Designation: B 199 – 99

Standard Specification for Magnesium-Alloy Permanent Mold Castings[1]

This standard is issued under the fixed designation B 199; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers magnesium alloy permanent mold casting alloys designated as shown in Table 1.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI values given in parentheses are provided for information only.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of order acceptance form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

B 275 Practice for Codification of Certain Nonferrous Metals and Alloys, Cast and Wrought[2]

B 296 Practice for Temper Designations of Magnesium Alloys, Cast and Wrought[2]

B 557 Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products[2]

B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products[2]

B 661 Practice for Heat Treatment of Magnesium Alloys[2]

E 8 Test Methods of Tension Testing of Metallic Materials[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specification[4]

E 35 Test Methods for Chemical Analysis of Magnesium and Magnesium Alloys[5]

E 88 Practice for Sampling Nonferrous Metals and Alloys in Cast Form for Determination of Chemical Composition[5]

E 94 Guide for Radiographic Testing[6]

E 155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings[6]

E 165 Test Methods for Liquid Penetrant Examination[6]

E 527 Practice for Numbering Metals and Alloys (UNS)[7]

2.3 *Federal Standards:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[8]

2.4 *Military Specification:*

MIL-M-6857 Heat Treatment of Magnesium Alloy Castings[8]

3. Terminology

3.1 *Definitions:*

3.1.1 *permanent mold casting*—a metal object produced by introducing molten metal by gravity or low pressure into a mold constructed of durable material, usually iron or steel, and allowing it to solidify.

3.1.2 *semipermanent mold casting*—a permanent mold casting which is made using an expendable core such as bonded sand.

4. Ordering Information

4.1 Orders for castings under this specification shall include the following information:

4.1.1 Quantity of each casting,

4.1.2 Alloy (Section 7 and Table 1),

4.1.3 Temper (Section 8 and Table 2),

4.1.4 Minimum properties of specimens cut from castings, if required (see section 9.3),

4.1.5 Drawing showing dimensions of the castings (the amount of stock left for machine finish should be indicated),

4.1.6 Surface treatment (see 10.1),

4.1.7 Whether inspection is required at the manufacturer's works (see section 11.1.1),

4.1.8 Special inspection requirements (see 11.2),

4.1.9 Whether certification is required (see 13.1), and

4.1.10 Whether marking for identification is required (see 14.1).

5. Manufacture

5.1 The responsibility of furnishing castings that can be laid out and machined to the finished dimensions within the permissible variations specified, as shown on the blueprints or drawings, shall rest with the supplier, except when molds are furnished by the purchaser. Sufficient stock shall be allowed for shrinkage, and where requested, for finishing; castings of excessive weight shall not be furnished.

5.2 The castings may be subjected to the heat treatment

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[1] This specification is under the jurisdiction of ASTM Committee B-7 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.04 on Magnesium Alloy Cast and Wrought Products.

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[2] *Annual Book of ASTM Standards,* Vol 02.02.

[3] *Annual Book of ASTM Standards,* Vol 03.01.

[4] *Annual Book of ASTM Standards,* Vol 14.02.

[5] *Annual Book of ASTM Standards,* Vol 03.05.

[6] *Annual Book of ASTM Standards,* Vol 03.03.

[7] *Annual Book of ASTM Standards,* Vol 01.01.

[8] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Chemical Composition Limits[A]

NOTE 1—Analysis shall regularly be made only for the elements specifically mentioned in this table. If, however, the presence of other elements is suspected or indicated in amounts greater than the specified limits, further analysis shall be made to determine that these elements are not present in excess of the specified limits.

NOTE 2—The following applies to all specified limits in this table: For purposes of acceptance and rejection, an observed value or a calculated value obtained from analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the specified limit.

