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## Standard Specification for Aluminum-Alloy Castings Produced by the Squeeze Casting, Thixocast and Rheocast Semi-Solid Casting Processes<sup>1</sup>

This standard is issued under the fixed designation B969; 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 aluminum-alloy castings, produced by the thixocast, rheocast, semi-solid and squeeze casting processes, shown in Table 1.

1.2 This specification is not intended for castings used in aerospace applications.

1.3 Alloy and temper designations are in accordance with ANSI H35.1/H35.1(M). The equivalent unified numbering system alloy designations are in accordance with Practice E527.

1.4 Unless the order specifies the “M” specification designation, the material shall be furnished to the inch-pound units.

1.5 For acceptance criteria for inclusion of new aluminum and aluminum alloys and their properties in this specification, see Annex A1 and Annex A2.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

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

B179 Specification for Aluminum Alloys in Ingot and Molten Forms for Castings from All Casting Processes

B275 Practice for Codification of Certain Nonferrous Metals and Alloys, Cast and Wrought

B557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products

B557M Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)

B660 Practices for Packaging/Packing of Aluminum and Magnesium Products

B881 Terminology Relating to Aluminum- and Magnesium-Alloy Products

B917/B917M Practice for Heat Treatment of Aluminum-Alloy Castings from All Processes

D3951 Practice for Commercial Packaging

E8/E8M Test Methods for Tension Testing of Metallic Materials

E23 Test Methods for Notched Bar Impact Testing of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys

E94 Guide for Radiographic Examination

E155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings

E165 Practice for Liquid Penetrant Examination for General Industry

E505 Reference Radiographs for Inspection of Aluminum and Magnesium Die Castings

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.01 on Aluminum Alloy Ingots and Castings.

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

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

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

Alloy ANSI <sup>D</sup> UNS	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Composition, %				Aluminum	
							Nickel	Zinc	Titanium	Tin		Other Elements <sup>E</sup> Each
319.0	A03190	5.5–6.5	1.0	3.0–4.0	0.50	0.10	0.35	1.0	0.25	0.50	0.50	Remainder
355.0	A03550	4.5–5.5	0.6 <sup>G</sup>	1.0–1.5	0.50 <sup>G</sup>	0.40–0.6	0.25	0.35	0.25	0.15	0.05	Remainder
356.0	A03560	6.5–7.5	0.6 <sup>G</sup>	0.25	0.35 <sup>G</sup>	0.20–0.45	0.35	0.35	0.25	0.15	0.05	Remainder
A356.0	A13560	6.5–7.5	0.20	0.20	0.10	0.25–0.45	0.10	0.10	0.20	0.15	0.05	Remainder
357.0	A03570	6.5–7.5	0.15	0.05	0.03	0.45–0.6	0.05	0.05	0.20	0.15	0.05	Remainder
366.0	A03660	6.5–7.5	0.15	0.05	0.03	0.5–1.2	0.05	0.05	0.20	0.15	0.05	Remainder
380.0	A03800	7.5–9.5	2.0	3.0–4.0	0.50	0.10	0.50	3.0	0.35	0.50	0.10	Remainder
A390.0	A13900	16.0–18.0	0.50	4.0–5.0	0.10	0.45–0.65 <sup>H</sup>	0.10	0.10	0.20	0.20	0.10	Remainder

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

<sup>B</sup> Analysis shall be made for the elements for which limits are shown in this table.

<sup>C</sup> The following applies to all specified limits in this table: For purposes of determining conformance to these limits, 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 in accordance with the rounding method of Practice E29.

<sup>D</sup> ASTM alloy designations are defined in ANSI H35.1/H35.1(M)

<sup>E</sup> Other includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the specification. However, such analysis is not required and may not cover all metallic *Other Elements*. Should any analysis by the producer or the purchaser establish that an *Other Element* exceeds the limit of *Each* or that the aggregate of several *Other Elements* exceeds the limit of *Total*, the material shall be considered nonconforming.

<sup>F</sup> *Other Elements*—Total shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.

