exceed 0.032, determined using Equation 1.

Example calculation:

$$\frac{0.006 \text{ wt \% Fe}}{0.20 \text{ wt \% Mn}} = 0.030 \text{ which is} < 0.032 \qquad \text{(Eq.1)}$$

3.2 Condition:

Solution and precipitation heat treated to the T6 temper.

3.3 Casting:

(R) Castings shall be produced from metal conforming to 3.1. Furnace or ladle additions of grain-refining elements or alloys are permissible. Molten metal taken from alloying furnaces, with or without additions of foundry operating scrap (gates, sprues, risers, and rejected castings), shall not be poured into castings unless first converted to ingot, analyzed, and remelted or unless the composition of a sample taken after the last addition to the melt conforms to 3.1.

3.3.1 A melt shall be the metal withdrawn from a batch-furnace charge of 2000 pounds (907 kg) or less as melted for pouring castings or, when permitted by purchaser, a melt shall be 4000 pounds (1814 kg) or less of metal withdrawn from one continuous furnace in not more than eight consecutive hours.

3.3.2 A lot shall be all castings poured from a single melt in not more than eight consecutive hours and solution and precipitation heat treated in the same heat treat batch.

3.4 Cast Test Specimens:

Chemical analysis specimens and tensile specimens shall be cast as follows:

3.4.1 (R) Chemical Analysis Specimens: Shall be cast from each melt and shall be of any suitable size, shape, and form.

3.4.2 Tensile Specimens: Shall be cast with each lot of castings, shall be of standard proportions conforming to ASTM B 557 or ASTM B 557M with 0.500 inch (12.70 mm) diameter at the reduced parallel gage section, and shall be cast to size in molds made of the regular foundry mix of sand without using chills. Metal for the specimens shall be part of the melt which is used for the castings and shall be subjected to the same grain-refining or alloying treatment given the metal for the castings. The temperature of the metal during pouring of the specimens shall be not lower than that during pouring of the castings.

3.4.3 Integrally-Cast Coupons for Corrosion Specimens: When salt spray (fog) corrosion properties are to be determined using integrally-cast coupons (See 3.6.4), specimens shall be approximately 3 inches (76 mm) square by 0.25 inch (6.4 mm) thick.

3.4.3.1 (R) One or more integrally-cast coupons should remain on the casting where possible until just prior to protective treatment specified in 5.2.1. If necessary to remove integrally-cast coupons prior to protective treatments, coupons shall accompany castings through any further processing such as, but not limited to, heat treatment, blasting, and etching.

3.5 Heat Treatment:

Castings and representative tensile specimens shall be solution and precipitation heat treated in accordance with MIL-M-6857. One or more sets of tensile specimens shall, during each stage of heat treatment, be placed into a batch-type furnace with each load of castings or into a continuous furnace at intervals of not longer than three hours.

3.6 Properties:

Castings and representative separately-cast tensile specimens produced in accordance with 3.4.2 shall conform to the following requirements:

3.6.1 Tensile Properties: Shall be as follows, determined in accordance with ASTM B 557 or ASTM B 557M; conformance to the requirements of 3.6.1.1 shall be used as the basis for acceptance of castings except when purchaser specifies that the requirements of 3.6.1.2 apply:

3.6.1.1 Separately-Cast Specimens: Shall meet the requirements shown in Table 2.

TABLE 2 - Minimum Tensile Properties

Property	Value
Tensile Strength	34.0 ksi (234 MPa)
Yield Strength at 0.2% Offset	16.0 ksi (110 MPa)
Elongation in 4D	3.0%

3.6.1.2 Specimens Cut from Castings: The average of not less than four, and preferably ten, specimens cut from thick and thin sections of a casting or castings shall be as shown in Table 3.

