



AEROSPACE MATERIAL SPECIFICATION

Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

AMS 4445D

Superseding AMS 4445C

Issued 1-15-57

Revised 1-15-79

UNS M13310

MAGNESIUM ALLOY CASTINGS, SAND

3.3Th - 0.75Zr (HK31A-T6)

Solution and Precipitation Heat Treated

SAE Technical Board rules provide that: "All technical reports, including standards approved and practices recommended, are advisory only. Their use by anyone engaged in industry or trade or their use by governmental agencies is entirely voluntary. There is no agreement to adhere to any SAE standard or recommended practice, and no commitment to conform to or be guided by any technical report. In formulating and approving technical reports, the Board and its Committees will not investigate or consider patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against liability for infringement of patents."

1. SCOPE:

- 1.1 Form: This specification covers a magnesium alloy in the form of sand castings.
- 1.2 Application: Primarily for parts operating at 350° - 600°F (175° - 315°C).
- 1.3 Material covered by this specification is radioactive. All applicable rules and regulations, including those of the Nuclear Regulatory Agency, pertaining to handling of radioactive material and all licensing provisions for use of such material should be observed.
2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., 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 Castings
- AMS 2361 - Elevated Temperature Tensile Properties of Castings
- AMS 2475 - Protective Treatments, Magnesium Base Alloys
- AMS 2635 - Radiographic Inspection
- AMS 2645 - Fluorescent Penetrant Inspection
- AMS 2646 - Contrast Dye Penetrant Inspection
- AMS 2804 - Identification, Castings

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

- ASTM B557 - Tension Testing Wrought- and Cast-Aluminum- and Magnesium-Alloy Products
- ASTM E10 - Brinell Hardness of Metallic Materials
- ASTM E21 - Elevated Temperature Tension Tests of Metallic Materials
- ASTM E35 - Chemical Analysis of Magnesium and Magnesium Alloys
- ASTM E155 - Reference Radiographs for Inspection of Aluminum and Magnesium Castings, Series III

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

2.3.1 Federal Standards:

- Federal Test Method Standard No. 151 - Metals; Test Methods

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, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, or by other approved analytical methods:

	min	max
Thorium	2.5	4.0
Zirconium, total	0.50	1.0
Zirconium, soluble (3.1.2)	0.50	--
Zinc	--	0.30
Copper (3.1.2)	--	0.10
Nickel (3.1.2)	--	0.01
Other Impurities, total	--	0.20
Magnesium		remainder

3.1.1 Soluble zirconium is that portion of the zirconium which is soluble in 1:4 hydrochloric acid held below its boiling point.

3.1.2 Determination not required for routine acceptance.

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 or alloys are permissible. Unless otherwise agreed upon by purchaser and vendor, 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 has been found to conform to 3.1.

3.3.1 A melt shall be the metal withdrawn from a batch furnace charge of 2000 lb (908 kg) or less as melted for pouring castings or, when permitted by purchaser, a melt shall be 4000 lb (1816 kg) or less of metal withdrawn from one continuous furnace in not more than 8 consecutive hours.

3.3.2 A lot shall be all castings poured from a single melt in not more than 8 consecutive hours.

3.4 **Cast Test Specimens:** Chemical analysis specimens and tensile test specimens shall be cast as follows and, when requested, shall be supplied with the 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 Test 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 gage section, and shall be cast to size in molds made with 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.

3.5 **Heat Treatment:** Castings and representative tensile test specimens shall be heat treated as follows; at least one set of tensile test 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 3 hours:

3.5.1 Solution Heat Treatment: Heat to $1050^{\circ}\text{F} \pm 15$ ($565^{\circ}\text{C} \pm 8$), hold at heat for not less than 2 hr, and cool in air.

3.5.2 Precipitation Heat Treatment: Heat to $400^{\circ}\text{F} \pm 10$ ($205^{\circ}\text{C} \pm 5$), hold at heat for not less than 16 hr, and cool in air.

