

Magnesium Alloy, Sand Castings
8.7Al - 0.70Zn - 0.26Mn (AZ91E-T6)
Solution and Precipitation Heat Treated
(Composition similar to UNS M11919)

RATIONALE

AMS4446C revises Composition (3.1), Heat Treatment (3.5), and Sampling (4.3.1), and results from a Five Year Review and update of this specification.

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

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AMS2175	Castings, Classification and Inspection of
AMS2360	Room Temperature Tensile Properties of Castings
AMS2475	Protective Treatments, Magnesium Alloys
AMS2694	In-Process Welding of Castings
AMS2768	Heat Treatment of Magnesium Alloy Castings
AMS2804	Identification, Castings

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2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B 117 Operating Salt Spray (Fog) 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 B 953 Sampling Magnesium and Magnesium Alloys for Spectrochemical Analysis

ASTM B 954 Analysis of Magnesium and Magnesium Alloys by Atomic Emission Spectrometry

ASTM E 10 Brinell Hardness of Metallic Materials

ASTM E 155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings

ASTM E 1417 Liquid Penetrant Testing

ASTM E 1742 Radiographic Examination

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the percentages by weight shown in Table 1, determined by spectrochemical methods in accordance with ASTM B 954, 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 Elements, Each (3.1.2)	--	0.01
Magnesium	remainder	

3.1.1 If iron exceeds 0.005, iron to manganese ratio shall not exceed 0.032.

Example calculation: 0.006% Fe and 0.20% Mn results in a ratio of 0.030. Since 0.030 does not exceed 0.032, the composition is acceptable.

3.1.2 Determination not required for routine acceptance.

3.2 Condition

Solution and precipitation heat treated to the T6 temper.

3.3 Casting

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 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 3.6.3), specimens shall be approximately 3 inches (76 mm) square by 0.25 inch (6.4 mm) thick.

3.4.3.1 One or more integrally-cast coupons should remain on the casting where possible until just prior to protective treatment (pickle) specified in 5.2.1. If necessary to remove integrally-cast coupons prior to protective treatments (pickle), 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 AMS2768. 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 3 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 AMS2360.

3.6.2 Grain Size

Shall be as agreed upon by purchaser and vendor.

3.6.3 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 3.6.3.1.

- 3.6.3.1 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 1 and 2:

$$\text{CR (mcd)} = \frac{\text{WL}}{\text{SA} \times \text{EP}} \quad (\text{Eq. 1})$$

$$\text{CR [mils (0.001 inch) per year]} = \frac{\text{CR (mcd)} \times 143.7}{\text{D}} \quad (\text{Eq. 2})$$

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

mcd = mg/cm^2 per day

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 sufficiently cleaned to permit fluorescent penetrant examination.
- 3.7.1.2 Castings, cleaned by blasting, shall be etched 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 Castings shall be produced under radiographic control. This control shall consist of 100% radiographic inspection of castings until process control factors (4.4.2) have been established to ensure production of acceptable castings. Unless otherwise specified by the purchaser, continued radiographic inspection of production castings shall be performed at a frequency determined by the vendor to assure continued maintenance of internal quality.
- 3.7.3 Methods of inspection and frequency of inspection shall be as agreed upon by purchaser and vendor. A "Casting Class" of AMS2175 may be selected to specify the method and frequency of inspection.
- 3.7.4 When acceptance standards are not specified, Grade C of AMS2175 shall apply. ASTM E 155 may be used to define radiographic acceptance standards.
- 3.7.5 Radiographic inspection shall be conducted in accordance with ASTM E 1742, unless otherwise specified by purchaser.
- 3.7.6 When specified by purchaser, castings shall be fluorescent penetrant inspected using a method specified by the purchaser, or, if not specified, a method in accordance with ASTM E 1417.

3.7.7 Castings shall not be peened, plugged, impregnated, or welded unless authorized by purchaser.

3.7.7.1 When authorized by purchaser, welding in accordance with AMS2694 or other welding program approved by the purchaser may 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 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 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), 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 (3.6.3) 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.

4.3 Sampling and Testing

Shall be in accordance with the following:

- 4.3.1 At least one chemical analysis specimen from each melt in accordance with 3.4.1 and ASTM B 953 for conformance to 3.1.
- 4.3.2 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 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.