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2345 S. 170th Street
New Berlin, Wisconsin 53151-2701
USA

Telephone : (262) 782-6344
Toll Free : (800) 726-6385
Telefax : (262) 782-3653
E-Mail : stork.technimet@stork.com
Website : www.technimet.com

Mr. Terry Schroeder
Masterdrive, Inc.
North American Warehouse
W8622 Willis Ray Road
Whitewater, WI 53190-3800

Report

Report No.: 0108-02156-1
Date : November 9, 2001
Subject : Material Specification for Gray and Ductile Iron Castings

Dear Mr. Schroeder:

As defined during our recent discussions and our meeting held on November 6, 2001, it was requested that a material specification be prepared for the sheaves, couplings and bushings manufactured from gray and ductile cast iron. It was stated that the gray iron parts should be manufactured from Class No. 30 Gray Iron, as this was similar to the Grade HT220 material defined in ISO 185, whereas the ductile iron parts should be made from Class 65-45-12 material. Based on our discussions, the material specification would reference standard ASTM specifications which would define the manufacturing controls required to produce the sheaves, couplings and bushings. In preparation of the specifications, the ISO 185, "Gray Cast Iron-Classification", the SAE J431, "Automotive Gray Iron Castings" and SAE J434, "Automotive Ductile (nodular) Iron Coatings" specifications were also referenced.

If you have any questions concerning the material specifications, please call.

Respectfully submitted,

Craig C. Brown
Metallurgical Engineering Manager

nmb

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Website : www.technimet.com

Mr. Terry Schroeder
Masterdrive, Inc.
North American Warehouse
W8622 Willis Ray Road
Whitewater, WI 53190-3800

Report

Report No. 0108-02156-GI Spec.

MATERIAL SPECIFICATION FOR GRAY IRON CASTINGS

Craig C. Brown

November 9, 2001

I. SCOPE

1.1 This specification covers the manufacture of cast iron sheaves, bushings or similar parts.

1.2 The requirements of this specification are in addition to the requirements defined on the part drawing. In case of conflict between this specification and the part drawing, the requirements of the drawing take precedence.

II. REFERENCE DOCUMENTS

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

Specification No.	Description
ASTM A 48*	"Gray Iron Castings"
ASTM A 247*	"Evaluating the Microstructure of Graphite in Iron Castings"
ASTM A 802*	"Steel Castings, Surface Acceptance Standards, Visual Examination"
ASTM A 834*	"Common Requirements for Iron Castings for General Industrial Use"
ASTM E 8	"Tension Testing of Metallic Materials"
ASTM E 10	"Brinell Hardness of Metallic Materials"
ASTM E 802*	"Reference Radiographs for Gray Iron Castings up to 4-1/2 inches in Thickness"
ASTM E 1030*	"Radiographic Examination of Metallic Castings"

*Included in appendix.

III. COMPOSITION

3.1 The chemical composition of the gray iron is subordinate to the mechanical properties, but the typical chemical composition of unalloyed iron should conform to the following ranges:

Element	Weight Percent
Total Carbon	3.20-3.50
Silicon	1.90-2.30
Manganese	0.60-0.90
Phosphorus	0.15 max.
Sulfur	0.15 max.
Approximate CE	3.9-4.2

CE = %C + 1/3% Si

3.2 Individual foundries may produce to narrower ranges than those shown in order to provide the specified material properties. Alloying elements such as chromium, copper, nickel, tin, molybdenum and other elements may be used to meet the mechanical properties and microstructure according to the section size of the casting.

3.3 The modified chemical composition may also be agreed upon with the supplier.

3.4 A lot of castings is defined in accordance with Section 10 of ASTM A 48.

3.5 The chemical composition shall be determined by the supplier by analyzing samples produced at the time the castings are poured or from samples taken from castings. The sampling and methods for determining the composition shall be conducted in accordance with the requirements of ASTM A 834.

IV. HEAT TREATMENT

4.1 The castings shall be in the as-cast condition unless a special heat treatment is specified by the part drawing or purchase order.

4.2 In order to minimize distortion after machining of the parts in the as-cast condition, the castings may be stress relieved.

V. MECHANICAL PROPERTIES

5.1 Separately cast test blocks shall be used to qualify each production lot. The separately cast test blocks shall be manufactured and poured in accordance with Section 11 of ASTM A 48. As an option, the separately cast test blocks may be prepared in accordance with ISO 185, Section 6.1.1.

5.2 The test blocks shall be subjected to the same thermal treatment as the castings they represent. Test specimens removed from the coupons must conform to the requirements of the Class No. 30 material as defined in Table 1 of ASTM A 48.

5.3 The tension specimens shall be machined from the coupons at the designated locations and shall meet the dimensional requirements defined in ASTM A 48. Tension test specimens A, B and C shall be selected based on the critical section thickness of the castings that they qualify or as defined by the part drawings.

5.4 The tension specimens may also be cut from castings to qualify each lot. The mechanical properties of the specimens cut from the castings shall meet the same requirements as the separately cast coupons.

5.5 The tensile specimens shall be tested in accordance with ASTM E 8. The number of tests and retests shall be in accordance with Section 12 of ASTM A 48.

5.6 Brinell hardness tests shall be conducted in accordance with ASTM E 10 at the location defined on the part drawing. After sufficient material has been removed from the casting surface to ensure a representative hardness reading, the parts shall have a Brinell hardness of 187 to 241.

5.7 The material shall have a tensile to hardness ratio (t/h) minimum of 150 psi per kgf/mm^2 unless otherwise agreed upon with the purchaser.

5.8 When requested by the purchaser, process capability studies shall be conducted to show that the hardness, tensile strength and tensile strength to hardness ratio requirements can be met. A minimum of 30 test specimens from separately cast test bars or from castings shall be used. The data should provide a Cpk value for each property, which must be 1.3 or larger.

VI. QUALITY REQUIREMENTS

6.1 Casting quality and inspection shall conform to the appropriate quality, workmanship and finish requirements of ASTM A 48 and A 834 and any other requirements specified on the part drawing or purchase order. Castings shall be free from shrinkage defects, hot tears, cracks, blow holes, porosity, foreign matter and other injurious discontinuities and must not disclose such defects during machining or subsequent testing.

6.2 Casting surfaces shall be reasonably smooth and shall be free of scale and burned on sand. Runners, risers, fins, and other such cast-on pieces shall be removed and dressed down to blend with the normal profile of the casting surface. The surface discontinuities shall be evaluated in accordance with and meet the visual acceptance standards defined in ASTM A 802, Level 2.

6.3 Magnetic particle inspection of prototype and pre-production castings, or production castings if required by the print, shall be conducted in accordance with ASTM A 834 supplementary requirement S1. This test method shall be used to qualify the manufacturing process prior to production release.

6.4 Radiographic inspection of prototype and pre-production parts shall be in accordance with ASTM A 834 supplementary requirement S2. The radiographic evaluation shall be conducted in accordance with ASTM E 1030, E 802, E 446 and E 186. The acceptance criteria shall be defined on the part drawing. This test method shall be used to qualify the manufacturing process prior to production release. Any significant changes to the manufacturing process require requalification of the parts. As an alternative method of establishing internal soundness, representative castings may be destructively sectioned at multiple locations and the results submitted to Masterdrive Quality Department for approval.

6.5 Casting dimensions shall meet the part drawing requirements.

6.6 The microstructure of the castings shall be evaluated in accordance with ASTM A 247 and shall consist of at least 80% Type A flake graphite with no more than 20% other types present. The flake size shall consist of greater than 80% size 3 or finer. The matrix shall consist of ferrite and pearlite and the material shall not contain greater than 2% carbides or steadite. The microstructure should be uniform so as not to impact machinability.

6.7 The supplier shall afford Masterdrive Quality Department representatives all reasonable access to their facilities and the inspection, process, or test reports necessary to confirm that the material is being furnished in accordance with this specification and associated procurement requirements.

VII. REPAIR

7.1 Castings shall not be repaired by welding, brazing or peening without approval of Masterdrive, Inc. If specific permission is granted, any repair must be conducted in accordance with a qualified repair procedure and performed by qualified personnel.

VIII. IDENTIFICATION

8.1 Unless otherwise specified, all castings shall be identified with a part number, supplier identification (logo), and heat lot or date code. Additional requirements shall be in accordance with the part drawing and/or purchase order. The markings must be cast in raised letters unless otherwise noted on the drawing.

IX. CERTIFICATION

9.1 A certificate stating that each lot has been sampled, tested and inspected in accordance with this specification shall be provided by the supplier. The certification must also include the chemical composition, tensile properties, hardness and tensile to hardness ratio for each lot of castings. When requested, the supplier shall furnish a certificate of microstructure.

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Mr. Terry Schroeder
Masterdrive, Inc.
North American Warehouse
W8622 Willis Ray Road
Whitewater, WI 53190-3800

Report

Report No. 0108-02156-DI Spec.

MATERIAL SPECIFICATION FOR DUCTILE IRON CASTINGS

Craig C. Brown

November 9, 2001

I. SCOPE

1.1 This specification covers the manufacture of cast iron bushings, couplings or similar parts.

1.2 The requirements of this specification are in addition to the requirements defined on the part drawing. In case of conflict between this specification and the part drawing, the requirements of the drawing take precedence.

II. REFERENCE DOCUMENTS

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

Specification No.	Description
ASTM A 247*	"Evaluating the Microstructure of Graphite in Iron Castings"
ASTM A 536*	"Ductile Iron Castings"
ASTM A 802*	"Steel Castings, Surface Acceptance Standards, Visual Examination"
ASTM A 834*	"Common Requirements for Iron Castings for General Industrial Use"
ASTM E 8	"Tension Testing of Metallic Materials"
ASTM E 10	"Brinell Hardness of Metallic Materials"
ASTM E 689*	"Reference Radiographs for Ductile Iron Castings"
ASTM E 1030*	"Radiographic Examination of Metallic Castings"

*Included in appendix.