3.6 Properties: Castings and representative tensile test specimens produced in accordance with 3.4.2 shall conform to the following requirements:

3.6.1 Tensile Properties:

3.6.1.1 At Room Temperature: Shall be as follows, determined in accordance with ASTM B557; conformance to the requirements of 3.6.1.1.1 shall be used as basis for acceptance of castings except when purchaser specifies that the requirements of 3.6.1.1.2 apply:

3.6.1.1.1 Separately-Cast Specimens:

Tensile Strength, min	27,000 psi (186 MPa)
Yield Strength at 0.2% Offset, min	13,000 psi (90 MPa)
Elongation in 4D, min	4%

3.6.1.1.2 Specimens Cut From Castings:

3.6.1.1.2.1 When tensile properties of actual castings are determined for acceptance, the average of not less than 4, and preferably 10, specimens cut from thick and thin sections shall be as follows:

Tensile Strength, min	23,000 psi (159 MPa)
Yield Strength at 0.2% Offset, min	11,700 psi (81 MPa)
Elongation in 4D, min	2%

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

Tensile Strength, min	19,000 psi (131 MPa)
Yield Strength at 0.2% Offset, min	10,500 psi (72 MPa)

3.6.1.2 At 600°F (316°C): Shall be as follows, determined in accordance with ASTM E21 on specimens heated to $600^{\circ}\text{F} \pm 5$ ($316^{\circ}\text{C} \pm 3$), held at heat for 10 min. before testing, and tested at $600^{\circ}\text{F} \pm 5$ ($316^{\circ}\text{C} \pm 3$):

3.6.1.2.1 Separately-Cast Specimens:

Tensile Strength, min	19,000 psi (131 MPa)
Yield Strength at 0.2% Offset, min	12,000 psi (83 MPa)

3.6.1.2.2 Specimens Cut From Castings:

Tensile Strength, psi	13,000 psi (90 MPa)
Yield Strength at 0.2% Offset, psi	9,500 psi (66 MPa)

3.6.1.3 When properties other than those of 3.6.1.1.2, and 3.6.1.2.2 are specified, tensile test specimens as in 4.3.4 taken from locations indicated on the drawing, from a casting chosen at random to represent the lot, shall have the properties indicated on the drawing for such specimens. Property requirements for such specimens at room temperature may be designated in accordance with AMS 2360 and at elevated temperatures in accordance with AMS 2361.

3.6.2 **Hardness of Castings:** Castings, except at sprue and riser locations, should have hardness of 45 - 70 HB/10/500, 45 - 70 HB/14.3/1000, or 50 - 75 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 3.6.1.1.2 are met.

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 internal and external 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, unless otherwise specified by purchaser.

3.7.2 Castings shall be produced under radiographic control, unless otherwise specified. 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 or to contrast dye penetrant inspection in accordance with AMS 2646.

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 provided the weld repair area has properties comparable to those of the parent metal. Repair welds shall be subjected to the same inspection procedures and acceptance standards required of the castings. Weld repair areas shall be suitably marked to facilitate inspection. Repair welding shall be performed prior to any heat treatment and nondestructive testing specified herein.

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 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 perform such confirmatory testing as he deems 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), room temperature tensile properties (3.6.1.1 or 3.6.1.2), hardness (3.6.2), and quality (3.7) are classified as acceptance tests and shall be performed to represent each lot.

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 600°F (316°C) tensile properties
Ø (3.6.1.2) are classified as periodic tests and shall be performed on the castings or separately-cast specimens 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 on the first-article shipment of a casting to a purchaser, when a change in processing requires reapproval, or when purchaser deems confirmatory testing is 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 and/or a casting from
Ø each lot.

Ø 4.3.2 Three tensile test specimens in accordance with 3.4.2 from each lot.

Ø 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 properties of specimens machined from castings are required. Specimens shall conform to ASTM B557 and shall be either 0.500 in. (12.50 mm) diameter at the reduced parallel gage section, subsize specimens proportional to the standard, or standard sheet-type specimens. For determining conformance to the requirements of 3.6.1.1.2, 3.6.1.2.2, or 3.6.1.3, if specimen locations are not shown on the drawing, not less than four specimens, two from the thickest section and two from the thinnest section, shall be cut from a casting or castings from each lot.

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.

4.4.2 Vendor shall establish for production of sample castings of each part number parameters for the control factors of processing 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
Ø change in parameters for the control factors of processing, vendor shall submit for reapproval a statement of the proposed changes in processing and, when requested, sample castings, test specimens, 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 or oxide removal procedure
Gating and risering practices
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 routine inspection

4.4.2.1.1 Any of the above control factors of processing 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.