Alloy Number[B]		Composition, %											
ASTM	UNS	Iron	Magnesium	Aluminum	Manganese	Zinc	Rare Earths	Zirconium	Silicon	Copper	Nickel	Total[C] Other Impurities	Others Each
AM100A	M10100	...	remainder	9.3 to 10.7	0.10–0.35	0.30	...	...	0.30	0.10	0.01	0.30	...
AZ81A	M11810	...	remainder	7.0 to 8.1	0.13–0.35	0.40 to 1.0	...	...	0.30	0.10	0.01	0.30	...
AZ91C	M11914	...	remainder	8.1 to 9.3	0.13–0.35	0.40 to 1.0	...	...	0.30	0.10	0.01	0.30	...
AZ91E	M11919	0.005[D]	remainder	8.1 to 9.3	0.17–0.35	0.40 to 1.0	...	...	0.20	0.015	0.0010	0.30	0.01
AZ92A	M11920	...	remainder	8.3 to 9.7	0.10–0.35	1.6 to 2.4	...	...	0.30	0.25	0.01	0.30	...
EQ21A[E]	M18330	...	remainder	...	...	...	1.5 to 3.0[F]	0.40 to 1.0	...	0.05–0.10	0.01	0.30	...
EZ33A	M12330	...	remainder	...	...	2.0 to 3.1	2.5 to 4.0	0.50 to 1.0	...	0.10	0.01	0.30	...
QE22A[G]	M18220[E]	...	remainder	...	...	...	1.8 to 2.5[F]	0.40 to 1.0	...	0.10	0.01	0.30	...

[A] Limits are in weight percent max unless shown as a range or stated otherwise.
[B] ASTM alloy designations were established in accordance with Practice B 275. UNS designations were established in accordance with Practice E 527.
[C] Includes listed elements for which no specific limit is shown.
[D] If iron exceeds 0.005 %, the iron to manganese ratio shall not exceed 0.032.
[E] Silver content for Alloy EQ21A (M18330) shall be 1.3 to 1.7 %.
[F] Rare earth elements are in the form of didymium.
[G] Silver content for Alloy QE22A (M18220) shall be 2.0 to 3.0, inclusive.

TABLE 2 Tensile Requirements

NOTE 1—For purposes of determining conformance with this specification, each value for tensile strength and yield strength shall be rounded to the nearest 0.1 ksi and each value for elongation shall be rounded to the nearest 0.5 % both in accordance with the rounding method of Practice E 29.

Alloy Number		Temper[A]	Tensile Strength, min. ksi (MPa)	Yield Strength[B] (0.2 % offset) min. ksi (MPa)	Elongation in 2 in., (50.8 mm) min., %
ASTM	UNS				
AM100A	M10100	F	20.0 (138)	10.0 (69)	[C]
		T4	34.0 (234)	10.0 (69)	6
		T6	34.0 (234)	15.0 (103)	2
		T61	34.0 (234)	17.0 (117)	[C]
AZ81A	M11810	T4	34.0 (234)	11.0 (76)	7
AZ91C	M11914	F	23.0 (158)	11.0 (76)	[C]
		T4	34.0 (234)	11.0 (76)	7
		T5	23.0 (158)	12.0 (83)	2
		T6	34.0 (234)	16.0 (110)	3
AZ91E	M11919	T6	34.0 (234)	16.0 (110)	...
AZ92A	M11920	F	23.0 (158)	11.0 (76)	[C]
		T4	34.0 (234)	11.0 (76)	6
		T5	23.0 (158)	12.0 (83)	[C]
		T6	34.0 (234)	18.0 (124)	[C]
EQ21A	M18330	T6	34.0 (234)	25.0 (172)	...
EZ33A	M12330	T5	20.0 (138)	14.0 (96)	2
QE22A	M18220	T6	35.0 (241)	25.0 (172)	2

[A] These temper designations were established in accordance with Practice B 296.
[B] See X1.3.
[C] Not required.

necessary to produce material that will conform to the requirements specified. Heat treatment 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.

6. General Quality

6.1 The castings shall be of uniform quality and condition, free of cracks or other injurious defects, and shall be well cleaned by sand blasting or any other approved process before inspection.

7. Chemical Composition

7.1 *Limits*—The material shall conform to the chemical composition limits prescribed in Table 1. Conformance shall be determined by analyzing samples taken when the castings are poured, or by analyzing samples taken from the finished product. If the chemical composition has been determined during the course of manufacture, sampling and analysis of the finished product is not necessary.

7.2 *Number of Samples*—The number of samples taken for determination of chemical composition shall be as follows:

7.2.1 When samples are taken at the time the castings are poured, at least one sample shall be taken from each melt of 2000 lb (907 kg) or fraction thereof.

7.2.2 When samples are taken from the castings or test bars, a sample shall be taken to represent each 2000 lb (907 kg) or fraction thereof in the shipment except that not more than one sample shall be required per casting.