<sup>G</sup> If the iron content exceeds 0.45 %, manganese content shall not be less than one half of the iron.

<sup>H</sup> The Aluminum Association ruling on the number of decimal places to which Mg percent is expressed is exempted for some long standing alloys. See A2.2.6.

E607 Test Method for Atomic Emission Spectrometric Analysis Aluminum Alloys by the Point to Plane Technique Nitrogen Atmosphere

E716 Practices for Sampling and Sample Preparation of Aluminum and Aluminum Alloys for Determination of Chemical Composition by Spectrochemical Analysis

E1251 Test Method for Analysis of Aluminum and Aluminum Alloys by Atomic Emission Spectrometry

2.2 *ANSI Standard:*<sup>3</sup>

H35.1 / H35.1 (M) - 2006 American National Standard Alloy and Temper Designation Systems for Aluminum

2.3 *NADCA Standards:*<sup>4</sup>

#403 Product Specification Standards for Die Castings Produced by the Semi-Solid and Squeeze Casting Processes

2.4 *NADCA Product Specification Standards for Die Castings:*

Engineering and Design: Coordinate Dimensioning

S-4A-1-09 Linear Dimensions: Standard Tolerances

S-4A-2-09 Parting Line: Standard Tolerances

S-4A-3-09 Moving Die Components (MDC): Standard Tolerances

S-4A-4-09 Draft Requirements: Standard Tolerances

S-4A-5-09 Flatness Requirements: Standard Tolerances

S-4A-6-09 Cored Holes for Cut Threads: Standard Tolerances

S-4A-8-09 Cored Holes for Pipe Threads: Standard Tolerances

P-4A-1-09 Linear Dimensions: Precision Tolerances

P-4A-2-09 Parting Line: Precision Tolerances

P-4A-3-09 Moving Die Components (MDC): Precision Tolerances

P-4A-4-09 Draft Requirements: Precision Tolerances

P-4A-5-09 Flatness Requirements: Precision Tolerances

P-4A-6-09 Cored Holes for Cut Threads: Precision Tolerances

P-4A-7-09 Cored Holes for Formed Threads: Precision Tolerances

S/P-4-9-09 Machining Stock Allowances (Standard and Precision) Engineering and Design: Additional Specification Guidelines

G-6-1-09 Pressure Tightness in Die Cast Parts

G-6-2-09 Fillets, Ribs and Corners in Die Cast Parts (1 of 2)

G-6-3-09 Fillets, Ribs and Corners in Die Cast Parts (2 of 2)

G-6-4-09 Ejector Pins, Pin Marks and Pin Flash

G-6-5-09 Casting Flash removal

G-6-6-09 Surface Finish, As Cast

G-6-7-09 Die Cast Lettering and Ornamentation

2.5 *Federal Standard:*<sup>5</sup>

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

2.6 *Military Standard:*<sup>5</sup>

MIL-STD-129 Marking for Shipment and Storage (Military Agencies)

MIL-STD-276

2.7 *SAE Standard:*

AMS-STD-184

AMS 2771

2.8 *Naval Standard:*

NAVSEA Technical Publication S9074-AR-GIB-010/278

2.9 *Other Standards:*<sup>6</sup>

EN 14242 Aluminum and Aluminum Alloys – Chemical Analysis – Inductively Coupled Plasma Optical Emission Spectral Analysis

### 3. Terminology

3.1 *Definitions*—Refer to Terminology B881 for definitions of product terms used in this specification.

3.2 *Definitions of Terms Specific to this Standard:*

3.2.1 *Squeeze Casting*—a process whereby a metal product is produced by injecting molten metal at a relatively slow speed through a large ingate into a metal die and held under high pressure until solidification is complete.

3.2.2 *Slurry*—a thick suspension of solids in a liquid.

<sup>3</sup> Available from Aluminum Association, Inc., 1525 Wilson Blvd., Suite 600, Arlington, VA 22209, <http://www.aluminum.org>.

