



## Standard Specification for Aluminum Alloy Castings, High-Strength<sup>1</sup>

This standard is issued under the fixed designation B 686; 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 high-strength castings designated as shown in Table 1.

1.2 Castings covered by this specification are intended for use in airframe, missile, and other critical applications where high strength, ductility, and sound castings are required.

1.2.1 Alloy A201.0 is intended for use in the – T7 temper, which provides a high level of resistance to stress-corrosion cracking, when properly heat treated. In other tempers, alloy A201.0 may exhibit susceptibility to stress-corrosion cracking. Additionally, its tendency for hot shortness may make alloy A201.0 unsuitable in some casting designs.

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

### 2. Referenced Documents

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

#### 2.2 ASTM Standards:

- B 179 Specification for Aluminum Alloys in Ingot and Molten Forms for Castings from All Casting Processes<sup>2</sup>
- B 557 Test Methods for Tension Testing Wrought and Cast Aluminum and Magnesium-Alloy Products<sup>2</sup>
- B 597 Practice for Heat Treatment of Aluminum Alloys<sup>2</sup>
- B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products<sup>2</sup>
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>3</sup>
- E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys<sup>4</sup>
- E 88 Practice for Sampling Nonferrous Metals and Alloys in Cast Form for Determination of Chemical Composition<sup>4</sup>
- E 94 Guide for Radiographic Testing<sup>5</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee B-7 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.01 on Aluminum Alloy Ingots and Casting.

Current edition approved May 10, 1999. Published July 1999. Originally published as B 686 – 81. Last previous edition B 686 – 97.

<sup>2</sup> Annual Book of ASTM Standards, Vol 02.02.

<sup>3</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>4</sup> Annual Book of ASTM Standards, Vol 03.05.

<sup>5</sup> Annual Book of ASTM Standards, Vol 03.03.

E 101 Test Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique<sup>6</sup>

E 155 Reference Radiographs for Examination of Aluminum and Magnesium Castings<sup>5</sup>

E 165 Test Method for Liquid Penetrant Examination<sup>5</sup>

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique<sup>4</sup>

E 527 Practice for Numbering Metals and Alloys (UNS)<sup>7</sup>

E 607 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique, Nitrogen Atmosphere<sup>8</sup>

E 716 Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis<sup>8</sup>

E 1251 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Argon Atmosphere, Point-to-Plane, Unipolar Self-Initiating Capacitor Discharge<sup>8</sup>

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System<sup>3</sup>

#### 2.3 ANSI Standards:

H35.1 Alloy and Temper Designation Systems for Aluminum<sup>2</sup>

Z1.4 Sampling Procedures and Tables for Inspection by Attributes<sup>2</sup>

#### 2.4 Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>9</sup>

#### 2.5 Federal Standard:

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

### 3. Classification

3.1 Castings shall be classified by inspection classes,

3.1.1 *Classes (Inspection):*

3.1.1.1 *Class 1*—A class of casting, the single failure of which would result in the loss of a missile, aircraft, or other vehicle.

3.1.1.2 *Class 2*—Class 1 castings not included in Class 1,

<sup>6</sup> Discontinued. See 1995 Annual Book of ASTM Standards, Vol 03.05.

<sup>7</sup> Annual Book of ASTM Standards, Vol 01.01.

<sup>8</sup> Annual Book of ASTM Standards, Vol 03.06.

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

**TABLE 1 Chemical Composition Limits**

NOTE 1—When single units are shown, they indicate the maximum amounts permitted.

NOTE 2—Analysis shall be made for the elements for which limits are shown in this table.

NOTE 3—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-off method of Practice E 29.

