



# Standard Specification for Magnesium-Alloy Die Castings<sup>1</sup>

This standard is issued under the fixed designation B 94; 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.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope \*

1.1 This specification covers magnesium-alloy die castings. Current alloy compositions are specified under the designations shown in Table 1.<sup>2</sup>

1.2 The values stated in inch-pound units are standard. The SI values 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 93/B 93M Specification for Magnesium Alloys in Ingot Form for Sand Castings, Permanent Mold Castings, and Die Castings<sup>3</sup>

B 275 Practice for Codification of Certain Nonferrous Metals and Alloys, Cast and Wrought<sup>3</sup>

B 557 Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products<sup>3</sup>

B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products<sup>3</sup>

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials<sup>4</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>5</sup>

E 35 Test Methods for Chemical Analysis of Magnesium and Magnesium Alloys<sup>6</sup>

E 88 Practice for Sampling Nonferrous Metals and Alloys in Cast Form for Determination of Chemical Composition<sup>6</sup>

E 505 Reference Radiographs for Inspection of Aluminum and Magnesium Die Castings<sup>7</sup>

E 527 Practice for Numbering Metals and Alloys (UNS)<sup>8</sup>

2.3 *American Die Casting Institute:*  
“E” Series Product Standards<sup>3</sup>

2.4 *Federal Standards:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)<sup>9</sup>

Fed. Std. No. 184 Identification Marking of Aluminum, Magnesium and Titanium<sup>9</sup>

2.5 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

## 3. Terminology

### 3.1 Definition:

3.1.1 *die casting*—a metal object produced by the introduction of molten metal under substantial pressure into a metal die and characterized by a high degree of fidelity to the die cavity.

## 4. Ordering Information

4.1 Orders for die castings shall include the following basic information:

4.1.1 This specification number and date,

4.1.2 Quantity and delivery schedule, as required,

4.1.3 Part name and number,

4.1.4 Alloy (Table 1), and

4.1.5 Drawing of die casting, when required, giving all necessary dimensions and showing latest revisions and allowances for machining, if any. Location of ejector pin marks or parting lines shall be at the option of the producer, unless specifically designated on the drawing.

4.2 Additional tests, options and special inspection requirements as provided below should be justified only on the basis of need. These shall be specified in the contract or purchase order, as additional procedures and extended delivery time may be involved.

4.2.1 Chemical analysis (7.1.1),

4.2.2 Quality assurance (Section 6),

4.2.3 Special proof tests or mechanical properties (Section 8),

4.2.4 General quality options for internal soundness or for finish (Section 10),

4.2.5 Source inspection (Section 11),

4.2.6 Certification (Section 12),

4.2.7 Marking for identification (Section 14), and

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee B07 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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<sup>2</sup> SAE specifications No. 501 and 501A conform to the requirements for Alloy AZ91A and AZ91B respectively.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 02.02.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 03.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 03.05.

<sup>7</sup> *Annual Book of ASTM Standards*, Vol 03.03.

<sup>8</sup> *Annual Book of ASTM Standards*, Vol 01.01.

<sup>9</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

\*A Summary of Changes section appears at the end of this standard.