III. COMPOSITION

3.1 The chemical composition of the ductile iron is subordinate to the mechanical properties, but the typical chemical composition of unalloyed iron should conform to the following ranges:

Element	Weight Percent
Total Carbon	3.20-4.10
Silicon	1.80-3.00
Manganese	0.10-1.00
Phosphorus	0.05 max.
Sulfur	0.02 max.

3.2 Individual foundries may produce to narrower ranges than those shown in order to provide the specified material properties. The spheroidal graphite structure is produced by alloying the molten iron with small amounts of one or more elements such as magnesium or cerium.

3.3 A modified chemical composition may also be agreed upon with the supplier.

3.4 A lot of castings is defined in accordance with ASTM A 834, Section 8.

3.5 The chemical composition shall be determined by the supplier by analyzing samples produced at the time the castings are poured or from samples taken from castings. The sampling and methods for determining the composition shall be conducted in accordance with the requirements of ASTM A 834.

IV. HEAT TREATMENT

4.1 The castings shall be in the as-cast condition or may be given a normalize and temper to meet the requirements for Grade 65-45-12, unless a special heat treatment is specified on the part drawing or purchase order.

4.2 In order to minimize distortion after machining of the parts in the as-cast condition, the castings may be stress relieved.

V. MECHANICAL PROPERTIES

5.1 Separately cast test blocks shall be used to qualify each production lot. The separately cast Keel blocks or Y Blocks shall be manufactured and poured in accordance with ASTM A 536, Section 6. The size of the Y Block shall represent the section thickness of the castings unless otherwise approved.

5.2 The test blocks shall be subjected to the same thermal treatment as the castings they represent. Test specimens removed from the coupons must conform to the requirements of the specified grade defined in Table 1 of ASTM A 536.

5.3 The tension specimens shall be machined from the coupons at the designated locations and shall meet the dimensional requirements defined in ASTM A 536.

5.4 The tension specimens may also be cut from castings to qualify each lot. The mechanical properties of the specimens cut from the castings shall meet the same requirements as the separately cast coupons.

5.5 The tensile specimens shall be tested in accordance with ASTM E 8. The number of tests and retests shall be in accordance with ASTM A 536, Section 10.

5.6 Brinell hardness tests shall be conducted in accordance with ASTM E 10 at the location defined on the part drawing. After sufficient material has been removed from the casting surface to ensure a representative hardness reading, the parts shall have a Brinell hardness of 156 to 217.

5.7 When requested by the purchaser, process capability studies shall be conducted to show that the hardness, tensile strength, yield strength and percent elongation

requirements can be met. A minimum of 30 test specimens from separately cast test coupons or form castings shall be used. The data should provide a Cpk value for each property, which must be 1.3 or larger.

VI. QUALITY REQUIREMENTS

6.1 Casting quality and inspection shall conform to the appropriate quality requirements of ASTM A 536 and A 834 and any other requirements specified on the part drawing or purchase order. Castings shall be free from shrinkage defects, hot tears, cracks, blow holes, porosity, foreign matter and other injurious discontinuities and must not disclose such defects during machining or subsequent testing.

6.2 Casting surfaces shall be reasonably smooth and shall be free of scale and burned on sand. Runners, risers, fins, and other such cast-on pieces shall be removed and dressed down to blend with the normal profile of the casting surface. The surface discontinuities shall be evaluated in accordance with and meet the visual acceptance standards defined in ASTM A 802, Level 2.

6.3 Magnetic particle inspection of prototype and pre-production castings, or production castings if required by the print, shall be conducted in accordance with ASTM A 834 supplementary requirement S1. This test method shall be used to qualify the manufacturing process prior to production release.

6.4 Radiographic inspection of prototype and pre-production parts shall be in accordance with ASTM A 834 supplementary requirement S2. The radiographic evaluation shall be conducted in accordance with ASTM E 1030, E 689, E 446 and E 186. The acceptance criteria shall be defined on the part drawing. This test method shall be used to qualify the manufacturing process prior to production release. Any significant changes to the manufacturing process require requalification of the parts. As an alternative method of establishing internal soundness, representative castings may be destructively sectioned at multiple locations and the results submitted to Masterdrive Quality Department for approval.

6.5 Casting dimensions shall meet the part drawing requirements.

6.6 The microstructure of the castings shall be evaluated in accordance with ASTM A 247 and shall consist of at least 85% spheroidal graphite conforming to Type I and II. The nodule count shall be greater than 150/mm^2 in all sections less than 2". The matrix shall consist of ferrite or ferrite and pearlite and the material shall not contain greater than 2% carbides or steadite. The microstructure should be uniform so as not to impact machinability.

6.7 The supplier shall afford Masterdrive Quality Department representatives all reasonable access to their facilities and the inspection, process, or test reports necessary to confirm that the material is being furnished in accordance with this specification and associated procurement requirements.

VII. REPAIR

7.1 Castings shall not be repaired by welding, brazing or peening without approval of Masterdrive. If specific permission is granted, any repair must be conducted in accordance with a qualified repair procedure and performed by qualified personnel.

VIII. IDENTIFICATION

8.1 Unless otherwise specified, all castings shall be identified with a part number, supplier identification (logo), and heat lot or date code. Additional requirements shall be in accordance with the part drawing and/or purchase order. The markings must be cast in raised letters unless otherwise noted on the drawing.

IX. CERTIFICATION

9.1 A certificate stating that each lot has been sampled, tested and inspected in accordance with this specification shall be provided by the supplier. The certification must also include the chemical composition, tensile properties and hardness for each lot of castings. When requested, the supplier shall furnish a certificate of microstructure.

Designation: A 48 – 94a$^{\epsilon 1}$

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428

Standard Specification for Gray Iron Castings[1]

This standard is issued under the fixed designation A 48; 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.

This standard has been approved for use by agencies of the Department of Defense. This specification replaces Federal Specification QQ-I-652.

ϵ^1 NOTE—Note 1 was added editorially in September 1998.

1. Scope

1.1 This specification covers gray iron castings intended for general engineering use where tensile strength is a major consideration. Castings are classified on the basis of the tensile strength of the iron in separately cast test bars.

1.1.1 This specification subordinates chemical composition to tensile strength.

1.2 Castings produced to this specification are graded on the basis of minimum tensile strength obtained in special test coupons designed to standardize cooling rate. The tensile strength developed in certain casting sections may vary from test coupon values (see X1.2).

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

NOTE 1—The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 644 Terminology Relating to Iron Castings[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

2.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[4]

2.3 *Federal Standard:*

Federal Standard No. 123 Marking for Shipment (Civil Agencies)[4]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions for many terms common to gray iron castings are found in Terminology A 644.

4. Classification

4.1 Castings ordered and produced in accordance with this specification are classified into a number of grades based on the properties of separately cast test bars (Table 1). Each class is designated by a number followed by a letter. The number indicates the minimum tensile strength of the separately cast test bar, and the letter indicates the size of the test bar. Examples of proper designations are as follows:

Gray Iron Castings, ASTM Specification A 48, Class 30B.

Gray Iron Castings, ASTM Specification A 48, Class 40C.

5. Ordering Information

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

5.1.1 ASTM designation number and year of issue,

5.1.2 Class of iron required (see 4.1 and Table 1),

5.1.3 The size of the separately cast test bar (letter classification—A, B, C, or S) that best represents the thickness of the controlling section of the casting (see Table 2),

5.1.4 The tension test specimen (B or C) to be machined from test bar C (see 13.3, Table 3, and Fig. 1),

5.1.5 The tension test specimen to be machined from test bar S (see 13.4, Table 3, and Fig. 1),

5.1.6 Lot size (see Section 10),

5.1.7 Special requirements (see Section 6),

5.1.8 Saving tested specimens or unbroken test bars (see 15.1), and

5.1.9 Special preparation for delivery (see Section 19).

6. Special Requirements

6.1 When agreed upon in writing between the manufacturer and the purchaser, it may be necessary for the castings to meet special requirements as to hardness, chemical composition, microstructure, pressure tightness, radiographic soundness, dimensions, surface finish, etc.

7. Tensile Requirements

7.1 Test bars representing castings conforming to this specification shall meet the requirements for tensile strength as described in Table 1.

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[1] This specification is under the jurisdiction of ASTM Committee A-4 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray Iron Castings.

Current edition approved July 15, 1994. Published September 1994. Originally published as A 48 – 05. Last previous edition A 48 – 94.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Requirements for Tensile Strength of Gray Cast Irons in Separately Cast Test Bars

Class	Tensile Strength, min, ksi (MPa)	Nominal Test Bar Diameter, in. (mm)
No. 20 A	20 (138)	0.88 (22.4)
No. 20 B		1.2 (30.5)
No. 20 C		2.0 (50.8)
No. 20 S		Bars S[A]
No. 25 A	25 (172)	0.88 (22.4)
No. 25 B		1.2 (30.5)
No. 25 C		2.0 (50.8)
No. 25 S		Bars S[A]
No. 30 A	30 (207)	0.88 (22.4)
No. 30 B		1.2 (30.5)
No. 30 C		2.0 (50.8)
No. 30 S		Bars S[A]
No. 35 A	35 (241)	0.88 (22.4)
No. 35 B		1.2 (30.5)
No. 35 C		2.0 (50.8)
No. 35 S		Bars S[A]
No. 40 A	40 (276)	0.88 (22.4)
No. 40 B		1.2 (30.5)
No. 40 C		2.0 (50.8)
No. 40 S		Bars S[A]
No. 45 A	45 (310)	0.88 (22.4)
No. 45 B		1.2 (30.5)
No. 45 C		2.0 (50.8)
No. 45 S		Bars S[A]
No. 50 A	50 (345)	0.88 (22.4)
No. 50 B		1.2 (30.5)
No. 50 C		2.0 (50.8)
No. 50 S		Bars S[A]
No. 55 A	55 (379)	0.88 (22.4)
No. 55 B		1.2 (30.5)
No. 55 C		2.0 (50.8)
No. 55 S		Bars S[A]
No. 60 A	60 (414)	0.88 (22.4)
No. 60 B		1.2 (30.5)
No. 60 C		2.0 (50.8)
No. 60 S		Bars S[A]

[A] All dimensions of test bar S shall be as agreed upon between the manufacturer and the purchaser.