| Composition, % |            |        |           |         |      |         |            |            |      |           |            |                   |                           |
|----------------|------------|--------|-----------|---------|------|---------|------------|------------|------|-----------|------------|-------------------|---------------------------|
| ANSI H35.1     | ASTM E 527 | Former | Aluminum  | Silicon | Iron | Copper  | Man-ganese | Magne-sium | Zinc | Titanium  | Beryl-lium | Each <sup>A</sup> | Others Total <sup>B</sup> |
| 354.0          | A03540     | SC92A  | remainder | 8.6–9.4 | 0.20 | 1.6–2.0 | 0.10       | 0.40–0.6   | 0.10 | 0.20      | ...        | 0.05              | 0.15                      |
| C355.0         | A33550     | SC51B  | remainder | 4.5–5.5 | 0.20 | 1.0–1.5 | 0.10       | 0.40–0.6   | 0.10 | 0.20      | ...        | 0.05              | 0.15                      |
| A356.0         | A13560     | SG70B  | remainder | 6.5–7.5 | 0.20 | 0.20    | 0.10       | 0.25–0.45  | 0.10 | 0.20      | ...        | 0.05              | 0.15                      |
| A357.0         | A13570     |        | remainder | 6.5–7.5 | 0.20 | 0.20    | 0.10       | 0.40–0.7   | 0.10 | 0.04–0.20 | 0.04–0.07  | 0.05              | 0.15                      |
| A201.0         | A12010     |        | remainder | 0.05    | 0.10 | 4.0–5.0 | 0.20–0.40  | 0.15–0.35  |      | 0.15–0.35 |            | 0.03 <sup>C</sup> | 0.10                      |

<sup>A</sup> "Others" 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 "Others" elements. Should any analysis by the producer or the purchaser establish that an "Others" element exceeds the limit of "Each" or that the aggregate of several "Others" elements exceeds the limit of "Total", the material shall be considered nonconforming.

<sup>B</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>C</sup> Silver 0.40 to 1.0 %.

the single failure of which would cause significant danger to operating personnel or would result in a significant operational penalty. In the case of missiles, aircraft, and other vehicles, this includes loss of major components, loss of control, unintentional release of inability to release armament stores, or failure of weapon installation components.

3.1.1.3 *Class 3*—Castings having a margin of safety of 200 % or less.

3.1.1.4 *Class 4*—Castings having a margin of safety of greater than 200 %, or for which no stress analysis is required. All target drone castings and aerospace ground support equipment fall in this category, except for such critical parts, the failure of which would make the equipment unsatisfactory and cause the vehicles which they are intended to support to be inoperable.

### 3.1.2 Grades (Radiographic Quality):

NOTE 1—Caution should be exercised in specifying the grade of maximum permissible radiographic discontinuity level to be met in the casting. Radiographic quality has only a qualitative relationship to mechanical properties. In general, the highest property levels of an alloy will require the higher grades of radiographic quality. However, section size and shape parameters may be able to tolerate certain discontinuities without significant reduction in functional integrity. Too severe soundness requirements may cause the part producibility to be impractical or uneconomical.

3.1.2.1 *Grade A*—A grade in which there is no discernible discontinuity visible on the radiograph of the specified area of the casting.

3.1.2.2 *Grade B*—A premium grade of casting for critical applications or specified area of a casting with low margins of safety.

3.1.2.3 *Grade C*—A high-quality grade of casting or area of a casting for general applications.

3.1.2.4 *Grade D*—A grade included for less important areas of a casting.

## 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),

4.1.2 Alloy number (Section 6, Table 1) radiographic grade (3.1.2, Table 2) inspection class of castings (3.1.1, Table 3) and class of mechanical properties (Table 4),

4.1.3 Tensile property requirements on the drawing or purchase order (8.1.5, 14.5, 14.6, Table 3 and Table 4),

4.1.4 Identification of product information (Section 10),

4.1.5 Applicable drawings or part number,

4.1.6 The quantity in either pieces or pounds.

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

4.2.1 Whether the material shall be packed or marked, or both, in accordance with MIL-STD-129, Practices B 660, or Fed. Std. No. 123 (15.3),

4.2.2 Where the preproduction samples shall be sent, and activity responsible for testing, and instructions concerning submittal of the test reports (13.2.1 and 13.2.2), and

4.2.3 Penetrant inspection standards (14.3).

## 5. Materials and 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 producer, except where pattern equipment is furnished by the purchaser and any dimensional discrepancies can be clearly attributed to the pattern equipment as furnished.

5.1.1 Unless otherwise specified, only aluminum alloy conforming to the requirements of Specification B 179 or producer's foundry scrap (identified as being made from alloy conforming to Specification B 179) 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.

5.1.2 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.

