



## 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>

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,

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<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.

<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	
Cracks	....	none		none		none		none	
Cold shuts	....	none		none		none		none	
Laps	....	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
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.

## 9. Heat Treatment

9.1 Heat treatment shall be performed in accordance with Practice B 597 on a whole casting and never on a portion only.

## 10. Identification of Product

10.1 Where practicable, or unless otherwise specified in the contract or order, each casting shall be identified with the part number and the serial number by the use of raised numbers in a location indicated on the drawing. When no location is shown on the drawing, the numbers shall be so located as not to be machined off in finishing to the required dimensions.

10.1.1 Castings on which it is impractical to provide raised numerals shall be marked in accordance with the purchaser's requirements.

## 11. Dimensions

11.1 The dimensions of the castings shall be within the dimensions and tolerances specified on the applicable drawing.

## 12. Workmanship, Finish, and Appearance

12.1 Requirements such as surface finish, parting line projections, snagging projections where gates and risers were removed, etc., may be checked visually. It is advisable to have agreed upon observational standards representing both acceptable and unacceptable material.

12.1.1 Castings may be repaired only by processes approved and agreed upon between the producer and purchaser; that is, welding, impregnation, chemical treatment or coating to prevent leaking, peening, blending, soldering, etc. Limitations on the extent and frequency of such repairs, and methods of inspection of repaired areas should also be agreed upon.

12.1.2 Castings shall not be mechanically straightened after precipitation heat treatment without written permission from the purchaser.

## 13. Responsibility for Quality Assurance

13.1 *Responsibility for Inspection and Tests*—Unless otherwise specified in the contract or purchase order, the producer shall be responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract or order, the producer 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 inspection and tests set forth in this specification where such inspections are deemed necessary to confirm that material conforms to prescribed requirements.

13.2 *Classification of Tests*—The inspection and testing of castings shall be classified as (1) preproduction tests and (2) quality-conformance tests.

13.2.1 *Preproduction Tests*—The first two castings submitted under each contract or order shall be the preproduction test samples. The manufacturer shall supply a certified statement of composition and prior tests that shows that the castings comply with the requirements of this specification.

13.2.2 *Preproduction Testing*—Preproduction testing of the castings shall consist of all tests described in Section 14.

13.3 *Quality-Conformance Tests*—Quality-conformance tests shall consist of all tests required under Section 14.

13.3.1 *Lot*—A lot shall consist of not more than 4000 lb (1815 kg) of castings of the same part number produced in a pouring period not exceeding eight hours with metal from a single melt that are heat-treated in one furnace load. A melt is defined as metal withdrawn from a single furnace to which all alloying, grain refining, degassing, and processing has been completed.

13.3.2 *Traceability*—Castings produced to this specification shall be serialized sequentially as they are produced. The serial number shall be used to provide traceability to all production and inspection operations. The drawing or contract shall denote the method of serialization, that is, cast-on, vibro-etched, etc.

13.3.3 *Sampling Instructions*—Sampling plans and procedures in the determination of the acceptability of products submitted by a supplier shall be in accordance with the provisions set forth in ANSI Z1.4 or as specified in this specification; however, more stringent sampling requirements may be specified on the drawing or in purchase documents.

## 14. Test Methods

14.1 *Chemical Composition*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E 34), or spectrochemical (Test Methods E 101, E 227, E 607 and E 1251) methods. Other methods may be used only when no published ASTM method is available. In case of dispute, the methods of analysis shall be agreed upon between the producer and the purchaser. If the contractor's method of composition control is acceptable and melt analyses are reported that are traceable to serialized castings, sampling for chemical analysis may be waived at the discretion of the purchaser.

14.1.1 *Random Samples*—A random sample shall be selected from each lot in accordance with ANSI Z1.4, Inspection Level S-1, acceptance number of zero.

14.1.2 *Samples for Chemical Analysis*—Samples for chemical analysis shall be taken by sawing, drilling, or milling the casting or test specimens in such a manner as to be representative of the material (Practice E 88). The weight of a prepared sample shall be not less than 75 g.

14.1.3 *Samples for Spectrochemical and Other Methods of Analysis*—Samples for spectrochemical analysis or other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical methods used.

### 14.2 Radiographic Inspection:

14.2.1 Radiographic inspection shall be in accordance with Guide E 94 and Reference Radiograph E 155.

14.2.2 Radiographic acceptance shall be in accordance with requirements selected from Table 2. Any modifications of this table and the frequency per unit area and location shall also be agreed upon.

14.2.3 Castings shall be radiographically inspected as indicated below:

14.2.3.1 *Class 1* (see Section 3) *Castings*—Each shall be completely examined.

14.2.3.2 *Class 2 Castings*—Casting shall be selected in accordance with Table 5 and completely examined.

14.2.3.3 *Class 3 Castings*—Castings shall be selected in accordance with Table 6 and completely examined.

14.2.3.4 *Class 4 Castings*—Radiographic examination is

**TABLE 5 Sample Size (Radiographic Class 2 Castings)**

NOTE 1—Acceptance number is 0.

Lot Size	Sample Size	Lot Size	Sample Size
2–5	all	27–36	10
6–8	5	37–51	11
9–11	6	52–82	12
12–15	7	83–162	13
16–20	8	163–971	14
21–26	9	972 and over	15

**TABLE 6 Sample Size (Radiographic Class 3 Castings)**

NOTE 1—Acceptance number is 0.