TABLE 2 Separately Cast Test Bars for Use When a Specific Correlation Has Not Been Established Between the Test Bar and the Casting

Thickness of the Wall of the Controlling Section of the Casting, in. (mm)	Test Bar
Under 0.25 (6)	S
0.25 to 0.50 (6 to 12)	A
0.51 to 1.00 (13 to 25)	B
1.01 to 2 (26 to 50)	C
Over 2 (50)	S

8. Dimensional Requirements

8.1 The castings shall conform to the dimensions or drawings furnished by the purchaser, or, if there are no drawings, to the dimensions predicted by the pattern equipment supplied by the purchaser.

9. Workmanship and Finish

9.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears, as determined by visual examination.

9.2 No repairing by plugging or welding of any kind shall be permitted unless written permission is granted by the purchaser.

10. Sampling

10.1 A lot shall consist of one of the following:

10.1.1 All the metal poured from a single heating in a batch type melting furnace.

10.1.2 All the metal from two or more batch type melting furnaces poured into a single ladle or a single casting.

10.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry or 4 h, whichever is the shorter period.

10.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

11. Cast Test Bars

11.1 Test bars shall be separate castings poured from the same lot as the castings they represent and shall have dimensions as shown in Table 3. Allowance may be made for reasonable pattern draft within the tolerances shown in Table 3. Test bars A, B, and C are all standard test bars in the form of simple cylinders. Test bar S is special and is intended for use where the standard bars are not satisfactory.

11.2 The test bars shall be cast in dried, baked, or chemically bonded molds made mainly of an aggregate of siliceous sand with appropriate binders. The average grain size of the sand shall approximate that of the sand in which the castings are poured. Molds for the test bars shall be approximately at room temperature when poured. More than one test bar may be cast in a single mold, but each bar in the mold shall be surrounded by a thickness of sand which is not less than the diameter of the bar. A suitable design for a mold is shown in Fig. 2.

NOTE 2—The intent of these provisions is as follows: to prohibit the casting of test bars in molds of metal, graphite, zircon, light-weight aggregates, or other materials which would significantly affect the tensile strength of the iron; to prohibit control of tensile strength of the test bars by manipulation of the grain size of the sand; and to prohibit the casting of test bars in molds preheated substantially above room temperature.

11.3 Test bars that are intended to represent castings that are cooled in the mold to less than 900°F (480° C), before shakeout, shall be cooled in their molds to a temperature less than 900°F (480° C). They then may be cooled in still air to room temperature.

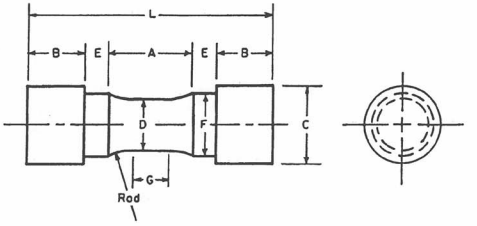
11.4 Test bars that are intended to represent castings that are hotter than 900°F (480° C), when shaken out of their molds, shall be cooled as described in 11.3 or (by agreement between the manufacturer and the purchaser) may be shaken out of their molds at approximately the same temperature as the castings they represent.

11.5 When castings are stress-relieved, annealed, or otherwise heat-treated, test bars shall receive the same thermal treatment and shall be treated adjacent to the castings they represent.

TABLE 3 Diameters and Lengths of Cast Test Bars

Test Bar	As-Cast Diameter, in. (mm)			Length, in. (mm)	
	Nominal (Mid-Length)	Minimum (Bottom)	Maximum (Top)	Minimum (Specified)	Maximum (Recommended)
A	0.88 (22.4)	0.85 (21.6)	0.96 (24.4)	5.0 (125)	6.0 (150)
B	1.20 (30.5)	1.14 (29.0)	1.32 (33.5)	6.0 (150)	9.0 (230)
C	2.00 (50.8)	1.90 (48.3)	2.10 (53.3)	7.0 (175)	10.0 (255)
S[A]	...	...	...	...	...

[A]All dimensions of test bar S shall be as agreed upon by the manufacturer and the purchaser.



Dimensions, in. (mm)	Tension Test Specimen A	Tension Test Specimen B	Tension Test Specimen C
G—Length of parallel, min	0.50 (13)	0.75 (19)	1.25 (32)
D—Diameter	0.500 ± 0.010 (12.7 ± 0.25)	0.750 ± 0.015 (19.1 ± 0.4)	1.25 ± 0.025 (31.7 ± 0.050)
R—Radius of fillet, min	1 (25)	1 (25)	2 (50)
A—Length of reduced section, min	1¼(32)	1½ (38)	2¼ (57)
L—Over-all length, min	3¾(95)	4 (100)	6⅜ (160)
C—Diameter of end section, approx	⅞ (22.2)	1¼ (31.8)	1⅞ (47)
E—Length of shoulder, min	¼(6)	¼ (6)	⅜ (8)
F—Diameter of shoulder	⅝± 1/64 (16 ± 0.5)	1⅜ ± 1/64 (25 ± 0.5)	1⅞ ± 1/64 (38 ± 0.5)
B—Length of end section	[A]	[A]	[A]

[A]Optional to fit holders on testing machine. If threaded, root diameter shall not be less than dimension *F*.

FIG. 1 Tension-Test Specimens

12. Number of Tests and Retests

12.1 The tension test shall be conducted in accordance with Test Method E 8.

12.2 One tension test shall be performed on each lot and shall conform to the tensile requirements specified.

12.3 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification requirements, the castings represented by these test specimens shall be rejected. A valid test is one wherein the specimen has been properly prepared and appears to be sound and on which the approved test procedure has been followed.

12.4 If sufficient separately cast test pieces are not available, the manufacturer shall have the option of removing a test specimen from a location of representative casting, as agreed upon between the manufacturer and purchaser.

12.5 If the first test results indicate that a heat treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be heat treated together. Testing shall proceed in accordance with 12.1-12.3.

12.6 If, after testing, a test specimen shows evidence of a defect, the results of the test may be invalidated and another made on a specimen from the same lot.

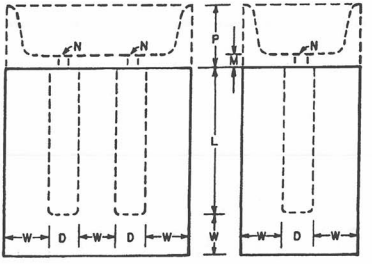
13. Tension Test Specimens

13.1 For test Bar A, the tension-test specimen A, as shown in Fig. 1, shall be machined concentric with the axis of the test bar.

13.2 For test Bar B, the tension test specimen B, as shown in Fig. 1, shall be machined concentric with the axis of the test bar.

13.3 For test Bar C, tension test specimens B or C, as shown in Fig. 1, shall be machined concentric with the axis of the test bar. Unless the size of the tension test specimen to be machined from test bar C is specified in writing by the purchaser, the decision whether to use tension test specimen B or C shall be made by the manufacturer of the castings.

13.4 For test bar S, the nature and dimensions of the tension test specimen shall be determined by agreement between the manufacturer and purchaser.



Required Features:

1. Material—Aggregate of dry siliceous sand.
2. Position—Bars vertical.
3. *L*—See Table 3.
4. *D*—See Table 3.
5. *W*—Not less than diameter *D*.

Optional Features:

1. Number of test bars in a single mold—Two suggested.
2. Design of pouring cup.
3. *P*—2 in. (50 mm), suggested.
4. *N*—¾in. (8 mm) in diameter, suggested.
5. $M = 1.5\ N$, suggested.

FIG. 2 Suitable Design and Dimensions for Mold for Separately Cast Cylindrical Test Bars for Gray Iron

14. Tension Test

14.1 Tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial.

14.2 The elapsed time from the beginning of loading in the tension test to the instant of fracture shall be not less than 15 s for test specimen A and not less than 20 s for specimens B and C.

15. Inspection

15.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities, and he shall maintain complete records of all such tests and inspections. Such records shall be available for review by the purchaser.

15.1.1 When agreed upon between the manufacturer and purchaser, tested specimens or unbroken test bars from the same lot shall be saved for a period of three months after the date of the test report.

15.2 The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to the prescribed requirements.

16. Rejection and Resubmission

16.1 Any castings or lot of castings failing to comply with the requirements of this specification may, where possible, be reprocessed, retested, and reinspected. If the tests and inspections on the reprocessed casting(s) show compliance with this specification, the castings shall be acceptable; if they do not, they shall be rejected.

16.2 If the purchaser should find that a casting or lot of castings fails to comply with this specification subsequent to receipt at his facility, he shall so notify the manufacturer promptly and in no case later than six weeks after receipt of the shipment, stating clearly the basis for rejection.

17. Certification

17.1 When specified by the purchaser's order or contract, a manufacturer's certification or compliance statement that the casting or lot of castings was made, sampled, tested, and inspected in accordance with this specification, including a report of test results shall be furnished at the time of shipment, and such certification or compliance statement shall be the basis for acceptance of the casting or lot of castings.

17.2 A signature is not required on the certification or test report. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

18. Product Marking

18.1 When the size of the casting permits, each casting shall bear the identifying mark of the manufacturer and the part or pattern number at a location shown on the covering drawing or, if not shown on the drawing, at a location at the discretion of the producer.

19. Preparation for Delivery

19.1 Unless otherwise stated in the contract or order, the cleaning, preservation and packing of castings for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

19.2 *U.S. Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military activities.

20. Keywords

20.1 gray iron castings

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of iron castings are influenced by the cooling rate during and after solidification, by chemical composition (particularly carbon equivalent), by the design of the casting, by the design and nature of the mold, by the location and effectiveness of gates and risers, and by certain other factors.

X1.2 The cooling rate in the mold and, hence, the properties developed in any particular section are influenced by the presence of cores; chills and chaplets; changes in section thickness; and the existence of bosses, projections, and intersections, such as junctions of ribs and bosses. Because of the complexity of the interactions of these factors, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specification application, it may be determined by appropriate experimentation.

