



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

This standard is issued under the fixed designation B 91; 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 ( $\epsilon$ ) 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 forgings designated as shown in Table 1.

1.2 The values stated in inch-pound units are the 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 material purchase form a part of this specification to the extent referenced herein:

### 2.2 ASTM Standards:<sup>2</sup>

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

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

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

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 35 Test Methods for Chemical Analysis of Magnesium and Magnesium Alloys

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition

### 2.3 Federal Standards:

No. 123 Marking for Shipment (Civil Agencies)<sup>3</sup>

No. 184 Identification Marking of Aluminum, Magnesium, and Titanium.

### 2.4 Military Standards:

MIL-M-3171 Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion on

MIL-STD-129 Marking for Shipment and Storage<sup>3</sup>

<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.

Current edition approved June 1, 2004. Published June 2004. Originally approved in 1932. Last previous edition approved in 1997 as B 91 – 97.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

## 3. Terminology

### 3.1 Definitions:

3.1.1 *forging*—a metal part worked to a predetermined shape by one or more such processes as hammering, upsetting, pressing, or rolling.

3.1.2 *die forging*—a forging formed to the required shape and size by working in impression dies.

3.1.3 *hammer forging*—a forging produced by repeated blows in a forging hammer.

3.1.4 *hand forging*—a forging worked between flat or simply shaped dies by repeated strokes or blows and manipulation of the piece.

## 4. Ordering Information

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

4.1.1 Quantity of each forging,

4.1.2 Alloy (Section 6 and Table 1),

4.1.3 Temper (Section 7 and Table 2),

4.1.4 Drawing showing dimensions of all die forgings and for all hand forgings not simple disks, rounds, squares, or rectangles (the amount of stock left for machine finish should be indicated),

4.1.5 Surface treatment (see 9.1),

4.1.6 Whether inspection is required at the manufacturer's works (see 10.1),

4.1.7 Special inspection requirements (see 10.2),

4.1.8 Whether certification is required (see 12.1), and

4.1.9 Whether marking for identification is required (see 13.1).

## 5. Quality Assurance

5.1 The manufacturer shall be responsible for the performance of all inspection and tests required by this specification, prior to shipment of the material.

## 6. Chemical Composition

6.1 *Limits*—The material shall conform to the chemical composition limits prescribed in Table 1. The manufacturer shall determine conformance by analyzing samples taken when the ingots are poured, or by analyzing samples taken from the

**TABLE 1 Chemical Composition Limits<sup>A,B</sup>**

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 should be rounded to the nearest unit in the last right-hand place of figures used in expressing the specified limit.

Element	Composition, %			
	Alloy AZ31B (UNS No. M11311)	Alloy AZ61A (UNS No. M11610)	Alloy AZ80A (UNS No. M11800)	Alloy ZK60A (UNS No. M16600)
Magnesium	remainder	remainder	remainder	remainder
Aluminum	2.5–3.5	5.8–7.2	7.8–9.2	...
Manganese	0.20–1.0	0.15–0.5	0.12–0.5	...
Zinc	0.6–1.4	0.40–1.5	0.20–0.8	4.8–6.2
Thorium	...	...	...	...
Zirconium, min	...	...	...	0.45
Silicon	0.10	0.10	0.10	...
Copper	0.05	0.05	0.05	...
Nickel	0.005	0.005	0.005	...
Iron	0.005	0.005	0.005	...
Calcium	0.04	...	...	...
Other impurities <sup>C</sup>	0.30	0.30	0.30	0.30

<sup>A</sup> Limits are in weight percent maximum unless shown as a range or stated otherwise.

<sup>B</sup> These alloy designations were established in accordance with Practice B 275.

<sup>C</sup> Includes listed elements for which no specific limit is shown.