<sup>4</sup> Available from North American die Casting Association, (NADCA,) 241 Holbrook Drive, Wheeling, IL 60090. ([www.diecasting.org](http://www.diecasting.org))

<sup>5</sup> Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://dodssp.daps.dla.mil>.

<sup>6</sup> Available from European Committee for Standardization (CEN), 36 rue de Stassart, B-1050, Brussels, Belgium, <http://www.cenorm.be>.

3.2.3 *Semi-Solid Slurry*—a mixture of solid spherical or globular primary phase dispersed in liquid, and which exhibits thixotropic behavior.

3.2.4 *Thixotropic*—a property of some materials to flow like a high viscosity liquid when a force is applied and maintain form when the force is removed.

3.2.5 *Semi-Solid Casting (SSM)*—a casting process wherein a partially solidified metal slurry is injected into a die cavity to form cast components,

3.2.6 *Thixocasting*—semi-solid casting process wherein the feed-stock is a pre-cast slug of aluminum alloy capable of acting in a thixotropic manner, that has been heated to its thixotropic state and injected into a metal die cavity and allowed to solidify.

3.2.7 *Rheocasting*—semi-solid casting process in which the thixotropic aluminum alloy feed-stock is produced at the die cast machine and injected whilst in its thixotropic state into a metal die cavity without an intermediate solidification stage.

3.2.8 *Die Casting*—a casting produced by introducing 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 material under this specification shall include the following information:

4.1.1 This specification designation (which includes the number, the year, and the revision letter, if applicable),

NOTE 1—For inch-pound application, specify Specification B969 and for metric application specify Specification B969M. Do not mix units.

4.1.2 Alloy (Section 7 and Table 1).

4.1.3 Temper (Section 11, Table X2.1 [Table X2.2], Table X2.3 [Table X2.4], and Table X2.5 [Table X2.6]),

4.1.4 Applicable drawing or part number,

4.1.4.1 Drawing of casting, when required, giving all necessary dimensions and showing latest revisions and allowances for linear dimensions (12.2), parting lines (12.3), moving die components (12.4), draft (12.5), flatness (12.6), cored hole threads (12.7-12.9), and machining stock (12.10). Location of ejector pin marks or parting lines shall be at the option of the producer, unless specifically designated on the drawing,

4.1.5 The quantity in either pieces or pounds [kilograms],

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,

4.3 Additionally, orders for material to this specification shall include the following information when required by the purchaser.

4.3.1 Whether squeeze casting process or the semi-solid thixocast or rheocast process is to be used to produce the parts,

4.3.2 Whether chemical analysis and tensile property reports are required (Sections 7.5 and 22, Table 1, and Table X2.1 [Table X2.2], Table X2.3 [Table X2.4], and Table X2.5 [Table X2.6]),

4.3.3 Whether foundry control is required (Section 9),

4.3.4 Whether mechanical property tests are required (Sections 10, 11, 14, Table X2.1 [Table X2.2], Table X2.3 [Table X2.4], and Table X2.5 [Table X2.6])

4.3.5 Whether yield strength tests are required (Footnote D in Table X2.1 [Table X2.2], Table X2.3 [Table X2.4], and Table X2.5 [Table X2.6]),

4.3.6 Whether heat treatment is to be performed in accordance with AMS 2771 or other practices (Section 16),

4.3.7 Whether repairs are permissible (Section 18),

4.3.8 Whether inspection is required at the producer's works (Section 19),

4.3.9 Whether surface requirements will be checked visually or by observational standards where such standards are established (20.1),

4.3.10 Whether liquid penetrant inspection is required (20.2),

4.3.11 Whether radiographic inspection is required (20.3),

4.3.12 Whether certification is required (Section 22),

4.3.13 Whether the standard AMS-STD-184 applies to the marking of castings, (24.1),

4.3.14 Whether Practices B660 applies and, if so, the levels of preservation, packaging and packing required (25.3).

~~4.3.15 Whether the material shall be packaged or marked, or both, in accordance with Practices B660, MIL-STD-129, Practice 4.3.15 Whether marking in accordance with Fed. Std. 123 or D3951, or Fed. Std. No. 123 (or MIL-STD-129 applies (25.2 and 25.3).~~

4.3.16 Whether Practices B660 applies and, if so, the levels of preservation, packaging and packing required (25.3).

#### 5. Manufacture

5.1 The responsibility of furnishing castings that can be laid out and machined to the final dimensions within the permissible variations specified, as shown on the blueprints or drawings, shall rest with the producer, except when the die is furnished by the purchaser.