## 6. Chemical Composition

6.1 The composition of the castings shall be within the

**TABLE 2 Discontinuity-Level Requirements for High-Strength Aluminum Castings—Maximum Permissible in Accordance with (Reference Radiographs E 155)**

NOTE 1—When two or more types of discontinuities are present within a 2 by 2-in. area to an extent equal to or not significantly better than the acceptance standards for respective discontinuities, the castings shall be rejected.

NOTE 2—When two or more types of discontinuities are present within a 2 by 2-in. area and the predominating discontinuity is not significantly better than the acceptance standard, the casting shall be considered borderline.

NOTE 3—Borderline castings shall be reviewed for acceptance or rejection by competent engineering personnel from the manufacturer and purchaser.

NOTE 4—Gas holes, sand spots, and inclusions allowed by this table shall be cause for rejection when closer than twice their maximum dimension to an edge or extremity of a casting.

NOTE 5—Castings with the following characteristics apply to Alloy A201.1 only:

1. Banding or striated segregation shall be acceptable to the extent that the mechanical properties in the affected section meet the requirements of Table 3.
2. Healed hot tears or discrete segregation cracks, evidenced by linear irregular white lines, shall be rejected.
3. Spheroidal segregation, evidenced by white spheroids, shall be evaluated for size and concentration by using the standards for gas holes.

| Discontinuity                          | Radiograph | Grade A                         |     | Grade B |              | Grade C |              | Grade D |              |
|--|------------|---------------------------------|-----|---------|--------------|---------|--------------|---------|--------------|
|  |            | Section Thickness, in.          |     |         |              |         |              |         |              |
|  |            | 1/4                             | 3/4 | 1/4     | 3/4          | 1/4     | 3/4          | 1/4     | 3/4          |
| Gas holes                              | 1.1        | none                            |     | 1       | 1            | 2       | 2            | 5       | 5            |
| Gas porosity (round)                   | 1.21       | none                            |     | 1       | 1            | 3       | 3            | 7       | 7            |
| Gas porosity (elongated)               | 1.22       | none                            |     | 1       | 1            | 3       | 4            | 5       | 5            |
| Shrinkage cavity                       | 2.1        | none                            |     | 1       | <sup>A</sup> | 2       | <sup>A</sup> | 3       | <sup>A</sup> |
| Shrinkage porosity or sponge           | 2.2        | none                            |     | 1       | 1            | 2       | 2            | 4       | 3            |
| Foreign material (less dense material) | 3.11       | none                            |     | 1       | 1            | 2       | 2            | 4       | 4            |
| Foreign material (more dense material) | 3.12       | none                            |     | 1       | 1            | 2       | 1            | 4       | 3            |
| Segregation                            | ....       | none                            |     | none    |              | none    |              | none    | none         |
| Cracks                                 | ....       | none                            |     | none    |              | none    |              | none    | none         |
| Cold shuts                             | ....       | none                            |     | none    |              | none    |              | none    | none         |
| Laps                                   | ....       | none                            |     | none    |              | none    |              | none    | none         |
| Surface irregularity                   | ....       | not to exceed drawing tolerance |     |         |              |         |              |         |              |
| Core shift                             | ....       | not to exceed drawing tolerance |     |         |              |         |              |         |              |

<sup>A</sup> Not available. Use 1/4 in. for all thicknesses.