**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 (0.7 MPa) 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 and Temper	Tensile Strength, min, ksi (MPa)	Yield Strength <sup>A</sup> (0.2 % offset), min, ksi (MPa)	Elongation in 2 in. (51 mm), or 4 × dia, min, %
AZ31B–F	34.0 (234)	19.0 (131)	6
AZ61A–F	38.0 (262)	22.0 (152)	6
AZ80A–F	42.0 (290)	26.0 (179)	5
AZ80A–T5	42.0 (290)	28.0 (193)	2
ZK60A–T5 die forgings <sup>B</sup>	42.0 (290)	26.0 (179)	7
ZK60A–T6 die forgings <sup>B</sup>	43.0 (296)	32.0 (221)	4

<sup>A</sup> See X1.1.6.

<sup>B</sup> Applicable only to die forgings not more than 3 in. (76 mm) in thickness. The tensile requirements for hand forgings will be lower and as agreed upon by the purchaser and manufacturer.

finished or semi-finished product. If the manufacturer has determined the chemical composition during the course of manufacture, he shall not be required to sample and analyze the finished product.

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

6.2.1 When samples are taken at the time the ingots are poured, at least one sample shall be taken for each group of ingots poured simultaneously from the same source of molten metal.

6.2.2 When samples are taken from the finished or semi-finished product, a sample shall be taken to represent each 2000 lb (905 kg), or fraction thereof, in the shipment, except that not more than one sample shall be required per piece.

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

6.3.1 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 55.

6.3.2 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.

6.4 *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 Test Methods E 35 or any other standard methods of analysis approved by ASTM unless some other method is agreed upon.

## 7. Tensile Properties

7.1 *Limits*—The forgings shall conform to the tensile properties prescribed in Table 2.

7.2 *Number of Specimens*—One tension test specimen shall be taken to represent each 1000 lb (455 kg) or fraction thereof of each part number in the shipment or inspection lot.

7.2.1 When specified, a grain flow pattern and tensile-property survey shall be made on a forging representative of the first production parts (see 7.3.1). It shall be repeated after any major change in forging technique.

7.3 *Test Specimens*—Tension test specimens shall be taken from a forging or from a separately forged coupon made from material representative of the forgings, in such a manner that the longitudinal axis of the specimen is parallel to the direction of maximum flow of the metal in the forging. The specimens shall be machined to the form and dimensions shown in Fig. 8 of Test Methods B 557 or in the case of thin material may be

machined to the form and dimensions shown for the 1/2 in. (12.7 mm) wide sheet-type specimen in Fig. 6 of Test Methods B 557.

7.3.1 If required, a die forging representative of the first production parts shall be selected after forging techniques have been established, and shall be tested as follows:

7.3.1.1 Tension test specimens shall be taken parallel to the forging flow lines. The locations shall be as indicated on the forging engineering drawing or, if not indicated, from generally representative areas.

7.3.1.2 A sample forging shall be sectioned at the locations of the specimens, to show the grain flow.

7.3.2 For hand forgings, the specimens shall be taken from a prolongation of the forgings or from a forging chosen to represent the lot. Tests will regularly be made only in the longitudinal direction.

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

NOTE 1—The values obtained for the tensile properties covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, the rate of stressing to the yield strength should not exceed 100 ksi (690 MPa)/min, and above the yield strength the movement per minute of the head under load should not exceed 0.5 in./in. (mm/mm) of gage length. Care must be exercised, especially when making yield strength determinations, that the speed of testing does not exceed the ability of the strain- and load-indicating equipment to function satisfactorily.

7.5 *Retests*—If any test specimen fails to conform to the requirements of Table 2, two additional representative specimens shall be selected and tested. If either of these specimens fails to conform to the requirements, the lot may be rejected. If, however, it is suspected that specimen failure is due to inadequate thermal treatment, the material may be reheat-treated and resampled in accordance with 7.2. Only one such reheat treatment shall be permitted.