X1.3 Gray iron castings in Classes 20, 25, 30 and 35 are characterized by excellent machinability, high damping capacity, low modulus of elasticity, and comparative ease of manufacture.

X1.3.1 Castings in Classes 40, 45, 50, 55 and 60 are usually more difficult to machine, have lower damping capacity and a higher modulus of elasticity, and are more difficult to manufacture.

X1.4 When reliable information is unavailable on the relationship between properties in a casting and those in a separately cast test specimen, and where experimentation would be unfeasible, the size of the test casting should be so selected as to approximate the thickness of the main or controlling section of the casting.

X1.5 If iron castings are welded (see 9.2), the microstructure of the iron is usually altered, particularly in the vicinity of the weldment. Therefore, the properties of the casting may be adversely affected by welding. Where practical, appropriate post weld heat treatment may reduce this effect of welding.

Designation: A 247 – 67 (Reapproved 1998)

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
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Standard Test Method for Evaluating the Microstructure of Graphite in Iron Castings[1]

This standard is issued under the fixed designation A 247; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the classification of graphite in cast irons in terms of type, distribution, and size. This test method is intended to be applicable for all iron-carbon alloys containing graphite particles, and may be applied to gray irons, malleable irons, and the ductile (nodular) irons.

1.2 The reference standards included in this test method are in no way to be construed as specifications. In an appropriate specification for a specific material where graphite microstructure is an important consideration this test method may be used as a reference to define concisely the graphite microstructure required.

1.3 These standards are offered primarily to permit accurate reporting of microstructures of cast irons and to facilitate the comparison of reports by different laboratories or investigators.

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

2. Referenced Documents

2.1 *ASTM Standards:*

E 3 Methods of Preparation of Metallographic Specimens[2]

3. Summary of Test Method

3.1 The reference diagrams included in this standard form the basis for classification. Characteristic features of graphite particles are designated by numerals and letters. Type, distribution, and size of observed graphite are compared with the idealized microstructures in the standard charts and rated accordingly as closely as possible to the equal or similar microstructures in the charts.

4. Significance and Use

4.1 The comparison of observed graphite particles with the structures shown in the charts give only purely descriptive information on the type, distribution, and size of the graphite in the sample being evaluated. It does not indicate except in a very broad way the origin of the graphite, or the suitability of the iron-carbon alloy for a particular service.

5. Test Specimens or Samples

5.1 The preferred sample is a section cut from an actual casting that is being evaluated. When this is impractical, a test lug or projection often can be cast attached to the casting and sawed or broken off to be used as the sample. If neither of these methods is convenient, microscopical test coupons, such as that recommended by the Ductile Iron Research Committee (12K) of the American Foundrymen's Society[3] should be cast from metal representative of the castings poured.

6. Polishing

6.1 Grinding and polishing may follow the usual accepted metallographic procedures as covered in Methods E 3, except that care must be taken that the graphite is retained at the polished surface and not torn or dragged out. Use of diamond powder polishing compound in one of the final stages of polishing is very effective in retaining the graphite at the polished surface.

7. Classification of Graphite Form with Chart

7.1 The graphite form type chart (Plate I)[4] is used as a reference standard by scanning the polished specimen under the microscope and noting the graphite forms in the microstructure that more nearly correspond to type designations on the chart.

7.2 Type I is the normal and usually desirable graphite form in ductile iron, although the presence of Type II graphite forms has little or no adverse effect on properties. Graphite forms represented by Types IV through VI often occur in ductile iron in conjunction with Types I and II. The percentages of each graphite type are estimated by observation, or better, by counting the particles of each type. Types present in a sample are to be reported in percentages to total 100. Any convenient magnification that clearly reveals the graphite form may be used.

7.3 Type III is the graphite form most often seen in malleable iron castings after annealing. Some malleable irons may contain Types I or II graphite particles also.

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[1] This test method is under the jurisdiction of ASTM Committee A-4 on Iron Castings and is the direct responsibility of Subcommittee A04.21 on Testing.

Current edition effective Aug. 25, 1967. Originally issued 1941. Replaces A 247 – 47.

[2] *Annual Book of ASTM Standards*, Vol 03.01.

[3] *Transactions*, American Foundrymen's Society, 1960, p. 655.

[4] Plates I, II, and III may be obtained from ASTM Headquarters. Order PCN 12-102470-09.

7.4 Type VII is the flake graphite form usually seen in gray iron.

8. Classification of Graphite Distribution with Chart

8.1 The graphite distribution chart (Plate II)[4] is useful principally in rating flake graphite, Type VII, distributions in gray cast iron. Occasionally, however, graphite in malleable or ductile iron may occur in a nonrandom distribution pattern which the distributions B to E may be used to describe.

9. Classification of Graphite Size by Chart

9.1 Two series of size charts, one for flake graphite, and one for nodules, are shown in Plate III[4] to facilitate comparisons. At exactly 100 diameters magnification the *maximum* dimension of the graphite particles for the various size classes are shown in Table 1.

9.2 For direct comparison with the size classes in Plate III, the specimen to be evaluated should be projected on the ground glass screen, or photographed, at a magnification of exactly 100 diameters. Usually visual comparison with the chart is adequate to define the size class. If carefully calibrated, ocular scales may be used to measure the serpentine length dimension of flakes or the diameter of nodules. Where a mixture of one or more sizes occurs in the same sample, the sizes may be reported as percentages of the total graphite area represented by the sizes involved. It is a common practice in malleable iron to use nodule count per unit area instead of a comparison chart as given here. Nodule count, with known free carbon content, is a measure of calculated average nodule area.

TABLE 1 Graphite Size

Size Class	Maximum Dimension at × 100, mm[A]
1	128
2	64
3	32
4	16
5	8
6	4
7	2
8	1

[A] The gradation of sizes shown in each size class from the maximum dimension were computer calculated at the National Bureau of Standards using data obtained from actual micrographs (Wyman, L. L., and Moore, G. A., "Quantitative Metallographic Evaluations of Graphite Microstructures," Modern Castings, Vol 43, No. 1, Jan. 1963, p. 7).

10. Report of Graphite Microstructure

10.1 To report the microstructure of graphite in cast iron the headings to be used are as follows: Sample identification; graphite form type or types; graphite distribution; graphite size class.

10.2 Graphite type, or types, is designated by a Roman numeral I through VII. Graphite distribution is designated by a capital letter A through E. Graphite size is designated by an Arabic numeral 1 through 8.

10.3 Graphite distribution is always designated for flake graphite irons, but may be omitted for malleable and ductile iron.

10.3.1 For example, a typical gray iron of normal graphite structure might be designated VII A4. If eutectiform graphite is present, the rating might be VII D7. Mixtures of these two may be described by giving both ratings with appropriate percentages, 70 % VII A4, 30 % VII D7.

10.3.2 A high-quality ductile iron could be designated I6. A slightly inferior ductile iron, with somewhat insufficient nodulizing alloy, might be 70 % I6, 30 % IV5.

10.3.3 Graphite in malleable irons may be similarly designated as Types III, II, or I and the size from the nodular size chart.

Designation: A 536 – 84 (Reapproved 1999)ε1

Standard Specification for Ductile Iron Castings[1]

This standard is issued under the fixed designation A 536; 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.

This standard has been approved for use by agencies of the Department of Defense.

ε[1] NOTE—Keywords were added editorially in October 1999.

1. Scope

1.1 This specification covers castings made of ductile iron, also known as spheroidal or nodular iron, that is described as cast iron with the graphite substantially spheroidal in shape and essentially free of other forms of graphite, as defined in Definitions A 644.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of castings and those of a test specimen cast from the same iron (see Appendix X1).

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 644 Terminology Relating to Iron Castings[3]

A 732/A 732M Specification for Castings, Investment, Carbon and Low–Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[3]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

2.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[5]

3. Ordering Information

3.1 Orders for material to this specification shall include the following information:

3.1.1 ASTM designation,

3.1.2 Grade of ductile iron required (see Table 1, and Sections 4 and 9),

3.1.3 Special properties, if required (see Section 7),

3.1.4 If a different number of samples are required (see Section 10),

3.1.5 Certification, if required (see Section 14), and

3.1.6 Special preparation for delivery, if required (see Section 15).

4. Tensile Requirements

4.1 The iron represented by the test specimens shall conform to the requirements as to tensile properties presented in Table 1 and Table 2. The irons listed in Table 1 cover those in general use while those listed in Table 2 are used for special applications (such as pipes, fittings, etc.).

4.2 The yield strength shall be determined at 0.2 % offset by the offset method (see Test Methods E 8). Other methods may be used by mutual consent of the manufacturer and purchaser.

5. Heat Treatment

5.1 The 60-40-18 grade will normally require a full ferritizing anneal. The 120-90-02 and the 100-70-03 grades generally require a quench and temper or a normalize and temper, or an isothermal heat treatment. The other two grades can be met either as-cast or by heat treatment. Ductile iron, that is heat treated by quenching to martensite and tempering, may have substantially lower fatigue strength than as cast material of the same hardness.

6. Test Coupons

6.1 The separately cast test coupons from which the tension test specimens are machined shall be cast to the size and shape shown in Fig. 1 or Fig. 2. A modified keel block cast from the mold shown in Fig. 3 may be substituted for the 1-in. Y-block or the 1-in. keel block. The test coupons shall be cast in open molds made of suitable core sand having a minimum wall thickness of 1½ in. (38-mm) for the ½-in. (12.5 mm) and 1-in. (25-mm) sizes and 3-in. (75-mm) for the 3-in. size. The coupons shall be left in the mold until they have cooled to a black color (approximately 900°F (482°C) or less). The size of coupon cast to represent the casting shall be at the option of the purchaser. In case no option is expressed, the manufacturer shall make the choice.

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[1] This specification is under the jurisdiction of the ASTM Committee A-4 on Castings and is the direct responsibility of Subcommittee A04.02 on Malleable and Ductile Iron Castings.