**TABLE 1 Chemical Requirements<sup>A,B,C,D</sup>**

Element	Composition, %							
	UNS M10600 (Alloy AM60A)	UNS M10410 (Alloy AS41A)	UNS M10412 (Alloy AS41B)	UNS M11910 (Alloy AZ91A)	UNS M11912 (Alloy AZ91B)	UNS M11916 (Alloy AZ91D)	UNS M10602 (Alloy AM60B)	UNS M10500 (Alloy AM50A)
Magnesium	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder
Aluminum	5.5–6.5	3.5–5.0	3.5–5.0	8.3–9.7	8.3–9.7	8.3–9.7	5.5–6.5	4.4–5.4
Manganese	0.13–0.6	0.20–0.50	0.35–0.7 <sup>E</sup>	0.13–0.50	0.13–0.50	0.15–0.50 <sup>E</sup>	0.24–0.6 <sup>E</sup>	0.26–0.6 <sup>E</sup>
Zinc	0.22	0.12	0.12	0.35–1.0	0.35–1.0	0.35–1.0	0.22 max	0.22
Silicon	0.50	0.50–1.5	0.50–1.5	0.50	0.50	0.10	0.10	0.10
Copper	0.35	0.06	0.02	0.10	0.35	0.030	0.010	0.010
Nickel	0.03	0.03	0.002	0.03	0.03	0.002	0.002	0.002
Iron, max	...	...	0.0035 <sup>E</sup>	...	...	0.005 <sup>E</sup>	0.005 <sup>E</sup>	0.004 <sup>E</sup>
Other metallic impurities, max, each	...	...	0.02	...	...	0.02	0.02	0.02

<sup>A</sup> 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 the course of routine analysis, further analysis shall be made to determine that these other elements are not in excess of 0.3 %.

<sup>B</sup> 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 should be rounded to the nearest unit in the last right-hand place of figures used in expressing the specified limit in accordance with the rounding procedure prescribed in Section 3 of Practice E 29.

<sup>C</sup> Where single units are shown, these indicate the maximum amounts permitted.

<sup>D</sup> ASTM alloy designations were established in accordance with Practice B 275, UNS designations were established in accordance with Practice E 527.

<sup>E</sup> In alloys AS41B, AM50A, AM60B, and AZ91D, if either the minimum manganese limit or the maximum iron limit is not met, then the iron/manganese ratio shall not exceed 0.010, 0.015, 0.021, and 0.032, respectively.

#### 4.2.8 Special packaging (Section 15).

### 5. Materials

5.1 The magnesium alloys used for the manufacture of die castings shall be such that the die castings produced will conform to the chemical composition requirements of this specification. Ingot in accordance with Specification B 93/ B 93M may be used but is not restricted to this source.

### 6. Quality Assurance

6.1 *Responsibility for Inspection*—When specified in the contract or purchase order, the producer or supplier is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract or order, the producer or supplier may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification. Quality assurance standards shall be agreed upon between the producer or supplier and purchaser at the time a contract or order is placed.

6.2 *Lot Definition*—An inspection lot shall be defined as follows:

6.2.1 An inspection lot shall consist of the production from each die or compound die on each machine for each 24 h during the first week of normal operation and the production for each 48 h thereafter of normal operation. Any significant change in the machine, composition, die or continuity of operation shall be considered as the start of a new lot. Die castings inspected by this method shall be so marked or handled during the finishing operations as not to lose their identity.

6.2.2 Each die casting of a randomly selected sample shall be examined to determine conformance to the requirements with respect to general quality, dimensions and identification marking. The producer or supplier may use a system of statistical quality control for such examinations.

### 7. Chemical Composition

7.1 *Limits*—The die casting shall conform to the requirements as to chemical composition prescribed in Table 1. Conformance shall be determined by the producer by analyzing samples taken at the time castings are made. If the producer has determined the chemical composition of the metal during the course of manufacture, he shall not be required to sample and analyze the finished product.

7.1.1 When a detailed chemical analysis is required with a shipment, it shall be called for in the contract or purchase order.

7.1.2 If the producer's or supplier's method of composition control is acceptable, sampling for chemical analysis may be waived at the discretion of the purchaser.

7.2 *Number of Samples*—When required, samples for determination of chemical composition shall be taken to represent the following:

7.2.1 A sample shall be taken from each of two representative castings selected from each lot defined in Section 6.2.1.

7.3 *Methods of Sampling*—Samples from die castings 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 Practice E 88.

7.3.2 By agreement, an appropriate spectrographic sample may be prepared at time of manufacture.

7.3.3 The method of sampling cast products for spectrochemical and other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.