TABLE 3 - Minimum Average Tensile Properties

Property	Value
Tensile Strength	25.5 ksi (176 MPa)
Yield Strength at 0.2% Offset	14.5 ksi (100 MPa)
Elongation in 4D	0.75%

3.6.1.2.1 Any specimen cut from a casting shall be as shown in Table 4.

TABLE 4 - Minimum Average Tensile Properties

Property	Value
Tensile Strength	17.0 ksi (117 MPa)
Yield Strength at 0.2% Offset	12.0 ksi (83 MPa)

3.6.1.2.2 When properties other than those specified in 3.6.1.2 and 3.6.1.2.1 are required, tensile specimens as in 4.3.4 machined from locations indicated on the drawing, from a casting or castings chosen at random to represent the lot, shall have the properties indicated on the drawing for such specimens. Property requirements may be designated in accordance with AMS 2360.

3.6.2 (R) Castings, except at sprue and riser locations, shall have a hardness of 65 to 85 HB10/500 or 75 to 95 HB10/1000, determined in accordance with ASTM E 10, but castings shall not be rejected for hardness if tensile properties are met on the specimen from which hardness is determined.

3.6.3 Grain Size: Shall be as agreed upon by purchaser and vendor.

3.6.4 (R) Corrosion Resistance: Shall not be greater than 0.050 inch (1.27 mm) per year for integrally-cast specimens or, when specified, specimens cut from castings, determined in accordance with 3.6.4. 1.

3.6.4.1 Corrosion rate shall be determined in accordance with ASTM B 117 except that, prior to exposure, specimens shall be accurately weighed to within ±0.01 gram (W_1). Specimens shall be exposed to the salt spray for not less than 120 hours. Following exposure, specimens shall be rinsed with tap water and cleaned of adherent corrosion product by immersing in a hot [190 °F (88 °C)] 20% chromic acid plus 1% silver nitrate solution for 1 to 2 minutes. Cleaned specimens shall be rinsed in hot water, dried in a stream of hot air, and reweighed (W_2). The measured weight loss (WL) shall be calculated (W_1 - W_2) and used for calculating corrosion rate, using Equations 2 and 3:

$$\text{CR (mg/cm}^2\text{ per day)} = \frac{\text{WL}}{\text{SA x EP}} \qquad \text{(Eq.2)}$$

$$\text{CR [mils (0.001 inch) per year]} = \frac{\text{CR (mcd)}}{\text{D}} \text{ x } 143.7 \qquad \text{(Eq.3)}$$

where:

WL = Measured weight loss in mg
SA = Total surface area of specimen in cm^2
EP = Exposure time in days
D = Density, 1.81 g/cm^3

3.7 Quality:

3.7.1 Castings, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the castings.

3.7.1.1 (R) Castings shall have smooth surfaces and shall be sufficiently cleaned to permit fluorescent penetrant examination.

3.7.1.2 Castings, cleaned by blasting, shall be pickled in a sulfuric or sulfuric-nitric acid solution to remove not less than 0.002 inch (0.05 mm) of metal before protective treatment as in 5.2.1.

3.7.2 (R) Castings shall be produced under radiographic control. This control shall consist of radiographic examination of castings in accordance with MIL-STD-453, or other radiographic procedure acceptable to purchaser, until proper foundry technique, which will produce castings free from harmful internal imperfections, is established for each part number and of production castings as necessary to ensure maintenance of satisfactory quality.

3.7.3 (R) When specified, castings shall be subjected to fluorescent penetrant inspection in accordance with MIL-STD-6866.

3.7.4 Radiographic, fluorescent penetrant, and other quality standards shall be as agreed upon by purchaser and vendor. ASTM E 155 may be used to define radiographic acceptance standards.

3.7.5 Castings shall not be repaired by peening, plugging, welding, or other methods without written permission from purchaser.

3.7.5.1 When permitted in writing by purchaser, defects in castings may be removed and the castings repaired by welding in accordance with AMS 2694.

3.7.6 Castings shall not be impregnated, chemically treated, or coated to prevent leakage unless specified or allowed by written permission of purchaser designating the method to be used.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

(R) The vendor of castings shall supply all samples for vendor's tests and shall be responsible for the performance of all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the castings conform to specified requirements.