Current edition approved June 15, 1984. Published December 1984. Originally published as A 536 – 65T. Last previous edition A 536 – 80.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

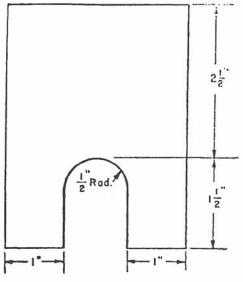
[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Tensile Requirements

	Grade 60-40-18	Grade 65-45-12	Grade 80-55-06	Grade 100-70-03	Grade 120-90-02
Tensile strength, min, psi	60 000	65 000	80 000	100 000	120 000
Tensile strength, min, MPa	414	448	552	689	827
Yield strength, min, psi	40 000	45 000	55 000	70 000	90 000
Yield strength, min, MPa	276	310	379	483	621
Elongation in 2 in. or 50 mm, min, %	18	12	6.0	3.0	2.0

TABLE 2 Tensile Requirements for Special Applications

	Grade 60-42-10	Grade 70-50-05	Grade 80-60-03
Tensile strength, min, psi	60 000	70 000	80 000
Tensile strength, min, MPa	415	485	555
Yield strength, min, psi	42 000	50 000	60 000
Yield strength, min, MPa	290	345	415
Elongation in 2 in. or 50 mm, min, %	10	5	3

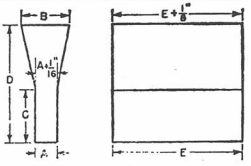


Metric Equivalents

in.	mm	in.	mm
½	12.7	1½	38.1
1	25.4	2½	63.5

NOTE—The length of the keel block shall be 6 in. (152 mm).

FIG. 1 Keel Block for Test Coupons



Dimensions	"Y" Block Size: For Castings of Thickness Less Than ½ in. (13 mm)		For Castings of Thickness ½ in. (13 mm) to 1½ in. (38 mm)		For Castings of Thickness of 1½ in. (38 mm) and Over	
	in.	mm	in.	mm	in.	mm
A	½	13	1	25	3	75
B	1¾	40	2⅛	54	5	125
C	2	50	3	75	4	100
D	4	100	6	150	8	200
E	7 approx	175 approx	7 approx	175 approx	7 approx	175 approx

FIG. 2 Y-Blocks for Test Coupons

6.2 When investment castings are made to this specification, the manufacturer may use test specimens cast to size incorporated in the mold with the castings, or separately cast to size using the same type of mold and the same thermal conditions that are used to produce the castings. These test specimens shall be made to the dimensions shown in Fig. 1 of Specification A 732 or Figs. 5 and 6 of Methods and Definitions A 370.

6.3 The manufacturer may use separately cast test coupons or test specimens cut from castings when castings made to this specification are nodularized or inoculated in the mold. Separately cast test coupons shall have a chemistry that is representative of castings produced from the ladle poured and a cooling rate equivalent to that obtained with the test molds shown in Figs. 1 and 2, Figs. 4-6, or Appendix X2. The size (cooling rate) of the coupon chosen to represent the casting should be decided by the purchaser. If test coupon size is not specified, the manufacturer shall make the choice. When test bars will be cut from castings, test bar location shall be agreed on by the purchaser and manufacturer and indicated on the casting drawing. The manufacturer shall maintain sufficient controls and control documentation to assure the purchaser that properties determined from test coupons or test bars are representative of castings shipped.

6.4 The test coupons shall be poured from the same ladle or heat as the castings they represent.

6.5 Test coupons shall be subjected to the same thermal treatment as the castings they represent.

7. Special Requirements

7.1 When specified in the contract or purchase order, castings shall meet special requirements as to hardness, chemical composition, microstructure, pressure tightness, radiographic soundness, magnetic particle inspection dimensions, and surface finish.

8. Workmanship, Finish, and Appearance

8.1 The castings shall be smooth, free of injurious defects, and shall conform substantially to the dimensions of the drawing or pattern supplied by the purchaser.

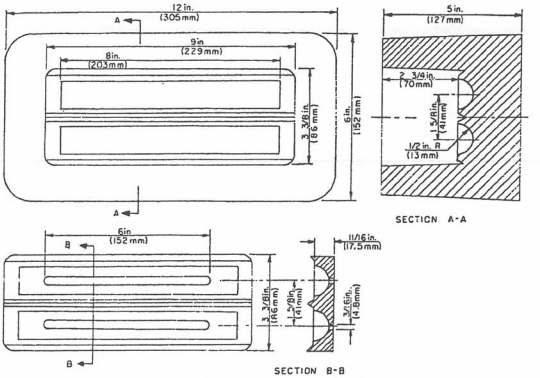


FIG. 3 Mold for Modified Keel Block

8.2 Castings shall not have chilled corners or center chill in areas to be machined.

9. Chemical Requirements

9.1 It is the intent of this specification to subordinate chemical composition to mechanical properties; however, any chemical requirements may be specified by agreement between the manufacturer and the purchaser.

10. Number of Tests and Retests

10.1 The number of representative coupons poured and tested shall be established by the manufacturer, unless otherwise agreed upon with the purchaser.

10.2 In the case of the Y-block, the section shall be cut from the block as shown in Fig. 4. If any tension test specimen shows obvious defects, another may be cut from the same test block or from another test block representing the same metal.

11. Tension Test Specimen

11.1 The standard round tension test specimen with a 2-in. or 50-mm gage length shown in Fig. 5 shall be used, except when the ½-in. (12.7-mm) Y-block coupon is used. In this case, either of the test specimens shown in Fig. 6 shall be satisfactory.

12. Responsibility for Inspection

12.1 Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

13. Identification Marking

13.1 When size permits, each casting shall be identified by the part or pattern number in raised numerals. Location of marking shall be as shown on the applicable drawing.

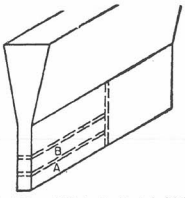
14. Certification

14.1 When agreed upon in writing by the purchaser and the seller, a certification shall be made the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the seller, accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

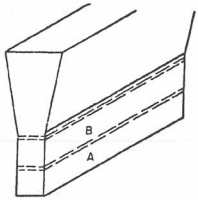
15. Preparation for Delivery

15.1 Unless otherwise specified in the contract or purchase order, cleaning, drying, preservation, and packaging of casting shall be in accordance with manufacturer's commercial practice. Packing and marking shall also be adequate to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

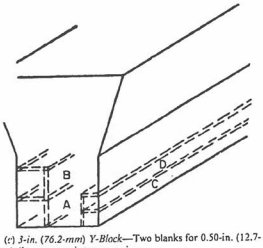
15.2 *Government Procurement*—When specified in the contract or purchase order marking for shipment shall be in accordance with the requirements of MIL-STD-129.



(*a*) *½-in. (12.7-mm) Y-block*—Two blanks for 0.252-in. (6.40-mm) diameter test specimens.

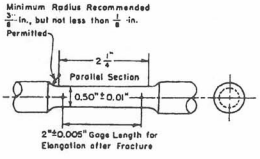


(*b*) *1-in. (25.4-mm) Y-Block*—Two blanks for 0.50-in. (12.7-mm) diameter tension test specimens.



(*c*) *3-in. (76.2-mm) Y-Block*—Two blanks for 0.50-in. (12.7-mm) diameter tension test specimens.

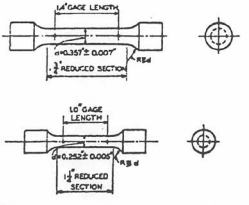
FIG. 4 Sectioning Procedure for Y-Blocks



Metric Equivalents			
in.	mm	in.	mm
0.005	0.13	0.50	12.7
0.10	2.5	2	50.8
⅛	3.2		
⅜	9.5	2¼	57.2

NOTE—The gage length and fillets shall be as shown but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. (0.08 to 0.13 mm) larger in diameter than the center.

FIG. 5 Standard Round Tension Test Specimen with 2-in. or 50-mm Gage Length



Metric Equivalents			
in.	mm	in.	mm
0.005	0.13	1.0	25.4
0.007	0.18	1¼	31.8
0.252	6.40	1.4	35.6
0.357	9.07	1¾	44.4

NOTE—If desired, the length of the reduced section may be increased to accommodate an extensometer.

FIG. 6 Examples of Small-Size Specimens Proportional to Standard ½-in. (12.7-mm) Round Specimen

16. Keywords

16.1 casting; ductile iron; modular iron; spheroidal graphite

APPENDIXES

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of iron castings are influenced by the cooling rate during and after solidification, by chemical composition, by heat treatment, by the design and nature of the mold, by the location and effectiveness of gates and risers, and by certain other factors.

X1.2 The cooling rate in the mold and, therefore, the properties developed in any particular section are influenced by the presence of cores, chills and chaplets, changes in section thickness, and the existence of bosses, projections, and intersections, such as junctions of ribs and bosses. Because of the interactions of these factors, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be more closely ascertained by appropriate experimentation.

X1.3 When reliable information is unavailable on the relationship between properties in a casting and those in a separately cast test specimen, and where experimentation would be unfeasible, the size of the test casting should be so selected as to approximate the cooling rate of the main or controlling section of the casting.

X2. Y-BLOCK SELECTION

X2.1 As a general guide for selection of the proper Y-block, the tabulation in Table X2.1, based on cooling rates, shows, for various test coupons, the equivalent geometric shapes with various dimensions.