7.3 *Methods of Sampling*—Samples for determination of chemical composition shall be taken in accordance with one of the following methods:

7.3.1 Samples for chemical analysis shall be taken from the material by drilling, sawing, milling, turning, or clipping a representative piece or pieces to obtain a weight of prepared sample not less than 75 g. Sampling shall be in accordance with Method E 88.

7.3.2 Samples for spectrochemical or other methods of analysis shall be taken by methods suitable for the form of material being analyzed and the type of analytical method used.

7.4 *Methods of Chemical Analysis*—Any suitable method of chemical analysis may be used. In case of dispute, the analysis shall be made by methods given in Methods E 35 or any other standard methods of analysis approved by ASTM unless some other method is agreed upon.

8. Heat Treatment

8.1 Unless otherwise specified, heat treatment for the applicable tempers designated in Table 2 shall be in accordance with Practice B 661 or with Military Specification MIL-M-6857.

9. Tensile Requirements

9.1 *Limits*—The tension test specimens representing the castings shall conform to the requirements of Table 2.

9.2 *Number of Tests*— At least one tension test specimen shall be cast from each melt of 2 000 lb (907 kg) or fraction thereof to represent the castings poured from the same melt. If the castings are to be heat treated, the specimens shall be heat treated with production castings of the same alloy and in the same temper as the specimens. The specimens shall then be tested to judge the response of their corresponding melts to the type of heat treatment to which the specimens were subjected.

9.2.1 Each heat-treating furnace charge shall include at least one tension test specimen poured from a production melt. Such specimens shall be of the same alloy and in the same temper as the castings, and shall be tested to judge the quality of the heat-treating operation given the furnace charge.

9.3 If test bars are cut from castings, the number and location shall be as agreed upon between the supplier and the purchaser. Depending on the radiographic quality specified (see 11.4), test bars cut from casting may not meet the requirements of Table 2. Mechanical property limits from cut

bars shall be agreed to by the supplier and purchaser.

9.4 *Test Specimens*—The tension test specimens shall be separately cast in a permanent mold and shall be cast to size in accordance with the dimensions shown in Fig. 8 of Method B 557. They shall not be machined prior to testing except to adapt the grip ends to the holders of the testing machine in such a manner as to ensure an axial load.

9.4.1 If any tension test specimen is improperly machined or shows flaws upon testing, it may be discarded and another specimen from the same heat or melt used instead. If no additional specimen is available, the supplier and the purchaser shall agree on an alternative procedure.

9.5 *Test Methods*— The tension tests shall be made in accordance with Method B 557.

10. Finish

10.1 Depending on casting processing and end use requirements, castings should be protected by the use of chrome pickling, anodizing, resin sealing, or other approved methods prior to shipment (see X1.4).

11. Inspection

11.1 If the purchaser desires that inspection be made at the supplier's works where the material is made, it shall be so stated in the contract or purchase order.

11.1.1 If the purchaser elects to have the inspection made at the supplier's works, the supplier shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections shall be so conducted as not to interfere unnecessarily with the operation of the works.

11.2 Special inspection requirements such as simulated service, pressure testing, X-ray, or fluorescent penetrant must be stated on the order.

11.3 *Liquid Penetrant Inspection*:

11.3.1 When specified, liquid penetrant inspection shall be in accordance with Practice E 165, and the required sensitivity shall be specified.

11.3.2 Acceptable standards for discontinuities shall be agreed upon, including size and frequency per unit area and location.

11.4 *Radiographic Inspection*:

11.4.1 When specified, radiographic inspection shall be in accordance with Methods E 94 and E 155.

11.4.2 Radiographic acceptance shall be in accordance with requirements selected from Table 3. Any modifications of this table, the frequency per unit area, and location should also be agreed upon.

11.4.3 The number, film size, and orientation of radiographs and the number of castings radiographically inspected shall be agreed upon between the supplier and the purchaser.

12. Rejection and Retest

12.1 Material failing to conform to the requirements of this specification may be rejected. If rejected, the supplier shall be responsible only for replacement of the material to the purchaser. As much as possible of the rejected original material shall be returned to the supplier.

12.2 *Retests*—If the results of the tension tests of alloys in heat-treated tempers do not conform to the requirements prescribed in Table 2, the castings may be re-heat treated once in an attempt to meet the required properties. The results of acceptable tests shall conform to the tensile properties requirements specified in Table 2. Castings still not conforming after the re-heat treatment shall be rejected.