Lot Size	Sample Size	Lot Size	Sample Size
2–4	all	18–27	7
5–6	4	28–48	8
7–11	5	49 and over	9
12–17	6		

the highest strength requirements for the casting. If cast-on coupons must be removed prior to heat treatment or if the casting must be reheat treated after they have been removed, the cast-on coupons shall accompany the part through the heat treat operation.

14.6.2 One casting shall be selected at random from each 25 castings or major fraction thereof. The casting selected for testing must be one of 25 castings remaining to be submitted from a sequence of pouring. All castings, sequentially serialized as they are poured, must be accounted for, either as scrapped out or submitted in the batch of 25 castings. Tension test specimens shall be taken from each tensile property strength zone in the casting from locations designated on the engineering drawings. In addition, the attached coupon or coupons shall be tested and reported as part of the survey.

14.6.3 All tests must meet the minimum requirements for the zone of the casting from which they are taken. In the event of a test failure, the group of 25 castings which the test casting represents shall be rejected pending material review board action by the purchaser.

14.7 *Visual and Dimensional Examination*—A random sample shall be selected from each lot in accordance with ANSI Z1.4, Inspection Level 11, Acceptance Quality Level 2.5 % Defective, for the examinations of Sections 11 and 12.

14.8 *Source Inspection*:

14.8.1 If the purchaser desires to make an inspection of the casting at the producers works, it shall be so stated in the contract or order.

14.8.2 If the purchaser elects to have inspection made at the producer's works, the producer shall afford the inspector 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.

## 15. Packaging, Marking, and Shipping

15.1 The material shall be packaged to provide adequate protection during normal handling and transportation, and each package shall contain only castings of the same configuration 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 to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

15.2 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 producer.

15.3 When specified in the contract or purchase order, castings shall be preserved, packaged, and packed in accordance with the requirements of Practices B 660. The applicable levels shall be 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.

## 16. Keywords

16.1 aluminum; high strength; sand casting

not required unless otherwise specified.

### 14.3 Liquid Penetrant Inspection:

14.3.1 When specified, liquid penetrant inspection shall be in accordance with Test Method E 165, and Type I penetrant shall be used unless otherwise specified.

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

14.3.3 Each casting shall be subjected to penetrant inspection.

14.4 *Tensile Properties*—The tensile properties shall be determined in accordance with Test Methods B 557. When the size or shape of the casting restricts the use of test specimens, or when otherwise determined, the full-size casting may be tested. When a complete casting test is required, the strength requirement and the direction or method of loading of the full-size casting shall be specified on the drawing for the part concerned.

14.5 *Tensile Properties—Small Castings*—Castings shall be selected at random from each lot, after heat treatment and nondestructive testing operations have been completed, in accordance with ANSI Z1.4, Inspection Level S-2, acceptance number zero, for the test of 8.1.5. Tension test coupons shall be cut from locations specified on the engineering drawing. If no location is shown, three specimens shall be taken from a thick, medium, and thin section of each casting selected at random. Tests of these coupons must meet the tensile property requirements specified for the zone of the casting from which they were taken. In the event of a failure of any test the lot of castings that the sample represents shall be rejected pending material review board action by the purchaser.

### 14.6 Tensile Properties—Larger Castings:

14.6.1 Each casting shall be cast with one or more cast-on coupons for tensile property testing. These coupons shall remain on the casting until after the completion of all heat-treat operations and shall then be tested to ensure that the casting has been heat-treated to achieve the required tensile properties. Regardless of where they are attached, the coupons shall meet

## ANNEXES

### (Mandatory Information)

#### A1. BASIS FOR INCLUSION OF PROPERTY LIMITS

A1.1 Limits are established at a level at which a statistical evaluation of the data indicates that 99 % of the population obtained from all standard material meets the limit with 95 % confidence. For the products described, mechanical property limits for the respective size ranges are based on the analyses of at least 100 data from standard production material with no

more than ten data from a given lot. All tests are performed in accordance with the appropriate ASTM test methods. For informational purposes, refer to “Statistical Aspects of Mechanical Property Assurance” in the Related Material section of the *Annual Book of ASTM Standards*, Vol 02.02.

#### A2. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION

A2.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1. The Aluminum Association<sup>10</sup> holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A2.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A2.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1. A designation not in conflict with other designation systems or a trade name is acceptable.

A2.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A2.2.3 The complete chemical composition limits are submitted.

A2.2.4 The composition is, in the judgement of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in this specification.

A2.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

A2.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 %	0.XX
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5)	
Over 0.55 %	0.X, X.X, etc.
(Except that combined Si + Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A2.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc (Note A2.1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (Note A2.2).

NOTE A2.1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

NOTE A2.2—Aluminum is specified as *minimum* for unalloyed aluminum and as a *remainder* for aluminum alloys.

<sup>10</sup> The Aluminum Association, 900 19th Street, NW, Washington, DC 20006.

**APPENDIX****(Nonmandatory Information)****X1. METRIC EQUIVALENTS**

X1.1 The SI unit for strength properties now shown is in accordance with the International Systems of Units (SI) (IEEE/ASTM SI 10). 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 1 kg gives it an acceleration of 1 m/s<sup>2</sup> (N = kg·m/s<sup>2</sup>). The derived SI unit for pressure or stress is the

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

**SUMMARY OF CHANGES**

Committee B-7 has identified the location of selected changes to this standard since the last issue (B 686-97) that may impact the use of this standard.

- (1) Summary of Changes section added.
- (2) Paragraph 1.3 revised to include reference to new Annex A1.
- (3) Annex A1 on Basis for Inclusion of Property Limits added.
- (4) Old Annex A1 renumbered to A2.

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