7.4 *Method of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E 35), spectrochemical, or other methods. In case of dispute, the results secured by Test Methods E 35 shall be the basis of acceptance.

## 8. Mechanical Properties and Tests

8.1 Unless specified in the contract or purchase order or specifically guaranteed by the manufacturer, acceptance of die castings under these specifications shall not depend on mechanical properties determined by tension or impact tests. Tables X1.1 and X1.2 show typical mechanical properties and characteristics. When tension or impact tests are made, the tension test specimen shown in Fig. 13 of Methods B 557, and the impact test specimen shown in Fig. 6 of Test Methods E 23 shall be used.

8.2 When specified in the contract or purchase order, die castings shall withstand proof tests without failure as defined by agreement between the purchaser and the producer or supplier.

## 9. Permissible Variations in Dimensions

9.1 Permissible variations in dimensions shall be within the limits specified on the drawings or in the contract or purchase order.

9.1.1 Any dimensions for which a tolerance is not specified shall be in accord with ADCI Product Standard Series E1 to E16 inclusive.

9.2 Dimensional tolerance deviations waived by the purchaser shall be confirmed in writing to the producer or supplier.

## 10. General Quality

10.1 *Internal Soundness*—When specified, the soundness of die castings shall conform to standards or requirements agreed upon between the producer or supplier and the purchaser. The number and extent of imperfections shall not exceed those specified by the purchaser. The standards or requirements may consist of radiographs in accordance with Reference Radiographs E 505, photographs, or sectioned die castings.

10.2 Imperfections inherent in die castings shall not be cause for rejection provided it is demonstrated that the die castings are in accordance with the requirements and standards agreed upon.

10.3 *Workmanship*—Die castings shall be of uniform quality, free from injurious discontinuities that will adversely affect their serviceability.

10.4 *Finish*—When specified in the contract or purchase order the as-cast surface finish required shall conform to standards agreed upon between the purchaser and the producer or supplier, or as prescribed in ADCI Product Standard E 18.

10.5 *Pressure Tightness*—When specified in the contract or purchase order the pressure tightness of die castings shall conform to standards agreed upon between the purchaser and the producer or supplier, or as prescribed in ADCI Product Standard E 17.

## 11. Source Inspection

11.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the product prior to shipment, such agreement shall be made by the purchaser and producer or supplier as part of the contract or purchase order.

11.2 When such inspection or witness of inspection and testing is agreed upon, the producer or supplier shall afford the purchaser's representative all reasonable facilities to satisfy him that the product meets the requirements of this specifica-

tion. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

## 12. Rejection and Retest

12.1 When one or more samples, depending on the approved sampling plan, fail to meet the requirements of this specification, the represented lot is subject to rejection except as otherwise provided in 12.2.

12.2 Lots rejected for failure to meet the requirements of this specification may be resubmitted for test provided:

12.2.1 The producer has removed the nonconforming material or the producer has reworked the rejected lot as necessary to correct the deficiencies.

12.3 Individual castings that show injurious imperfections during subsequent manufacturing operations may be rejected. The producer or supplier shall be responsible only for replacement of the rejected castings to the purchaser. As much of the rejected original material as possible shall be returned to the producer or supplier.

## 13. Certification

13.1 The producer or supplier shall, when called for in the contract or purchase order, furnish to the purchaser a certificate of inspection stating that each lot has been sampled, tested, and inspected in accordance with this specification, and has been found to meet the requirements specified.

## 14. Product Marking

14.1 When specified in the contract or purchase order, all castings shall be properly marked for identification with the part number, name or brand of the producer, as agreed upon. Government applications shall be marked in accordance with Fed. Std. No. 184.

## 15. Packaging, Marking, and Storage

15.1 *Packaging*—Unless otherwise specified, the die castings shall be packaged to provide adequate protection during normal handling and transportation. Each package shall contain only one type of item unless otherwise agreed upon. The type of packaging and gross weight of containers shall, unless otherwise agreed upon, be at the producer'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. Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for Military agencies.