TABLE X2.1 Equivalent Geometric Shapes Corresponding to Y-Blocks

Y-Block Size, in. (mm)	Infinite Plate Thickness, in. (mm)	Round Diameter, in. (mm)	Cube Edge, in. (mm)
½ (12.7)	0.5 (12.7)	1.2 (30.5)	1.75 (44.4)
1 (25.4)	0.9 (22.9)	1.75 (44.4)	2.75 (69.8)
3 (76.2)	1.6 (40.6)	3.1 (78.7)	4.8 (121.9)

Designation: A 834 – 95

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428

Standard Specification for Common Requirements for Iron Castings for General Industrial Use[1]

This standard is issued under the fixed designation A 834; 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 a group of requirements that are mandatory requirements when used in conjunction with the following iron casting specifications issued by ASTM:

ASTM Specification[2]
A47
A48
A197
A220
A278
A319
A395
A436
A439
A 518
A 532
A536
A571
A 823
A 842
A 874
A 897

1.2 This specification also covers a group of supplementary requirements which may be applied to the above specifications as indicated herein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 The requirements of the individual material specification, and this general specification shall prevail in the sequence named.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 47 Specification for Ferritic Malleable Iron Castings[2]
A 48 Specification for Gray Iron Castings[2]
A 197 Specification for Cupola Malleable Iron[2]
A 220 Specification for Pearlitic Malleable Iron[2]
A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings[2]
A 278 Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F[2]
A 319 Specification for Gray Iron Castings for Elevated Temperatures for Non-Pressure Containing Parts[2]
A 395 Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures[2]
A 436 Specification for Austenitic Gray Iron Castings[2]
A 439 Specification for Austenitic Ductile Iron Castings[2]
A 518 Specification for Corrosion-Resistant High-Silicon Iron Castings[2]
A 532 Specification for Abrasion-Resistant Cast Irons[2]
A 536 Specification for Ductile Iron Castings[2]
A 571 Specification for Austenitic Ductile Iron Castings for Pressure-Containing Parts Suitable for Low-Temperature Service[2]
A 644 Terminology Relating to Iron Castings[2]
A 802/A802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination[2]
A 823 Specification for Statically Cast Permanent Mold Gray Iron Castings[2]
A 842 Specification for Campacted Graphite Iron Castings[2]
A 874 Specification for Ferritic Ductile Iron Castings for Low-Temperature Service[2]
A 897 Specification for Austempered Ductile Iron Castings[2]
A 919 Terminology Relating to Heat Treatment of Metals[2]
E 8 Test Methods for Tension Testing of Metallic Materials[3]
E 10 Test Method for Brinell Hardness of Metallic Materials[3]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]
E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[5]
E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[5]
E 94 Guide for Radiographic Testing[6]
E 165 Test Method for Liquid Penetrant Examination[6]
E 351 Test Methods for Chemical Analysis of Cast Iron—All Types[5]
E 689 Reference Radiographs for Ductile Iron Castings[6]
E 709 Guide for Magnetic Particle Examination[6]

[1] This specification is under the jurisdiction of ASTM Committee A-4 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray Iron Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

[6] *Annual Book of ASTM Standards*, Vol 03.03.

E 802 Reference Radiographs for Gray Iron Castings Up to 4½ in. (114 mm) in Thickness[6]

2.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[7]

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[7]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions for many terms common to iron castings and their heat treatment are found in Terminology A 919 and Terminology A 644. A classification of graphite structure is found in Test Method A 247.

4. Ordering Information

4.1 The purchase order for castings ordered under this specification shall stipulate the applicable material specification(s), grade of iron, and any options or additions to the basic requirements, including the supplementary requirements included in this specification.

5. Tensile Requirements

5.1 The individual product specifications vary as to whether tension tests are required. For this reason, and to determine specific test requirements, the individual product specification shall be reviewed. When required, tension tests shall be determined in accordance with Test Methods E 8.

6. Chemical Requirements

6.1 The individual product specifications vary as to whether chemical analysis is required. To determine specific requirements, the individual product specification should be reviewed.

6.2 Sampling shall be conducted in accordance with Test Method E 59. Spectrographic or other methods such as those in Test Methods E 30 and E 351 may be used for chemical analysis. In the event of a dispute regarding chemical composition, Test Methods E 351 and E 30 shall be used for referee purposes.

6.3 The chemical analysis for total carbon shall be made on chilled pencil-type specimens or from thin wafers approximately 1/32 in. (0.8 mm) thick cut from test coupons. Drillings are not reliable because of a probable loss of graphite.

6.4 Chemical analysis results shall be rounded, in accordance with Practice E 29, to the nearest unit in the last right-hand place of values in the table of chemical requirements.

6.5 A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis shall be taken no closer than ¼ in. to a cast surface, and shall follow the practice in 5.3, except where the size or shape of the casting does not permit such sampling. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved.

7. Workmanship, Finish, and Appearance

7.1 All castings shall be made in a workman-like manner and shall conform to the dimensions on drawings furnished by the purchaser before manufacture is started. If the pattern is supplied by the purchaser, the dimensions of the casting shall be as predicted by the pattern.

8. Sampling

8.1 A lot shall consist of one of the following:

8.1.1 All the metal from a single heating in a batch–type melting furnace.

8.1.2 All the metal poured from two or more batch–type melting furnaces into a single ladle or a single casting.

8.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry, or 4 h, whichever is the shorter period.

8.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

9. Inspection

9.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable sources whose services have been contracted for by the manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer and shall be available for review by the purchaser.

9.2 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations.

9.3 When agreed upon between manufacturer and purchaser, test specimens or unbroken test bars from the same lot shall be saved for a period of 3 months after date of the test report.

9.4 When unbroken test bars are reprocessed with castings for rehearing, test specimens from these bars shall be saved, as described in 9.3.

9.5 The purchaser reserves the right to perform any inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to the prescribed requirements.

10. Repair

10.1 Any repair shall be made in accordance with the requirements of the individual specification using procedures qualified by the manufacturer for the type of repair involved.

11. Rejection and Rehearing

11.1 Castings which fail to conform to the requirements specified when inspected or tested by the purchaser or his agent may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the test results, the manufacturer or supplier may make claim for a rehearing.

12. Packaging and Package Marking

12.1 Unless otherwise specified in the contract or purchase

[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

order, cleaning, preservation, and packaging of castings shall be in accordance with the manufacturer's commercial practice. Packing and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

12.2 *Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military activities.

13. Quality Assurance

13.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

13.2 When additional inspection is desired, Supplementary Requirements S1, S2, or S3 may be specified.

14. Keywords

14.1 chemical composition; common requirements; general industry; inspection; iron castings; ordering information; packaging; quality assurance; repair; sampling; tensile requirements; terminology; workmanship

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Magnetic Particle Examination

S1.1 Castings shall be examined for surface discontinuities by magnetic particle examination. The examination shall be in accordance with Practice E 709. The extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S2. Radiographic Examination

S2.1 Castings shall be examined for internal defects by means of X-rays or gamma rays. The procedure shall be in accordance with Guide E 94, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 689 and E 802. The extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Practice E 165. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S4. Certification

S4.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification, including the year date, and was found to meet the requirements. Additionally, the certification shall include for each lot the results of all tests required by the material specification and any supplementary or additional requirements imposed by the purchase order.

S4.2 A signature is not required on the certification or test report. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

S4.3 The test report shall be furnished within 5 working days of shipment of the castings.

S5. Prior Approval of Major Repairs

S5.1 Major repairs as defined and agreed upon between the manufacturer and purchaser shall be subject to the prior approval of the purchaser.

S6. Marking

S6.1 The manufacturer's name or identification mark and the part identification number shall be cast or stamped on all castings. When further specified, lot numbers shall be marked on individual castings.

S6.2 When the castings are of such size that individual marking is impracticable, they shall be grouped by part identification or lot number and placed in a container. The container shall be marked with the required identification.

S7. Hardness Test

S7.1 Hardness measurements at specified locations on the castings shall be made in accordance with Test Method E 10 and reported.

Designation: A 802/A 802M – 95 (Reapproved 2001)

An American National Standard

Standard Practice for Steel Castings, Surface Acceptance Standards, Visual Examination[1]

This standard is issued under the fixed designation A 802/A 802M; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice covers the acceptance criteria for the surface inspection of steel castings by visual examination. Four levels of acceptance standards are provided.

1.2 Acceptance levels utilize Steel Castings Research and Trade Association (SCRATA)[2] graded reference comparators for the visual determination of surface texture, surface roughness, and surface discontinuities described as follows:

Acceptance levels

A—Surface Texture
B—Nonmetallic Inclusions
C—Gas Porosity
D—Solidification Discontinuities
E—Sand Expansion Discontinuities
F—Metal Inserts
G—Thermally Cut Surfaces
H—Mechanically Prepared Surfaces
J—Welded Surfaces

1.3 Descriptions of terms related to casting discontinuities are in Section 2.

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

2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *expansion discontinuities:*

2.1.1.1 *veins, n*—raised, narrow, linear ridges that form upon cracking of the sand mold or core due to expansion of sand and the resulting mold or core stresses during filling of the mold with liquid steel.

2.1.1.2 *rat tails, n*—long, narrow, linear depressions or small steps occurring on a casting surface. Rat tails form as a result of sand expansion and minor buckling of the mold surface during filling of the mold with liquid metal.

2.1.1.3 *scab, n*—a raised, rough area on a casting that usually consists of a crust of metal covering a layer of sand. Sometimes, a scab consists of a raised, rough area of essentially solid metal on the surface of a casting.

2.1.2 *external chills:*

2.1.2.1 *external chills, n*—usually metal blocks, or graphite and carbon blocks, that are incorporated into the mold to locally increase the rate of heat removal during solidification. Brackets have the same purpose but represent an integral part of the casting. Brackets are produced by providing suitable cavities in the mold or core. External chills may produce flat spots and edges (raised areas or depressions) on the casting surface. Brackets merely change the casting appearance due to their presence. Brackets may be removed or allowed to remain on the casting.

2.1.2.2 *parting line and core print fins, n*—thin projections of excess metal at the parting plane between mold halves or core and mold. Causes are improper closing of the mold, insufficient weighting or clamping of the mold for pouring, or uneven pattern surfaces at the matching locations. Core print fins are usually caused by improper dimensions of core prints of the pattern or core box, by rough placement of cores in a soft mold, or by inadequately secured cores.

2.1.3 *fusion discontinuities:*

2.1.3.1 *wrinkles, n*—elongated, smooth depressions of the casting surface, frequently appearing in closely spaced groups. Wrinkles result from irregularities of the liquid metal flow in the mold cavity, frequently associated with low temperature, and are distinguished from the more severe phenomenon of laps, folds, or cold shuts where the casting surface is actually folded over.