13. Certification

13.1 The supplier shall, on request, furnish to the purchaser a certificate stating that the material has been sampled, tested, and inspected in accordance with this specification and has met the requirements

14. Product Marking

14.1 Unless otherwise specified, each casting shall be marked with the applicable drawing or part number.

15. Packaging and Package Marking

15.1 *Packaging*—Unless otherwise specified: castings shall be packaged to provide adequate protection during normal handling and transportation; each package shall contain only one type of item; and the type of packaging and gross weight of containers shall be at the supplier's discretion, provided they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

15.2 *Marking*—Each shipping container shall be legibly marked with the purchase order number, gross and net weights, and the supplier's name or trademark.

15.3 *Preservation*— Material intended for prolonged storage in unheated locations shall be adequately packed and protected to avoid deterioration and damage. When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of

TABLE 3 Discontinuity-Severity Level Requirements for Magnesium Castings (Reference Radiograph E 155)

Discontinuity	Grade A		Grade B		Grade C		Grade D	
	Section Thickness, in.							
	¼	¾	¼	¾	¼	¾	¼	¾
Gas Holes	none		1	1	2	2	5	5
Microshrinkage (feathery)	none		1	1	2	2	4	3
Microshrinkage (sponge)	none		1	1	2	2	4	3
Foreign material (less dense)	none		1	1	2	2	4	4
Foreign material (more dense)	none		1	1	2	2	4	3
Cracks	none		none		none		none	
Cold Shuts	none		none		none		none	
Surface irregularity	not to exceed drawing tolerance							
Core Shift	not to exceed drawing tolerance							

Practices B 660. The applicable levels shall be specified in the contract or order.

16. Quality Assurance

16.1 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the specification, where such inspections are deemed necessary, to assure that supplies and services conform to the prescribed requirements.

17. Keywords

17.1 casting grade; certification; chemical compositions; ductility; gravity die castings; low pressure die castings; ordering information; rejection criteria; strength requirements; tensile properties

APPENDIX

(Nonmandatory Information)

X1. EXPLANATORY NOTES

X1.1 General Information

X1.1.1 Property limits in Table 2 are based on an analysis of data from separately cast tension test bars and are established at a level at which at least 99 % of the population of the values meets the established value.

X1.1.2 Alloy AM100A has a specific gravity of about 1.81. It is used both in the solution heat-treated and in the solution heat-treated and aged tempers. Aging increases the yield strength and hardness and decreases the toughness and elongation.

X1.1.3 Alloy AZ81A has a specific gravity of about 1.80. It is used primarily in the solution heat-treated temper. This alloy will produce castings having maximum soundness with moderate mechanical properties.

X1.1.4 Alloy AZ91C has a specific gravity of about 1.81. It should be used for those applications requiring the maximum of strength and hardness as well as ductility.

X1.1.5 Alloy AZ91E is a high purity version of AZ91C. As a result it has very high corrosion resistance to salt water (NaCl) corrosion.

X1.1.6 Alloy EQ21A has a specific gravity of about 1.81. It has lower silver content than Alloy QE22A but similar mechanical properties.

X1.1.7 Alloy AZ92A has a specific gravity of about 1.82. It is used where good soundness and mechanical properties are required. The alloy is heat treatable and is then characterized by high strength and hardness. Under service conditions where the castings attain a temperature of 200°F (93°C) or higher, the castings of Alloy AZ92A, heat treated, will gradually change to the heat treated and aged temper.

X1.1.8 Alloy EZ33A has a specific gravity of about 1.84. It is used in the artificially-aged temper. It is recommended for use at elevated temperatures, especially in the range of 300 to 500°F (149 to 260°C). This alloy will produce sound castings for pressure tightness.

X1.1.9 Alloy QE22A has a specific gravity of about 1.82. It is used primarily where a high yield strength is needed at temperatures up to 400°F (204°C).

X1.2 Properties and Characteristics

X1.2.1 The data on properties and characteristics given in Table X1.1 are approximate and are supplied for general information only.

X1.3 Yield Strength and Brinell Hardness

X1.3.1 The yield strength of magnesium-base alloys is defined as the stress at which the stress-strain curve deviates 0.2 % from the modulus line. It may be determined by the "offset method" or the "extension-under-load method" (the latter is often referred to as the "approximate method without the stress-strain diagram") as described in Methods E 8. In case of dispute, the "offset method" shall be used. The data in Table X1.2 gives minimum yield strength values for the various alloys, together with the corresponding unit deformations for use with the "extension-under-load method" based on a modulus of elasticity, E = 6 500 ksi (44 800 MPa).