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

## 16. Keywords

16.1 casting characteristics; composition; high pressure die

cast alloy; magnesium; mechanical properties; performance characteristics

## APPENDIXES

### (Nonmandatory Information)

#### X1. MECHANICAL PROPERTIES AND CHARACTERISTICS

X1.1 Table X1.1 shows certain casting and other outstanding characteristics which are usually considered in selecting a magnesium die casting alloy for a specific application. A number 1 rating is the highest.

X1.2 The use of separately die-cast test bars was omitted from this specification revision because they are considered unreliable. Different machines and dies continue to be necessary for die castings and test bars. Comparison between static breakdown or proof test and the mechanical properties of separately die-cast test bars revealed that test bars made in a different machine in a different die had no correlation with the die casting, other than a common chemical composition. For this reason, it is considered that the only practical method is to have mechanical property control based on proof testing of whole die castings. For information only, typical separately die-cast specimen tensile properties are presented in Table X1.2. These properties are of tension specimens of the form and dimensions shown in Fig. 13 in Methods B 557 and Fig. 6 of Test Methods E 23, when cast in a die in regular production routine and conforming to the chemical composition specified in Table 1. In the tension testing of magnesium alloy specimens, the rate of stressing up to the yield strength shall not exceed 100 ksi (700 MPa)/min. Exceedingly slow rates of testing may result in creep and hence are to be avoided. Beyond the yield strength, the rate of straining shall not exceed

0.25 in./in.·min, measured on the gage length of the specimen. It should be thoroughly understood that the figures in the table represent die-cast test specimens and not specimens cut from commercial die-cast parts.

X1.3 Alloy AM60A has a specific gravity of about 1.78. It is suggested for use for those applications requiring a combination of good elongation, yield strength, and tensile strength.

X1.4 Alloy AS41A has a specific gravity of about 1.78. The alloy possesses good room temperature elongation, yield strength, and tensile strength. At temperatures up to about 350° F (175° C) it has a much increased creep resistance over Alloys AZ91A, AZ91B, and AM60A. Maximum resistance to creep is obtained at the lower aluminum content.

X1.5 Alloys AZ91A and AZ91B have a specific gravity of about 1.81. The copper and nickel contents in AZ91A should be kept low to minimize corrosion. The corrosion resistance of Alloy AZ91B is decreased by the higher copper content and die castings made from this alloy should be used under a known range of atmospheric conditions for which their life can be considered satisfactory.

X1.6 Alloys AZ910 and AS41B are high purity versions of AZ91A and AS41A. As a result they have high resistance to salt-water (NaCl) corrosion.

TABLE X1.1 Die Casting and Other Characteristics

Alloy UNS	ASTM	Approximate Melting Range, °F (°C)	Resistance to Cold Defects <sup>A</sup>	Pressure Tightness	Resistance to Hot Cracking <sup>B</sup>	Machining <sup>C</sup>	Electroplating <sup>D</sup>	Surface Treatment <sup>E</sup>	Strength at Elevated Temperatures <sup>F</sup>
M10500	AM50A	1025–1145 (551–618)	3 <sup>G</sup>	1 <sup>G</sup>	2 <sup>G</sup>	1 <sup>G</sup>	2 <sup>G</sup>	1 <sup>G</sup>	3 <sup>G</sup>
M10600	AM60A	1005–1140 (540–615)	3 <sup>G</sup>	1 <sup>G</sup>	2 <sup>G</sup>	1 <sup>G</sup>	2 <sup>G</sup>	1 <sup>G</sup>	3
M10410	AS41A	1050–1150 (565–620)	4 <sup>G</sup>	1 <sup>G</sup>	1 <sup>G</sup>	1 <sup>G</sup>	2 <sup>G</sup>	1 <sup>G</sup>	2
M10412	AS41B	1050–1150 (565–620)	4 <sup>G</sup>	1 <sup>G</sup>	1 <sup>G</sup>	1 <sup>G</sup>	2 <sup>G</sup>	1 <sup>G</sup>	2
M11910	AZ91A	875–1105 (470–595)	2	2	2	1	2	2	4
M11912	AZ91B	875–1105 (470–595)	2	2	2	1	2	2	4
M11916	AZ91D	875–1105 (470–595)	2	2	2	1	2	2	4
M10602	AM60B	1005–1140 (540–615)	3 <sup>G</sup>	1 <sup>G</sup>	2 <sup>G</sup>	1 <sup>G</sup>	2 <sup>G</sup>	1 <sup>G</sup>	3

