Designation: ~~B686/B686M – 11~~ B686/B686M – 14

Standard Specification for Aluminum Alloy Castings, High-Strength[1]

This standard is issued under the fixed designation B686/B686M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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.

1.3 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 *Units*—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 regular limitations prior to use.*

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:*[2]

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
B985 Practice for Sampling Aluminum Ingots, Billets, Castings and Finished or Semi-Finished Wrought Aluminum Products for Compositional Analysis
D3951 Practice for Commercial Packaging
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
E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

[1] This specification 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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[2] 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

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 E29.

		Composition, %											
ANSI H35.1	ASTM E527	Former	Silicon	Iron	Copper	Man-ganese	Magne-sium	Zinc	Titanium		Others		Aluminum
											Each[A]	Total[B]	
A201.0	A12010		0.05	0.10	4.0–5.0	0.20–0.40	0.15–0.35		0.15–0.35	[C]	0.03	0.10	remainder
354.0	A03540	SC92A	8.6–9.4	0.20	1.6–2.0	0.10	0.40–0.6	0.10	0.20		0.05	0.15	remainder
C355.0	A33550	SC51B	4.5–5.5	0.20	1.0–1.5	0.10	0.40–0.6	0.10	0.20		0.05	0.15	remainder
A356.0	A13560	SG70B	6.5–7.5	0.20	0.20	0.10	0.25–0.45	0.10	0.20		0.05	0.15	remainder
A357.0	A13570		6.5–7.5	0.20	0.20	0.10	0.40–0.7	0.10	0.04–0.20	[D]	0.05	0.15	remainder

[A] ~~"Others"~~"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",~~"Total," the material shall be considered nonconforming.
[B] ~~Other~~Other Elements—Total shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.
[C] ~~Silver~~Silver 0.40 to 1.0 %.
[D] Beryllium 0.04–0.07.

E607 Test Method for Atomic Emission Spectrometric Analysis Aluminum Alloys by the Point to Plane Technique Nitrogen Atmosphere (Withdrawn 2011)[3]
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 Spark Atomic Emission Spectrometry
E2422 Digital Reference Images for Inspection of Aluminum Castings
IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System
2.3 *AMS Standard:*[4]
AMS 2771 Heat Treatment of Aluminum Alloy Castings
2.4 *ANSI Standards:*[5]
~~H35.1 / H35.1 (M) – 2006~~H35.1/H35.1 (M)-2006 Alloy and Temper Designation Systems for Aluminum
Z1.4 Sampling Procedures and Tables for Inspection by Attributes
2.5 *Military Standard:*[6]
MIL-STD-129 Marking for Shipment and Storage
2.6 *Federal Standard:*[6]
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
2.7 *Other Standards:*[7]
CEN EN 14242 Aluminum and ~~aluminum alloys . Chemical analysis. Inductively coupled plasma optical emission spectral analysis~~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.~~
3.1 *Definitions*—Refer to Terminology B881 for definitions of product terms used in this specification.

4. Classification

4.1 Castings shall be classified by inspection classes.
4.1.1 *Classes (Inspection):*
4.1.1.1 *Class 1*—A class of casting, the single failure of which would result in the loss of a missile, aircraft, or other vehicle.
4.1.1.2 *Class 2*—Class 1 castings not included in Class 1, 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] The last approved version of this historical standard is referenced on www.astm.org.
[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.
[5] Available from Aluminum Association, Inc., 1525 Wilson Blvd., Suite 600, Arlington, VA 22209, http://www.aluminum.org.
[6] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.
[7] Available from European Committee for Standardization (CEN), 36 ~~rue~~Rue de Stassart, B-1050, Brussels, Belgium, http://www.cenorm.be.

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

4.1.1.4 *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.

4.1.2 *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.

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

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

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

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

5. Ordering Information

5.1 Orders for material under this specification shall include the following information:

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

NOTE 2—For inch-pound application, specify Specification B686 and for metric application specify Specification B686M. Do not mix units.

5.1.2 Alloy number (Section 7.1~~,~~ and Table 1~~)~~), radiographic grade (4.1.2~~,~~ and Table 2~~)~~), inspection class of castings (4.1.1~~,~~ and Table 3 ~~or~~ [Table 4~~]~~)]), and class of mechanical properties (Table 5 ~~or~~and [Table 6]),

5.1.3 Tensile property requirements on the drawing or purchase order (9.1.5, 15.4, 15.5, Table 3 ~~and Table 5 or~~ [Table 4~~]~~], and Table 5 [Table 6]),

5.1.4 Identification of product information (Section 11),

5.1.5 Applicable drawings or part number, and

5.1.6 The quantity in either pieces or ~~[kilograms],~~[kilograms].

TABLE 2 Discontinuity-Level Requirements for High-Strength Aluminum Castings—Maximum Permissible in Accordance with (Film Reference Radiographs E155 or Digital Reference Radiographs E2422)