X1.3.2 The typical Brinell hardness numbers shown in Table X1.2 were obtained using a 10-mm ball and 500-kgf load. They are shown for information only.

X1.4 Surface Protection

X1.4.1 The chrome pickle affords measurable protection against corrosion and tarnish during shipment and storage of the castings. After pickling, the castings will be grey to bronze or yellow in color, depending on alloy and condition. The chrome pickle is not recommended for castings containing metal inserts. Such castings should be ordered shipped without surface treatment or protected with a slushing compound. Other corrosion protection treatments include fluoride and electrolytic anodizing, resin sealing, electroplating, enameling, and painting.

TABLE X1.1 Properties and Characteristics

Alloy Number		Melting Range (Approx.), °F (°C)			Foundry Characteristic[A]				Other Characteristics[A]				
ASTM	UNS	Nonequilibrium Solidus[B]	Solidus	Liquidus	Pressure Tightness	Fluidity[C]	Microporosity Tendency[D]	Normally Heat Treated	Machining[E]	Electroplating[F]	Surface Treatment[G]	Suitability to Brazing[H]	Suitability to Welding[I]
AM100A	M10100	810 (432)	867 (464)	1100 (593)	2	1	2	yes	1	1	2	no	1
AZ81A	M11810	790 (421)	882 (472)	1110 (602)	2	1	2	yes	1	2	2	no	1
AZ91C	M11914	785 (418)	875 (468)	1105 (596)	2	1	2	yes	1	1	2	no	2
AZ91E	M11919	785 (418)	875 (468)	1105 (596)	2	1	2	yes	1	2	2	no	1
AZ92A	M11920	770 (410)	830 (443)	1100 (593)	3	1	3	yes	1	1	2	no	2
EQ21A	M18330	...	995 (535)	1184 (640)	2	2	2	yes	1	2	1	no	1
EZ33A	M12390	...	1010 (543)	1189 (643)	1	2	1	yes	1	1	1	no	1
QE22A	M18220	...	1020 (549)	1190 (643)	2	2	2	yes	1	2	1	no	1

[A] Rating of 1 indicates best of group; 3 indicates poorest of group.
[B] As measured on metal solidified under normal casting conditions.
[C] Ability of liquid alloy to flow readily in mold and fill thin sections.
[D] Based on radiographic evidence.
[E] Composite rate based on ease of cutting, chip characteristics, quality of finish, and tool life. Ratings, in the case of heat-treatable alloys based on T6 type temper. Other tempers, particularly the annealed temper, may have lower rating.
[F] Ability of casting to take and hold an electroplate applied by present standards methods.
[G] Ability of casting to be cleaned in standard pickle solutions and to be conditioned for best paint adhesion.
[H] Refers to suitability of alloy or withstand brazing temperature without excessive distortion or melting.
[I] Based on ability of material to be fusion welded with filler rod of same alloy, or of an alloy whose composition is recommended.

TABLE X1.2 Data for Use With Extension-Under Load Method and Typical Brinell Hardness

Alloy Number		Temper	Yield Strength (0.2 % offset), min, ksi (MPa)	Unit Deformation in./in. (mm/mm) of gage length	Typical Brinell Hardness Number, HB
ASTM	UNS				
AM100A	M10100	F	10.0 (69)	0.0035	53
		T4	10.0 (69)	0.0035	52
		T6	15.0 (103)	0.0043	67
		T61	17.0 (117)	0.0046	69
AZ81A	M11810	T4	11.0 (76)	0.0037	55
AZ91C	M11914	F	11.0 (76)	0.0037	60
		T4	11.0 (76)	0.0037	55
		T5	12.0 (83)	0.0038	62
		T6	16.0 (110)	0.0045	70
AZ91E	M11919	T6	16.0 (110)	0.0045	70
AZ92A	M11920	F	11.0 (76)	0.0037	65
		T4	11.0 (76)	0.0037	63
		T5	12.0 (83)	0.0038	69
		T6	18.0 (124)	0.0048	81
EQ21A	M18330	T6	25.0 (172)	0.0058	78
EZ33A	M12330	T5	14.0 (96)	0.0042	50
QE22A	M18220	T6	25.0 (172)	0.0058	78