#### 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 (or five calendar days) of continuous normal operation and the production for each 48 h thereafter of continuous normal operation. (Normal operations are those without occurrences such as, but not limited to, equipment breakdowns, unscheduled work stoppages, out of control situations, etc.) Castings inspected by this method shall be so marked or handled during the finishing operations as not to lose their identity.

6.2.2 Normal operation shall be considered production in the absence of any significant change in the machine, alloy composition, die or continuity of operation. Should significant changes occur they shall be considered as the start of a new lot.

6.2.3 Each 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.

6.3 All testing shall be performed in accordance with applicable ASTM test methods.

## 7. Chemical Composition

7.1 The product shall conform to the chemical composition limits prescribed in Table 1. Conformance shall be determined by the producer by taking samples at the time castings are poured in accordance with E716 and analyzed in accordance with E607, E1251, E34 or EN 14242. If the producer has determined the composition of the material during casting, they shall not be required to sample and analyze the finished product.

7.2 If it becomes necessary to analyze castings for conformance to chemical composition limits, the method used to sample castings for the determination of chemical composition shall be by agreement between the producer and the purchaser. Analysis shall be performed in accordance with E716, E607, E1251, E34 or EN 14242 (ICP method).

7.3 Other methods of analysis or in the case of a dispute the method of analysis shall be agreed upon by the producer and the purchaser.

7.4 A sample for determination of chemical composition shall be taken to represent one of the following:

7.4.1 For production runs of less than 8 h, one sample from each die or compound die on each machine.

7.4.2 For production runs of more than 8 h, one sample from each die or compound die on each machine every 8 h.

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

7.6 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.

## 8. Material Requirements (Castings Produced for Governmental and Military Agencies)

8.1 Unless otherwise specified, only aluminum alloy conforming to the requirements of Specification B179 or producer's foundry scrap (identified as being made from alloy conforming to Specification B179) shall be used in the remelting furnace from which molten metal is taken for pouring directly into castings. Additions of small amounts of modifiers and grain refining elements or alloys are permitted.

8.1.1 Pure materials, recycled materials, and master alloys may be used to make alloys conforming to this specification, provided chemical analysis can be taken and adjusted to conform to Table 1 prior to pouring any castings.

## 9. Foundry Control (Castings Produced for Governmental or Military Agencies, or Both)

9.1 When specified, castings shall be produced under foundry control approved by the purchaser. Foundry control shall consist of examination of castings by radiographic or other approved methods for determining internal discontinuities until the gating, pouring, and other foundry practices have been established to produce castings meeting the quality standards furnished by the purchaser or agreed upon between the purchaser and the producer. When foundry practices have been so established, the production method shall not be significantly changed without demonstrating to the satisfaction of the purchaser that the change does not adversely affect the quality of the castings. Minor changes in pouring temperature of  $\pm 50^{\circ}\text{F}$  [ $\pm 25^{\circ}\text{C}$ ] from the established nominal temperature are permissible.

## 10. Mechanical Properties

10.1 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.

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

## 11. Tensile Properties

11.1 The tensile properties shall be determined in accordance with Test Methods B557 [B557M].

12.2 If Grade D quality castings as described in Table 2 are specified, no tensile tests shall be specified nor tensile requirements be met on specimens cut from castings.

**12. Dimensions, Mass, and Permissible Variations**

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

12.2 *Linear Dimensions*—Unless otherwise specified on the drawing or in the contract or purchase order, linear dimension tolerances shall conform to NADCA Product Specification Standard S-4A-1-09, Standard Tolerances, or by agreement between the producer and the supplier, P-4A-1-09, Precision Tolerances.