2.1.3.2 *laps, folds, and cold shuts, n*—interchangeable terms to describe the appearance of the casting surface that is actually folded over. They develop due to low temperature, unfavorable flow conditions caused by oxide films, or combinations thereof.

2.1.3.3 *misrun, n*—an incompletely formed casting, due to only partial filling of the mold cavity when the liquid metal solidifies prematurely. The resulting casting appearance is characterized by rounded edges, for a mild degree of misrun. Irregular, malformed edges of more severe misruns, and not fully formed castings, are characteristic. Frequently, misruns

[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloysand is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Sept. 10, 1995. Published November 1995. Originally published as A 802 – 82. Last previous edition A 802/A 802M – 89.

[2] Available from Steel Founders Society of America, 455 State St., Des Plaines, IL 60016.

are associated with such discontinuities as wrinkles or laps and folds, or both.

2.1.4 *gas porosity, n*—a concave discontinuity in castings due to the evolution of gas, either from the solidifying metal or the surrounding mold.

2.1.5 *inserts:*

2.1.5.1 *chaplets, n*—metallic (steel) devices used to maintain the spacing between the core and the mold. Low liquid metal temperature and unfavorable flow conditions in the mold may produce insufficient fusion and cause irregular contact areas on the casting surface.

2.1.5.2 *internal chills, n*—metallic (steel) devices used to locally increase the rate of heat removal during solidification. Incomplete fusion due to low liquid steel temperatures and prevailing flow conditions may produce irregularities of the surface similar to those that may be associated with chaplets.

2.1.6 *linear discontinuities, n*—elongated discontinuities are considered linear if their length equals or exceeds three times the width.

2.1.6.1 *cracks, n—cold and hot*, less jagged, sometimes straight ruptures that occur after solidification of the casting, due to excessive strain. Sometimes cracks are referred to as cold, hot, or heat treat-cracks to indicate the condition of the castings, or the operation during which the cracks occur.

2.1.6.2 *hot tears, n*—jagged ruptures in castings that occur during the final stages of solidification, while there is still some liquid in the interdendritic spaces, or shortly after solidification is complete.

2.1.7 *metal removal marks, n*—flame cutting and air carbon-arc cutting produce parallel grooves in the cut-off area. Finer marks are produced with the abrasive cut-off wheel and grinding.

2.1.8 *nonmetallic inclusions, n*—casting surface inclusions such as ceroxides, slag, and sand are partially or completely removed during the cleaning process of pressure blasting. Surface discontinuities left by these inclusions are referred to by the inclusion type that caused their formation:

2.1.8.1 Ceroxides cause depressions on the surface of the casting by displacement of molten metal. Ceroxides consist of a mixture of low-melting oxides and partially fused sand. The crater-like appearance of the casting surface depression is typical.

2.1.8.2 Depressions on the casting surface caused by slag are similar to those caused by ceroxides. They differ by a more rounded appearance of the depression and do not exhibit the crater-like appearance of ceroxides.

2.1.8.3 Depressions caused by sand are similar to those of ceroxides and slag. Their appearance may, at times, more closely reflect the granular nature of the sand.

2.1.9 *shrinkage under risers and gates, and revealed by machining, n*—a shrinkage void is a discontinuity in castings due to the lack of available liquid feed metal during solidification contraction. Riser removal and machining may reveal shrinkage that extends from the interior of the casting to the near surface area.

2.1.10 *surface texture, n*—cast surfaces have a multi-directional lay, without the uniform sequence of ridges and valleys of machined surfaces.

2.1.11 *welding:*

2.1.11.1 *weld undercuts, n*—narrow elongated depressions that border the weld contour and result from improper welding conditions or inadequate control of welding operations.

2.1.11.2 *weld spatter, n*—weld metal droplets that solidified against and adhere to the component being welded.

3. Ordering Information

3.1 The inquiry and order should specify the following information:

3.1.1 *Acceptance Level*—More than one acceptance level may be specified for different surfaces of the same casting (see Section 4),

3.1.2 If any types of discontinuities are unacceptable,

3.1.3 Extent of casting surfaces to be examined, and

3.1.4 Number of castings to be examined.

4. Acceptance Standards

4.1 Levels of acceptance for visual inspection are listed in Table 1.

4.2 Surface discontinuities not covered in Practice A 802/A 802M shall be a matter of agreement between the purchaser and the manufacturer.

5. Keywords

5.1 steel castings; surface acceptance standards; visual

TABLE 1 Visual Inspection Acceptance Criteria

Surface Feature	Level I	Level II	Level III	Level IV
Surface texture	A1	A2	A3	A4
Nonmetallic inclusions	B1	B2	B4	B5
Gas porosity	C2	C1	C3	C4
Fusion discontinuities	...[A]	D1	D2	D5
Expansion discontinuities	...[A]	...[A]	E3	E5
Inserts	...[A]	...[A]	F1	F3
Metal removal marks:				
Thermal	G1	G2	G3	G5
Mechanical	H1	H3	H4	H5
Welds	J1	J2	J3	J5

[A] No reference comparator plate is available for this surface feature and level.

Designation: E 689 – 95 (Reapproved 1999)

An American National Standard

Standard Reference Radiographs for Ductile Iron Castings[1]

This standard is issued under the fixed designation E 689; 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 These reference radiographs extend the application of reference radiographs for steel castings to ductile iron castings.

1.2 In some instances, reference radiographs for steel castings may not be entirely applicable to ductile cast iron material dependent upon design or other usage criteria. Refer to 4.1 for guidance.

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

2. Referenced Documents

2.1 *ASTM Standards:*

E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (51 to 114-mm)) Steel Castings[2]

E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings[2]

E 446 Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness[2]

E 1316 Terminology for Nondestructive Examinations[2]

3. Terminology

3.1 Definitions of terms used in these reference radiographs may be found in Terminology E 1316, Section D.

4. Significance and Use

4.1 These reference radiographs invoke Reference Radiographs E 446, E 186, and E 280 for establishing categories and severity levels of internal discontinuities common to ductile iron castings subject to mutual agreement between purchaser and supplier in contractual specifications. The casting process has shown radiographic similarities between internal discontinuities for ductile cast iron and cast steel to the extent that the reference radiographs for steel castings are applicable. The exact application and usage of the above categories and severity levels must, however, give consideration to the differences in material properties between cast steel and ductile cast iron end usage applications.

4.2 Production radiographs are to be compared with the applicable set of reference radiographs for classification on the basis of section thickness, radiation energy level and type, and category and severity level of discontinuity specified.

4.3 The standard reference radiographs are published in three nominal section thickness ranges in separate documents as follows:

4.3.1 Castings up to 2 in. (51 mm): Reference Radiographs E 446.

4.3.2 Heavy-walled castings 2 to 4½ in. (51 to 114 mm): Reference Radiographs E 186.

4.3.3 Heavy-walled castings 4½ to 12 in. (114 to 305 mm): Reference Radiographs E 280.

5. Determination of Radiographic Classification

5.1 For purposes of evaluation of castings, a determination must be made of the radiographic classification to be assigned to individual castings or specific areas of castings. The determination of the applicable radiographic-severity classification shall be based on an evaluation of the casting applications, design, and service requirements. In these evaluations, consideration shall be given to such factors as pressure, temperature, section thickness, applicable design safety factor, vibration, shock, resistance to corrosion, involvement of penetrating radiations or radiation products, and involvement of dangerous gases or liquids.

6. Classification Specifications

6.1 The applicable radiographic severity level should be designated for each discontinuity type by the contracting agency in formal specifications or drawings and in the specific contract or order. For castings, the level should be independently specified for each discontinuity type, since they have been shown to affect strength properties differently. For example, in the same casting Severity Level 2 might be specified for shrinkage Type 3 and Severity Level 4 for gas porosity Type 1. The specifications, drawings, contract, or order should also designate the sampling plan for the castings to be radiographed and the extent and quality level of the radiographic coverage.

7. Procedure for Evaluation

7.1 Compare radiographs of the casting submitted for evaluation with the reference radiographs applicable to the section

[1] These reference radiographs are under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.02 on Reference Radiological Images.

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[2] *Annual Book of ASTM Standards*, Vol 03.03.

thickness and the source used.

7.2 When a particular class or severity is called for and the radiograph being evaluated is equal to or better than the reference, indicate the casting as radiographically acceptable. If the radiograph shows a discontinuity of greater severity than the reference radiograph, the casting shall be rejected.

7.3 When two or more types of discontinuities are present in the same radiograph, the predominating ones, if unacceptable, shall govern without regard to the other types of discontinuities.

7.4 When two or more categories of discontinuity are present to an extent equal to the maximum permissible level, as shown in the pertinent standards for each category, then that part of the casting shall be judged unacceptable until satisfactorily repaired.

7.5 In general, there is no limit with regard to the extent of acceptable discontinuities in a casting, provided that no area throughout the casting contains discontinuities that exceed those indicated on the minimum acceptable area of applicable reference radiographs.

7.6 Where the reference image consists of a collection of discontinuities, as in the case of porosity, for example, acceptability may be based on the aggregate size of the discontinuities present on both the reference radiograph and the object radiograph, the maximum defect size present, the spacing between discontinuities, or a combination of these or other criteria. These criteria must be determined based upon the particular application or part under consideration and must be specified by agreement between the purchaser and supplier.

8. Keywords

8.1 casting; discontinuity; radiograph; radiographic severity level; reference radiograph

Designation: E 802 – 95 (Reapproved 1999)

An American National Standard

Standard Reference Radiographs for Gray Iron Castings Up to 4½ in. (114 mm) in Thickness[1]

This standard is issued under the fixed designation E 802; 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 These reference radiographs for gray iron castings consist of one set of illustrations of centerline shrinkage with severity levels 1 to 5 using three radiation source types as follows:

1.1.1 *Volume I: Medium Voltage (nominal 250 kVp) X-Ray Reference Radiographs*——Set of 5 severity levels in a 15 by 17 in. folder.