NOTE 1—When two or more types of discontinuities are present within a 2 by 2-in. [50 ~~mm~~ by ~~50 mm]~~ 50-mm] 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. [50 ~~mm~~ by ~~50 mm]~~ 50-mm] 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.							
		¼ [6 mm]	¾ [19 mm]	¼ [6 mm]	¾ [19 mm]	¼ [6 mm]	¾ [19 mm]	¼ [6 mm]	¾ [19 mm]
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	[A]	2	[A]	3	[A]
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							

[A] ~~Not~~Not available. Use ¼ ~~in.[6~~ in. [6 mm] for all section thicknesses.

TABLE 3 Mechanical Properties of Specimens[A] Cut from Designated Areas of Casting[B] (Inch-Pound ~~Units).~~Units)

Alloy Number			Class Number	Tensile Strength, min, ksi	Yield Strength, 0.2 % Offset, min, ksi	Elongation in 2 in. or 4*D*, min, %
ANSI H35.1	ASTM E527 (UNS)	Former				
A201.0[C]	A12010		1	60.0	50.0	3
			2[D]	60.0	50.0	5
354.0	A03540	SC92A	1	47.0	36.0	3
			2[D]	50.0	42.0	2
C355.0	A33550	SC51	1	41.0	31.0	3
			2	44.0	33.0	3
			3[D]	50.0	40.0	2
A356.0	A13560	SC70B	1	38.0	28.0	5
			2	40.0	30.0	3
			3[D]	45.0	34.0	3
A357.0	A13570		1	45.0	35.0	3
			2[D]	50.0	40.0	5

[A] ~~For~~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 E29.
[B] ~~For~~For any casting process utilized, 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.
[C] ~~Alloy~~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.
[D] ~~This~~This class is obtainable in favorable casting configurations and must be negotiated with the foundry for particular configuration desired. See Note 1 and 8.3.

TABLE 4 Mechanical Properties of Specimens[A] Cut from Designated Areas of Casting[B] (SI Units) ~~[Metric].~~[Metric][C]

Alloy Number			Class Number	Tensile Strength, min, MPa	Yield Strength, 0.2 % Offset, min, MPa	Elongation in 5*D*, min, %
ANSI H35.1	ASTM E527 (UNS)	Former				
A201.0[D]	A12010		1	415	345	3
			2[E]	415	345	5
354.0	A03540	SC92A	1	325	250	3
			2[E]	345	290	2
C355.0	A33550	SC51	1	285	215	3
			2	305	230	3
			3[E]	345	275	2
A356.0	A13560	SC70B	1	260	195	5
			2	275	205	3
			3[E]	310	235	3
A357.0	A13570		1	310	240	3
			2[E]	345	275	5

[A] ~~For~~For purposes of determining conformance with this specification, each value for tensile strength and yield strength shall be rounded to the nearest 1 MPa, and each value for elongation shall be rounded to the nearest 0.5 %, both in accordance with the rounding method of Practice E29.
[B] ~~For~~For any casting process utilized, special mold or sand mold, or 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 **(8.3)**. Special negotiated properties may be called for by the drawing note.
[C] Guidelines for metric conversion from the *Tempers for Aluminum and Aluminum Alloys, Metric Edition (Tan Sheets)* were used to convert the tensile and yield values to SI units. Section 15.4 and 15.5.3 state that the "coupons must meet the tensile property requirements specified," therefore there has been no reduction in elongation values during metric conversion.[8]
[D] ~~Alloy~~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.
[E] ~~This~~This class is obtainable in favorable casting configurations and must be negotiated with the foundry for particular configuration desired. See Note 1 and 8.3.

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

5.2.1 Whether heat treatment is to be performed in accordance with AMS 2771 (10.2),

5.2.2 Where the preproduction samples shall be sent, ~~and~~ activity responsible for testing, and instructions concerning submittal of the test reports (14.2.1 and 14.2.2),

5.2.3 Penetrant inspection standards (15.2~~).~~),

5.2.4 Whether Practices B660 ~~applies~~apply and, if so, the levels of preservation, packaging, and packing required (16.3),

5.2.5 Whether marking in accordance with ~~Fed. Std. 123 or~~Fed. Std. No. 123, Practice D3951, or MIL-STD-129 applies (16.3), and

5.2.6 Whether certification is required ~~(~~(Section 17).

6. Materials and Manufacture

6.1 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.

