

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

SAE AMS 4446

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MAGNESIUM ALLOY CASTINGS, SAND 8.7Al - 0.70Zn - 0.26 Mn (AZ91E-T6) Solution and Precipitation Heat Treated

1. SCOPE:

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

1.2 Application: Primarily for parts operating up to 300°F (150°C), requiring moderate strength and excellent corrosion resistance.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 2360 - Room Temperature Tensile Properties of Casting
AMS 2475 - Protective Treatment, Magnesium Alloys
AMS 2635 - Radiographic Inspection
AMS 2645 - Fluorescent Penetrant Inspection
AMS 2646 - Contrast Dye Penetrant Inspection
AMS 2694 - Repair Welding of Aerospace Castings
AMS 2804 - Identification, Castings

REAFFIRMED

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2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM B117 - Method of Salt Spray (Fog) Testing
ASTM B557 - Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
ASTM E10 - Brinell Hardness of Metallic Materials
ASTM E35 - Chemical Analysis of Magnesium and Magnesium Alloys
ASTM E155 - Reference Radiographs for Inspection of Aluminum and Magnesium Castings

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Specifications:

MIL-M-6857 - Magnesium Alloy Castings, Heat Treatment of

2.3.2 Military Standards:

MIL-STD-649 - Aluminum and Magnesium Products, Preparation for Shipment and Storage

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, determined by wet chemical methods in accordance with ASTM E35 or by spectrographic or other analytical methods approved by purchaser:

	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.

Example calculation: $\frac{0.006 \text{ wt \% Fe}}{0.20 \text{ wt \% Mn}} = 0.030$ which is < 0.032

3.2 Condition: Solution and precipitation heat treated.

- 3.3 Casting: Castings shall be produced in lots from metal conforming to 3.1. Metal remelted from previously analyzed ingot may be poured directly into castings. Furnace or ladle additions of grain-refining elements of alloys are permissible. If grain-refining elements or alloys are not added, the molten metal shall be subjected to superheating or other grain-refining treatment. 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 lb (900 kg) or less as melted for pouring castings or, when permitted by purchaser, a melt shall be 4000 lb (1800 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 and, when requested by purchaser, shall be supplied with castings:
- 3.4.1 Chemical Analysis Specimens: Shall be cast from each melt and shall be of a size and shape agreed upon by purchaser and vendor.
- 3.4.2 Tensile Specimens: Shall be cast with each lot of castings, shall be of standard proportions conforming to ASTM B557 with 0.500 in. (12.50 mm) diameter at the reduced parallel gauge section, and shall be cast to size in molds made of the regular foundry mix of sand without using chills. Metal for 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 in. (75 mm) square by 0.25 in. (6.0 mm) thick.
- All integrally-cast coupons should remain on castings where possible until just prior to protective treatment, specified in 5.2. If it is 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; at least one set of tensile specimens shall, during each stage of heat treatment, be put 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 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 B557; 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:

Tensile Strength, min	34,000 psi (235 MPa)
Yield Strength at 0.2% Offset, min	16,000 psi (110 MPa)
Elongation in 4D, min	3.0%

3.6.1.2 Specimens Cut from Castings:

3.6.1.2.1 The average of not less than 4, and preferably 10, specimens cut from thick and thin sections of a casting or castings shall be as follows:

Tensile Strength min	25,500 psi (175 MPa)
Yield Strength at 0.2% Offset, min	14,500 psi (100 MPa)
Elongation in 4D, min	0.75%

3.6.1.2.2 Any specimen cut from a casting shall meet the following:

Tensile Strength, min	17,000 psi (115 MPa)
Yield Strength at 0.2% Offset, min	12,000 psi (85 MPa)

3.6.1.2.3 When properties other than those specified in 3.6.1.2.1 and 3.6.1.2.2 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 Hardness: Castings, except at sprue and riser locations, should have hardness of 65 - 85 HB/10/500 or 75 - 95 HB/10/1000, determined in accordance with ASTM E10, but castings shall not be rejected on the basis of hardness if the tensile property requirements of 3.6.1.2 are met.

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

3.6.4 Corrosion Resistance: Shall be as follows, determined in accordance with 3.6.4.3; conformance to the requirements of 3.6.4.1 shall be used as the basis for acceptance of castings except when purchaser specifies that the requirements of 3.6.4.2 apply:

3.6.4.1 Integrally-Cast Coupons: Corrosion rate shall be not greater than 0.050 in. (1.25 mm) per year.

3.6.4.2 Specimens Cut from Castings: Corrosion rate of any specimen cut from a casting shall be not greater than 0.050 in. (1.25 mm) per year.

- 3.6.4.3 Corrosion rate shall be determined in accordance with ASTM B117 except that, prior to exposure, specimens shall be accurately weighed to within +0.01g (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 (90°C)] 20% chromic acid plus 1% silver nitrate solution for 1 - 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 the following equations:

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

$$CR \text{ [mils (0.001 in.) per year]} = \frac{CR \text{ (mcd)}}{D} \times 143.7$$

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 Castings shall have smooth surfaces and shall be well cleaned.
- 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 in. (0.05 mm) of metal before protective treatment as in 5.2.
- 3.7.2 Castings shall be produced under radiographic control. This control shall consist of radiographic examination of castings in accordance with AMS 2635 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 When specified, castings shall be subjected to fluorescent penetrant inspection in accordance with AMS 2645, to contrast dye penetrant inspection in accordance with AMS 2646, or to both.
- 3.7.4 Radiographic, fluorescent penetrant, contrast dye penetrant, and other quality standards shall be as agreed upon by purchaser and vendor. ASTM E155 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: The vendor of castings shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the castings conform to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for 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), and quality (3.7) are classified as 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 shall be determined only when specified by purchaser or when separately-cast specimens are not available. Tensile properties of separately-cast specimens need not be determined when tensile properties of specimens cut from castings are determined.

4.2.2 Periodic Tests: Tests to determine conformance to requirements for corrosion resistance of integrally-cast coupons (3.6.4.1) or, when specified, specimens cut from castings (3.6.4.2) are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: Tests to determine conformance to all technical requirements of this specification are classified as 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, processing, or both 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: Shall be in accordance with the following:

4.3.1 Two chemical analysis specimens in accordance with 3.4.1 from each melt or a casting from each lot.

- 4.3.2 Three tensile specimens in accordance with 3.4.2 from each lot except when purchaser requires properties of specimens cut from castings.
- 4.3.3 Two preproduction castings in accordance with 4.4.1 of each part number.
- 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 B557 and shall be either 0.500 in. (12.50 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 3.6.1.2.3, 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 integrally-cast coupons for corrosion resistance testing when required. Location of such coupons 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 Control factors for producing castings include, but are not limited to, the following:
- Type of furnace
 - Furnace atmosphere
 - Fluxing and deoxidation procedures
 - Gating and risering practices
 - Metal pouring temperature; variation of $\pm 50^{\circ}\text{F}$ ($\pm 30^{\circ}\text{C}$) from the 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.