**TABLE 3 Mechanical Properties of Specimens<sup>A</sup> Cut from Designated Areas of Casting<sup>B</sup>**

| Alloy Number |           |        | Class Number   | Tensile Strength, min, ksi (MPa) <sup>C</sup> | Yield Strength, 0.2 % Offset, min, ksi (MPa) <sup>C</sup> | Elongation in 2 in. or 4D, min, % |
|--------------|-----------|--------|----------------|---|---|-----------------------------------|
| ANSI H35.1   | ASTM E527 | Former |                |   |   |                                   |
| 354.0        | A03540    | SC92A  | 1              | 47.0 (324)                                    | 36.0 (248)  | 3                                 |
|              |           |        | 2 <sup>D</sup> | 50.0 (345)                                    | 42.0 (290)  | 2                                 |
| C355.0       | A33550    | SC51   | 1              | 41.0 (283)                                    | 31.0 (214)  | 3                                 |
|              |           |        | 2              | 44.0 (303)                                    | 33.0 (228)  | 3                                 |
|              |           |        | 3 <sup>D</sup> | 50.0 (345)                                    | 40.0 (276)  | 2                                 |
| A356.0       | A13560    | SC70B  | 1              | 38.0 (262)                                    | 28.0 (193)  | 5                                 |
|              |           |        | 2              | 40.0 (276)                                    | 30.0 (207)  | 3                                 |
|              |           |        | 3 <sup>D</sup> | 45.0 (310)                                    | 34.0 (234)  | 3                                 |
|              |           |        | 1              | 45.0 (310)                                    | 35.0 (241)  | 3                                 |
| A357.0       | A13570    |        | 1              | 45.0 (310)                                    | 35.0 (241)  | 3                                 |
|              |           |        | 2 <sup>D</sup> | 50.0 (345)                                    | 40.0 (276)  | 5                                 |
| A201.0       | A12010    |        | 1              | 60.0 (414)                                    | 50.0 (345)  | 3                                 |
|              |           |        | 2 <sup>C</sup> | 60.0 (414)                                    | 50.0 (345)  | 5                                 |

<sup>A</sup> 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.

<sup>B</sup> For any casting process, special mold, or sand mold permanent mold with chills may be used. Properties in other areas may vary with mold process and foundry techniques used but will be inspected under foundry control (0.1.2). Special negotiated properties may be called for by the drawing note.

<sup>C</sup> SI units for information only. For explanation of the SI unit "MPa" see Appendix X1.

<sup>D</sup> This class is obtainable in favorable casting configurations and must be negotiated with the foundry for particular configuration desired. See Note 1 and 7.3.

limits specified in Table 1.

6.2 Sampling for spectrochemical analysis shall be in accordance with Practices E 716. Samples for other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.

## 7. Preproduction Sample

7.1 In advance of production, unless otherwise specified in the contract or order, two castings heat treated and straightened to drawing requirements shall be submitted as directed by the purchaser for examination and written approval. One casting shall be completely laid out by the foundry and identified as the

“dimensional sample” for dimensional approval. The other casting shall be identified as the “foundry control sample” and shall be for all other inspections and requirements as necessary for approval.

7.2 The submitted castings shall be fully representative of the foundry practice that will be used in production. If temporary gating was used to develop suitable foundry practice, the submitted casting shall be made after the gating has been installed. If chills are required, their size and location shall also be permanently identified and recorded. Pouring temperature of the submitted casting shall be recorded. All

**TABLE 4 Mechanical Properties of Specimens<sup>A</sup> Cut from Any Area of Casting<sup>B</sup>**

| Alloy Number |           |        | Class Number <sup>C</sup> | Tensile Strength, min, ksi (MPa) <sup>C</sup> | Yield Strength, 0.2 % Offset, min, ksi (MPa) <sup>C</sup> | Elongation in 2 in. or 4 <sup>D</sup> , min, % |
|--------------|-----------|--------|---------------------------|---|---|--|
| ANSI H35.1   | ASTM E527 | Former |                           |   |   |  |
| 354.0        | A03540    | SC92A  | 10                        | 47.0 (324)                                    | 36.0 (248)  | 3  |
|              |           |        | 11                        | 43.0 (297)                                    | 33.0 (228)  | 2  |
| C355.0       | A33550    | SC51   | 10                        | 41.0 (283)                                    | 31.0 (214)  | 3  |
|              |           |        | 11                        | 37.0 (255)                                    | 30.0 (207)  | 1  |
|              |           |        | 12                        | 35.0 (241)                                    | 28.0 (193)  | 1  |
| A356.0       | A13560    | SG70B  | 10                        | 38.0 (262)                                    | 28.0 (193)  | 5  |
|              |           |        | 11                        | 33.0 (228)                                    | 27.0 (186)  | 3  |
|              |           |        | 12                        | 32.0 (221)                                    | 22.0 (152)  | 2  |
| A357.0       | A13570    |        | 10                        | 38.0 (262)                                    | 28.0 (193)  | 5  |
|              |           |        | 11                        | 41.0 (283)                                    | 31.0 (214)  | 3  |
| A201.0       | A12010    |        | 10                        | 60.0 (414)                                    | 50.0 (345)  | 3  |
|              |           |        | 11                        | 56.0 (386)                                    | 48.0 (331)  | 1.5  |

<sup>A</sup> For any casting process, special mold, permanent mold, or sand mold with chills may be used.