TABLE 5 Mechanical Properties of Specimens[A] Cut from Any Area of Casting[B] (Inch-Pound Units)

Alloy Number			Class of Mechanical Property (see 5.1.2)[C]	Tensile Strength, min, ksi	Yield Strength, 0.2 % Offset, min, ksi[C]	Elongation in 2 in. or 4, min, %
ANSI H35.1	ASTM E527 (UNS)	Former				
A201.0[D]	A12010		10	60.0	50.0	3
			11	56.0	48.0	1.5
354.0	A03540	SC92A	10	47.0	36.0	3
			11	43.0	33.0	2
C355.0	A33550	SC51	10	41.0	31.0	3
			11	37.0	30.0	1
			12	35.0	28.0	1
A356.0	A13560	SG70B	10	38.0	28.0	5
			11	33.0	27.0	3
			12	32.0	22.0	2
A357.0	A13570		10	38.0	28.0	5
			11	41.0	31.0	3

[A] ~~For~~For any casting process utilized, special mold or sand mold, or 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 (8.3). Special negotiated properties may be called for by the drawing note.
[B] ~~For~~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 E29.
[C] ~~For~~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 5. See Note 1 and 8.3.
[D] ~~Alloy~~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.

TABLE 6 Mechanical Properties of Specimens[A] Cut from Any Area of Casting[B] (SI Units) –[Metric][C]

Alloy Number			Class of Mechanical Property (see 5.1.2)[C]	Tensile Strength, min, MPa[C]	Yield Strength, 0.2 % Offset, min, MPa[D]	Elongation in 5*D*, min, %
ANSI H35.1	ASTM E527 (UNS)	Former				
A201.0[E]	A12010		10	415	345	3
			11	385	330	1.5
354.0	A03540	SC92A	10	325	250	3
			11	295	230	2
C355.0	A33550	SC51	10	285	215	3
			11	255	205	1
			12	240	195	1
A356.0	A13560	SG70B	10	260	195	4
			11	230	185	3
			12	220	150	2
A357.0	A13570		10	260	195	4
			11	285	215	3

[A] ~~For~~For purposes of determining conformance with this specification, each value for tensile strength and yield strength shall be rounded to the nearest 1 MPa, and each value for elongation shall be rounded to the nearest 0.5 %, both in accordance with the rounding method of Practice E29.
[B] ~~For~~For any casting process utilized, special mold, sand mold, or permanent mold chills may be used. Properties in other areas may vary with mold process and foundry techniques used, but will be inspected under foundry control (**8.3**). Special negotiated properties may be called for by the drawing note.
[C] Guidelines for metric conversion from the *Tempers for Aluminum and Aluminum Alloys, Metric Edition (Tan Sheets)* were used to convert the tensile and yield values to SI units. Section 15.4 and 15.5.3 state that the "coupons must meet the tensile property requirements specified," therefore there has been no reduction in elongation values during metric conversion.[8]
[D] ~~For~~For any alloy, yield strength will be reasonably consistent throughout the casting. This should be considered when selecting combinations of classes from Table 5 and Table 6. See Note 1 and 8.3.
[E] ~~Alloy~~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.

6.1.1 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.

6.1.2 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.

7. Chemical Composition and Sampling

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 Practices E716 and analyzed in accordance with Test Methods E34, E607, or E1251, ~~E34~~or CEN 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.

7.1.1 A sample for determining of chemical composition shall be taken to represent the following:

7.1.1.1 Not more than 2000 lb [1000 kg] of clean castings (gates and risers removed) or a single casting poured from one furnace.

7.1.1.2 Castings poured continuously from one furnace for not more than eight consecutive hours.

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~~in accordance with Practice B985~~producer and the purchaser.~~ . Analysis shall be performed in accordance with Practices E716, Test Methods E34, E607, or E1251, ~~E34~~or CEN EN 14242 (ICP method).

~~7.3 Other methods of analysis or in the case of dispute may be by agreement between the producer and the purchaser.~~

~~7.4 A sample for determining of chemical composition shall be taken to represent the following:~~
~~7.4.1 Not more than 2000 lb [1000 kg] of clean castings (gates and risers removed) or a single casting poured from one furnace.~~
~~7.4.2 Castings poured continuously from one furnace for not more than 8 consecutive hours.~~

8. Preproduction Sample

8.1 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.

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

8.3 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.

9. Radiographic Soundness and Mechanical Property Control

9.1 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.

9.1.1 *Radiographic Requirements*—After the foundry control methods have been established as specified in 8.1, 8.2, and 8.3, castings shall be radiographically inspected as specified in 15.1. Unless otherwise specified in the contract or order, acceptance shall be by comparison with a standard set of radiographs contained in Reference Radiograph E155. 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 (4.1.2). 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.

9.1.1.1 Acceptability is indicated in Table 2 by the indexed number of the E155 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.

9.1.2 *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.

9.1.3 *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.

9.1.4 *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 9. 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:

9.1.4.1 When a new pattern or permanent mold is used,

9.1.4.2 For each new pattern or cavity in multiple tooling,