12.3 *Parting Lines*—Unless otherwise specified on the drawing or in the contract or purchase order, parting line dimension tolerances shall conform to NADCA Product Specification Standard S-4A-2-09, Standard Tolerances, or by agreement between the producer and the supplier, P-4A-2-09, Precision Tolerances.

12.4 *Moving Die Components*—Unless otherwise specified on the drawing or in the contract or purchase order, moving die component dimension tolerances shall conform to NADCA Product Specification Standard S-4A-3-09, Standard Tolerances, or by agreement between the producer and the supplier, P-4A-3-09, Precision Tolerances.

12.5 *Draft*—Unless otherwise specified on the drawing or in the contract or purchase order, draft tolerance dimensions shall conform to NADCA Product Specification Standard S-4A-4-09, Standard Tolerances, or by agreement between the producer and the supplier, P-4A-4-09, Precision Tolerances.

12.6 *Flatness*—Unless otherwise specified on the drawing or in the contract or purchase order, flatness dimensional tolerances shall conform to NADCA Product Specification Standard S-4A-5-09, Standard Tolerances, or by agreement between the producer and the supplier, P-4A-5-09, Precision Tolerances.

12.7 *Cored Holes for Cut Threads*—Unless otherwise specified on the drawing or in the contract or purchase order, the dimensional tolerances for cored holes for cut threads shall conform to NADCA Product Specification Standard S-4A-6-09, Standard Tolerances, or by agreement between the producer and the supplier, P-4A-6-09, Precision Tolerances.

12.8 *Cored Holes for Pipe Threads*—Unless otherwise specified on the drawing or in the contract or purchase order, the dimensional tolerances for cored holes for cut threads shall conform to NADCA Product Specification Standard S-4A-8-09.

12.9 *Cored Holes for Formed Threads*—Unless otherwise specified on the drawing or in the contract or purchase order, the dimensional tolerances for cored holes for cut threads shall conform to NADCA Product Specification Standard P-4A-7-09.

12.10 *Machining Stock*—Unless otherwise specified on the drawing or in the contract or purchase order, allowances for machining stock shall conform to the standard tolerances detailed in NADCA Product Specification Standard S/P-4-9-09, or by agreement between the producer and the supplier, the precision tolerances shown in S/P-4-9-09.

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

**13. General Quality**

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

13.2 *Internal Soundness*—When specified, the soundness of the 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 E505, photographs or sectioned castings.

13.3 *Pressure Tightness*—When specified in the contract or purchase order, the pressure tightness of the castings shall conform to standards agreed upon between the purchaser and the producer or supplier, or as prescribed in NADCA Product Specification Standards for Die Castings G-6-1-09.

**TABLE 2 Discontinuity—Level Requirements for Aluminum Castings in Accordance with Reference Radiographs E155**

Discontinuity	Grade A <sup>A</sup>		Grade B		Grade C		Grade D	
	Section Thickness, in. (mm)							
	1/4 to 3/4 [6 to 19-mm]	1/4 [6-mm]	3/4 [19-mm]	1/4 [6-mm]	3/4 [19-mm]	1/4 [6-mm]	3/4 [19-mm]	
Gas holes	none	1	1	2	2	5	5	
Gas porosity (round)	none	1	1	3	3	7	7	
Gas porosity (elongated)	none	1	1	3	4	5	5	
Shrinkage cavity	none	1	<sup>B</sup>	2	<sup>B</sup>	3	<sup>B</sup>	
Shrinkage porosity or sponge	none	1	1	2	2	4	3	
Foreign material (less dense material)	none	1	1	2	2	4	4	
Foreign material (more dense material)	none	1	1	2	1	4	3	
Segregation	none		none		none		none	
Cracks	none		none		none		none	
Cold shuts	none		none		none		none	
Surface irregularity								
Core shaft					not to exceed drawing tolerance			
					not to exceed drawing tolerance			

<sup>A</sup> Caution should be exercised in requesting Grade A because of the difficulty in obtaining this level.

<sup>B</sup> No radiographs available. Use 1/4-in [6-mm] for all thicknesses.