## 8. General Quality

8.1 All material shall be of uniform quality, free of injurious surface defects, and shall have a workmanlike finish.

## 9. Finish

9.1 Unless otherwise specified, the forgings shall be chrome pickled prior to shipment (see X1.1.7).

## 10. Inspection

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

10.1.1 If the purchaser elects to have the inspection made at the manufacturer's works, the manufacturer 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 inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

10.2 Special inspection requirements such as inspection by ultrasonic reflection or by fluorescent penetrant, must be shown on the order. Acceptance standards for special inspection requirements shall be as agreed upon between purchaser and manufacturer.

## 11. Rejection

11.1 Material failing to conform to the requirements of this specification, or in which defects are found during subsequent manufacturing operations, may be rejected. If rejected, the manufacturer shall be responsible only for replacement of the material to the purchaser. All of the rejected original material shall be returned to the manufacturer.

## 12. Certification

12.1 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.

## 13. Product Marking

13.1 The material shall be marked as specified in the purchase order.

13.2 Each package or container shall be marked with the purchase order number, drawing number, quantity, specification number, alloy and temper, gross and net weights, and the name of the manufacturer.

## 14. Packaging

14.1 The material shall be packaged in such a manner as to prevent damage in ordinary handling and transportation. The type of packing and gross weight of individual containers shall be left to the discretion of the manufacturer unless otherwise agreed upon. Packaging methods and containers shall be so selected as to permit maximum utility of mechanical equipment in unloading and subsequent handling. Each package or container shall contain only one size, alloy, and temper of material when packaged for shipment unless otherwise agreed upon.

14.2 Packages or containers shall be such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the point of delivery.

14.3 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. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

14.4 When specified in the contract or purchase order, material shall be marked in accordance with Fed. Std. No. 184.

## 15. Keywords

15.1 forgings; magnesium alloy

**APPENDIX**
**(Nonmandatory Information)**
**X1. EXPLANATORY NOTES**
**X1.1 General Information**

X1.1.1 Standard mechanical property limits for the respective size ranges are based on an analysis of data from fully worked production material and are established at a level at which at least 99 % of the population of the values obtained from all fully worked material in the size range meets the established value. The expression “fully worked” refers to material that has been worked sufficiently during the forging operations to develop maximum properties. Material that has been given smaller amounts of working will have correspondingly lower properties.

X1.1.2 Alloy AZ31B has a specific gravity of about 1.77. It has better press-forging characteristics than any of the other alloys and may be worked on hammers or mechanical presses.

X1.1.3 Alloy AZ61A has a specific gravity of about 1.81. The forgeability and mechanical properties are intermediate between those of alloy AZ31B and AZ80A.

X1.1.4 Alloy AZ80A has a specific gravity of about 1.83. It is used for hot-press forgings of relatively simple design requiring maximum mechanical properties.

X1.1.5 Alloy ZK60A has a specific gravity of about 1.83. It has excellent press-forging characteristics and the best combinations of strength and ductility of the magnesium-forging alloys.

X1.1.6 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 Test Methods B 557.

X1.1.7 The chrome pickle treatment increases the resistance to surface tarnish and corrosion during shipment and storage. After treatment, the forgings will be dull bronze to bright yellow in color. The color varies with alloy and temper.

X1.1.7.1 When specified, the chrome pickle treatment shall conform to Type I and VI of MIL-M-3171.

**TABLE X1.1 Unit Deformation Values<sup>A</sup>**

Alloy and Temper	Yield Strength (0.2 % offset), min, ksi (MPa)	Unit Deformation, in./ in. (mm/mm) of Gage Length
AZ31B–F	19.0(131)	0.0049
AZ61A–F	22.0(152)	0.0054
AZ80A–F	26.0(179)	0.0060
AZ80A–T5	28.0(193)	0.0063
ZK60A–T5 die forgings	26.0(179)	0.0060

<sup>A</sup> The unit deformation values given in the table for use with the “extension-under-load method” are based on a modulus of elasticity.  $E = 6\,500\,000$  psi (4.48 GPa).

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