4.2 Classification of Tests:

4.2.1 (R) Acceptance Tests: Except as specified in 4.2.1.1, composition (3.1), tensile properties of separately-cast specimens (3.6.1.1) or, when specified, tensile properties of specimens cut from castings (3.6.1.2), hardness (3.6.2), and quality (3.7) are acceptance tests and shall be performed to represent each melt or lot as applicable.

4.2.1.1 Tensile properties of specimens cut from castings or from integrally-cast coupons shall be determined only when specified by purchaser or when separately-cast specimens are not available. Tensile properties of separately-cast specimens or integrally-cast coupons need not be determined when tensile properties of specimens cut from castings are determined.

4.2.2 Periodic Tests: Corrosion resistance (3.6.4) is a periodic test and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: All technical requirements are preproduction tests and shall be performed prior to or on the first-article shipment of a casting to a purchaser, when a change in material and/or processing requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S. Military procurement, substantiating test data and, when requested, preproduction test material shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.

4.3 Sampling and Testing:

Shall be in accordance with the following:

4.3.1 (R) One chemical analysis specimen from each melt for conformance to 3.1.

4.3.2 (R) One or more tensile specimens in accordance with 3.4.2 from each lot except when purchaser requires properties of specimens cut from castings.

4.3.3 (R) Sufficient castings of each part number in accordance with 4.4.1 to satisfy dimensional, property, and quality evaluations.

4.3.4 One or more castings from each lot when tensile properties are required from specimens cut from castings. Specimens shall conform to ASTM B 557 or ASTM B 557M and shall be either 0.500 inch (12.70 mm) diameter at the reduced parallel gage section, sub-size specimens proportional to the standard, or standard sheet-type specimens. For determining conformance to the requirements of 3.6.1.2.2, if specimen locations are not shown on the drawing, not less than four tensile specimens, two from the thickest section and two from the thinnest section, shall be cut from a casting or castings from each lot.

4.3.5 Two specimens for corrosion resistance testing in accordance with 3.6.4, when required. Location of such specimens shall be as agreed upon by purchaser and vendor.

4.4 Approval:

4.4.1 Sample castings from new or reworked patterns and the casting procedure shall be approved by purchaser before castings for production use are supplied, unless such approval be waived by purchaser.

4.4.2 Vendor shall establish, for production of sample castings of each part number, parameters for the process control factors which will produce acceptable castings; these shall constitute the approved casting procedure and shall be used for producing production castings. If necessary to make any change in parameters for the process control factors, vendor shall submit for reapproval a statement of the proposed changes in processing and, when requested, test specimens, sample castings, or both. Production castings incorporating the revised operations shall not be shipped prior to receipt of reapproval.

4.4.2.1 (R) Process control factors for producing castings include, but are not limited to, the following; supplier procedure shall identify tolerances, ranges, and/or control limits as applicable.

Type of furnace
Furnace atmosphere
Ladle addition or grain refining practice
Fluxing sand formulation or oxide removal procedure
Gating and risering practices
Metal pouring temperature; variation of ±50 F (±28 C) degrees from established limit is permissible
Solidification and cooling procedures
Solution and precipitation heat treatment cycles
Cleaning operations
Methods of inspection

4.4.2.1.1 Any of the above process control factors for which parameters are considered proprietary by the vendor may be assigned a code designation. Each variation in such parameters shall be assigned a modified code designation.

4.5 Reports:

The vendor of castings shall furnish with each shipment a report showing the results of tests for chemical composition of at least one casting or of separately-cast specimens from each melt and for tensile properties of separately-cast specimens representing each lot or of specimens cut from castings from each lot and stating that the castings conform to the other technical requirements. This report shall include the purchase order number, lot number, AMS 4446A, part number, and quantity.

4.6 Resampling and Retesting:

If any specimen used in the above tests fails to meet 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 to meet specified requirements shall be cause for rejection of the castings represented. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Identification: Shall be in accordance with AMS 2804.

5.1.1 Impregnated castings shall be marked “IMP”.