<sup>A</sup> The ability of alloy to resist formation of cold defects; For example, cold shuts, cold cracks, non-fill "woody" areas, swirls, etc.

<sup>B</sup> Ability of alloy to withstand stresses from contraction while cooling through the hot-short or brittle temperature range.

<sup>C</sup> Composite rating based on ease of cutting, chip characteristics, quality of finish and tool life.

<sup>D</sup> Ability of the die casting to take and hold an electroplate applied by present standard methods.

<sup>E</sup> Ability of castings to be cleaned in standard pickle solutions and to be conditioned for best paint adhesion.

<sup>F</sup> Rating based on resistance to creep at elevated temperatures.

<sup>G</sup> Rating based upon limited experience, given guidance only.

**TABLE X1.2 Typical Properties of Magnesium Alloy Die-Cast Test Specimens<sup>A</sup>**

Property	Alloy UNS M10500 (AM50A)	Alloy UNS M10600 (AM60A <sup>A</sup> ) and Alloy UNS M10602 (AM60B)	Alloy UNS M10410 and M10412 (AS41A) and (AS41B)	Alloys UNS M11910 M11912 and M11916 (AZ91A, AZ91B and AZ91D)
Tensile strength, ksi (MPa)	29 (200)	32 (220)	31 (210)	34 (230)
Tensile yield strength, ksi (MPa)	16 (110)	19 (130)	20 (140)	23 (160)
Compression yield strength, ksi (MPa)	—	—	—	23 (160)
Elongation in 2 in. (50 mm), percent	10	8	6	3
Impact, ft-lb <sup>B</sup> (J)	—	—	—	2 (3)
Shear strength <sup>C</sup> , ksi (MPa)	—	—	—	20 (140)
Fatigue strength <sup>D</sup> , ksi (MPa)	—	—	—	14 (100)
Brinell hardness	58	62	—	63
Rockwell hardness, F scale	—	—	—	75

<sup>A</sup> ksi = 1000 psi. For explanation of SI unit MPa see Appendix X2.

<sup>B</sup> Unnotched.

<sup>C</sup> Double-shear tests converted to single-shear values.

<sup>D</sup>  $5 \times 10^8$  cycles.

## X2. METRIC EQUIVALENTS

X2.1 The SI unit for strength properties (MPa) is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ( $N = \text{kg}\cdot\text{m}/\text{s}^2$ ). The derived SI unit for pressure or

stress is the newton per square metre ( $\text{N}/\text{m}^2$ ), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since  $1 \text{ ksi} = 6\,894\,757 \text{ Pa}$  the metric equivalents are expressed as megapascal (MPa), which is same as  $\text{MN}/\text{m}^2$  and  $\text{N}/\text{mm}^2$ .

## SUMMARY OF CHANGES

This section identifies the location of changes to this standard that have been incorporated since the last issue.

(1) Alloy AM50A was added to Table 1, Table X1.1, Table X1.2.  
(2) An upper limit was added to the manganese specifications for alloys AM60A, AM60B, AZ91A, AZ91B, and AZ91D—Table 1.

(3) Compliance with regard to the minimum manganese limit and maximum iron limit was deferred to the critical iron manganese ratio for alloys AM60B and AZ91D in Table 1.

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