<sup>B</sup> 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.

<sup>C</sup> For any alloy, yield strength will be reasonably consistent throughout the casting. This should be considered when selecting combinations of classes from Table 3 and Table 4. See Note 1 and 7.3.

<sup>D</sup> SI units for information only. For explanation of the SI unit “MPa” see Appendix X1.

details of manufacture and processing shall be recorded and documented by photographs, sketches, specifications, and manufacturing procedures.

7.3 The user of this specification is specifically cautioned to verify the capability of the foundry to competently produce parts to the specification. On-site survey should be performed to verify the producers’ technical, manufacturing, and quality control capabilities. Verification of properties of sample test parts is suggested. The ability to produce guaranteed property castings requires technical knowledge, foundry technique, and vigorous controls uncommon to conventional foundries.

## 8. Radiographic Soundness and Mechanical Property Control

8.1 Prior to production, radiographic and mechanical property control shall be established. Castings shall be examined by radiographic methods for internal discontinuities. Sectioning and etching may be performed to determine the presence of internal discontinuities. Full-size casting or tension specimens machined from castings shall be tested for conformance to the required mechanical properties. This control shall be continued until the gating and other foundry practices have been established to produce castings conforming to this specification.

8.1.1 *Radiographic Requirements*—After the foundry control methods of 8.3 have been established, castings shall be radiographically inspected as specified in 14.2. Unless otherwise specified in the contract or order, acceptance shall be by comparison with a standard set of radiographs contained in Reference Radiograph E 155. Unless otherwise specified, radiographic indications shall be identified in terms of the discontinuities listed in Table 2. Unless otherwise specified, acceptance shall be made in accordance with one of four grades specified on the engineering drawing (3.1.2). When no grade is specified, Grade C shall apply. When a drawing specifies “critical” area and indicates no grade, Grade B shall apply to that area and Grade C to the remainder of the casting.

8.1.1.1 Acceptability is indicated in Table 2 by the indexed number of the E 155 radiograph which is acceptable for the applicable grade. To be acceptable to the applicable grade, a casting must be acceptable for all discontinuities listed in Table

2. Nonconformance with the applicable standard for any single discontinuity shall make a casting nonacceptable.

8.1.2 *Acceptance Procedure*—The radiographs shall be reviewed to determine conformance to Table 2. Unless otherwise noted, mechanical property test coupons shall be located in relation to the radiographs and high- and low-stress areas of the casting. Mechanical properties tests shall be made to assure conformance to this specification. Mechanical property test coupons sectioned through areas of discrete allowable radiographic soundness discontinuities should be tested for information only and shall not be cause for rejection of the casting or lot except when the test coupon includes a significant portion of the total cast section.

8.1.3 *Foundry Control Approval*—Production of a given casting shall not begin until the foundry control is approved, unless such approval is waived in writing by the purchaser.

8.1.4 *Manufacturing Changes*—The manufacturer shall use the same foundry practices and the same heat-treating procedures for production castings as for approved sample castings. If necessary to make any change, the foundry shall notify the purchaser prior to the first shipment of castings incorporating such a change, and shall submit sample castings produced by the changed procedure for approval in accordance with Section 8. A sample casting may be required by the purchaser to assure that any of the following change(s) do not adversely affect the quality of the casting:

- 8.1.4.1 When a new pattern or permanent mold is used,
- 8.1.4.2 For each new pattern or cavity in multiple tooling,
- 8.1.4.3 When a duplicate pattern or mold is to be used,
- 8.1.4.4 When any change is made in gates, risers, or chills,
- 8.1.4.5 When any change in the “as-cast” shape is made,
- 8.1.4.6 When strength requirements are raised,
- 8.1.4.7 When an old pattern is transferred to a new vendor,
- 8.1.4.8 When another alloy is used, or
- 8.1.4.9 When melting or processing techniques are changed.

8.1.5 *Tensile Properties*—The mechanical properties of test specimens, taken as specified in 8.1.2, shall conform to the requirements of Table 3 and Table 4. The strength requirement of the casting tested in full size shall be as agreed upon between the foundry and the purchaser.