1.1.2 *Volume II: Iridium-192 Reference Radiographs*—Set of 5 severity levels in a 15 by 17 in. folder.

1.1.3 *Volume III: Cobalt-60 Reference Radiographs*—Set of 5 severity levels in a 15 by 17 in. folder.

1.2 The values stated in inch-pound units are to be regarded as the standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*

E 94 Guide for Radiographic Testing[2]

E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (51 to 114-mm)) Steel Castings[2]

E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness[2]

E 1316 Terminology for Nondestructive Examinations[2]

2.2 ASTM Adjuncts:[3]

Reference Radiographs for Gray Iron Castings Up to 4½ in. (114 mm) in Thickness:

Volume I, Medium Voltage (Nominal 250 kVp) X Rays[4]

Volume II, Iridium-192[5]

Volume III, Cobalt-60[6]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this document, see Terminology E 1316, Section D.

4. Significance and Use

4.1 These reference radiographs, along with the referenced applicable steel casting standards (Reference Radiographs E 186 and E 446), are supplied as a means of establishing categories and severity levels of common internal discontinuity types in gray iron castings subjected to radiographic examination. They may be used in accordance with contractual specifications as agreed upon between purchaser and supplier.

4.2 The use of this standard is not intended to be restricted to the specific energy level or to the absolute thickness limits that are contained in this standard title. The title is intended to be descriptive and not restrictive. This document may be used, where there is no other applicable document, for other energy levels or thicknesses, or both, for which it is found to be applicable and for which agreement has been reached between purchaser and supplier.

5. Method of Preparation

5.1 The original radiographs used to prepare the accompanying reference radiographs were produced on high contrast, fine-grain film by the respective use of radiation energies stated in 1.1.1-1.1.3. The radiographs were made with a penetrameter sensitivity as determined by ASTM penetrameters (see Guide E 94) of 2-2T. The reproductions have been prepared to an H&D density from 2.00 to 2.25 and they have retained substantially the contrast of the original radiographs.

5.2 *Film Deterioration*—Radiographic films are subject to wear and tear from handling and use. The extent to which the image deteriorates over time is a function of storage conditions, care in handling and amount of use. Reference radiograph films are no exception and may exhibit a loss in image quality over time. The radiographs should therefore be periodically examined for signs of wear and tear, including scratches, abrasions, stains, and so forth. Any reference radiographs which show signs of excessive wear and tear which could influence the interpretation and use of the radiographs should be replaced.

6. Determination of Radiographic Classification

6.1 For purposes of evaluation of castings, a determination

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[1] These reference radiographs are under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and are the direct responsibility of Subcommittee E07.02 on Reference Radiographs.

Current edition approved Dec. 10, 1995. Published February 1996. Originally published as E 802 – 82. Last previous edition E 802 – 91.

[2] *Annual Book of ASTM Standards*, Vol 03.03.

[3] Available from ASTM Headquarters.

[4] Order PCN 17-508021-22.

[5] Order PCN 17-508022-22.

[6] Order PCN 17-508023-22.

must be made of the radiographic classification to be assigned to individual castings or specific areas of castings. The determination of the applicable radiographic-severity classification shall be based on an evaluation of the casting applications, design, and service requirements. In these evaluations, considerations shall be given to such factors as pressure, temperature, section thickness, applicable design safety factor, vibration, shock, resistance to corrosion, involvement of penetrating radiations or radiation products, and involvement of dangerous gases or liquids.

NOTE 1—The radiographic definition of the defects illustrated will vary according to the energy levels of the sources employed in the radiography.

7. Classification Specifications

7.1 The applicable radiographic severity level should be designated for each discontinuity type by the contracting agency in formal specifications or drawings and in the specific contract or order. For castings, the level should be independently specified for each discontinuity type, since they have been shown to affect strength properties differently. For example, in the same casting severity level 2 might be specified for shrinkage Type 3 and severity level 4 for gas porosity Type 1. The specifications, drawings, contract, or order should also designate the sampling plan for the castings to be radiographed and the extent and quality level of the radiographic coverage.

8. Procedure for Evaluation

8.1 Compare radiographs of the casting submitted for evaluation with the reference radiographs applicable to the section thickness and the source used.

8.2 When a particular class or severity is called for and the radiograph being evaluated is equal to or better than the reference, indicate the casting as radiographically acceptable. If the radiograph shows a discontinuity of greater severity than the reference radiograph, the casting shall be rejected.

8.3 When two or more types of discontinuities are present in the same radiograph, the predominating ones, if unacceptable, shall govern without regard to the other types of discontinuities.

8.4 When two or more categories of discontinuities are present to an extent equal to the maximum permissible level, as shown in the pertinent standards for each category, then that part of the casting shall be judged unacceptable until satisfactorily repaired, if permissible.

8.5 In general, there is no limit with regard to the extent of acceptable discontinuities in a casting, provided that no 5 by 7-in. (127 by 178-mm) area throughout the casting contains discontinuities that exceed those indicated on the minimum acceptable reference radiographs.

8.6 Where the reference image consists of a collection of discontinuities, as in the case of porosity, for example, acceptability may be based on the aggregate size of the discontinuities present on both the reference radiograph and the object radiograph, the maximum defect size present, the spacing between discontinuities, or a combination of these or other criteria. These criteria must be determined based upon the particular application or part under consideration and must be specified by agreement between the purchaser and supplier.

9. Keywords

9.1 castings; discontinuities; gamma ray; gray iron; reference radiographs; X-ray

Designation: E 1030 – 95

An American National Standard

Standard Test Method for Radiographic Examination of Metallic Castings[1]

This standard is issued under the fixed designation E 1030; 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 test method[2] provides a uniform procedure for radiographic examination of metallic castings using radiographic film as the recording medium.

1.2 Due to the many complex geometries and part configurations inherent with cast products, it is necessary to recognize potential limitations associated with obtaining complete radiographic coverage on castings. Radiography of areas where geometry or part configuration does not allow achievement of complete coverage with practical radiographic methods shall be subject to mutual agreements between purchaser and supplier. The use of alternative nondestructive methods for areas that are not conducive to practical radiography shall also be specifically agreed upon between purchaser and supplier.

1.3 The radiographic method is highly sensitive to volumetric discontinuities that displace a detectable volume of cast material. Discontinuities that do not displace an appreciable volume of material, however, such as cracks or other planar-type indications, may not be detected with radiography unless the radiation beam is coincidentally aligned with the planar orientation of the discontinuity. In view of this limitation, it may be considered appropriate to use the radiographic method in conjunction with additional nondestructive methods that maintain reliable detection capabilities for these types of discontinuities. The use of additional methods shall be specifically agreed upon between the purchaser and supplier.

1.4 The values stated in inch-pound units are to be regarded as standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*

E 94 Guide for Radiographic Testing[3]

E 142 Method for Controlling Quality of Radiographic Testing[3]

E 155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings[3]

E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (51 to 114-mm)) Steel Castings[3]

E 192 Reference Radiographs of Investment Steel Castings for Aerospace Applications[3]

E 272 Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Alloy Castings[3]

E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings[3]

E 310 Reference Radiographs for Tin Bronze Castings[3]

E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness[3]

E 505 Reference Radiographs for Inspection of Aluminum and Magnesium Die Castings[3]

E 543 Practice for Evaluating Agencies that Perform Nondestructive Testing[3]

E 689 Reference Radiographs for Ductile Iron Castings[3]

E 746 Test Method for Determining Relative Image Quality Response of Industrial Radiographic Film[3]

E 747 Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology[3]

E 802 Reference Radiographs for Gray Iron Castings Up to 4½ in. (114 mm) in Thickness[3]

E 999 Guide for Controlling the Quality of Industrial Radiographic Film Processing[3]

E 1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology[3]

E 1254 Guide for Storage of Radiographs and Unexposed Industrial Radiographic Film[3]

E 1316 Terminology for Nondestructive Examinations[3]

2.2 *ASNT/ANSI Standards:*

Recommended Practice No. SNT-TC-1A "Personnel Qualification and Certification in Nondestructive Testing"[4]

[1] This test method is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on Radiology (X and Gamma) Method.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Test Method SE-1030 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 03.03

[4] Available from the American Society for Nondestructive Testing, (ASNT), 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228.

CP-189 Qualification and Certification of Nondestructive Testing Personnel[4]

2.3 *Military Standard:*

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification[5]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, see Terminology E 1316.

4. Significance and Use

4.1 The requirements expressed in this test method are intended to control the quality of the radiographic images, to produce satisfactory and consistent results, and are not intended for controlling the acceptability or quality of materials or products.

5. Basis of Application

5.1 The following items shall be agreed upon by the purchaser and supplier:

5.1.1 *Nondestructive Testing Agency Evaluation*—If specified in the contractual agreement, nondestructive testing (NDT) agencies shall be qualified and evaluated in accordance with Practice E 543. The applicable version of Practice E 543 shall be specified in the contractual agreement.

5.1.2 *Personnel Qualification*—NDT personnel shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, MIL-STD-410 or a similar document. The practice or standard used and its applicable revision shall be specified in the contractual agreement between the using parties.

5.1.3 *Requirements*—General requirements (see 8.1, 8.2, 8.5, and 8.7.4) shall be specified.

5.1.4 Procedure Requirements (see 9.1, 9.1.1, 9.3, and 9.7.7) shall be specified.

5.1.5 *Records*—Record retention (see 12.1) shall be specified.

6. Apparatus

6.1 *Radiation Sources*:

6.1.1 *X Radiation Sources*—Selection of appropriate X-ray voltage and current levels is dependent upon variables regarding the specimen being examined (material type and thickness) and economically permissible exposure time. The suitability of these X-ray parameters shall be demonstrated by attainment of required penetrameter (IQI) sensitivity and compliance with all other requirements stipulated herein. Guide E 94 contains provisions concerning exposure calculations and charts for the use of X-ray sources.

6.1.2 *Gamma Radiation Sources*—Isotope sources, when used, shall be capable of demonstrating the required radiographic sensitivity.

6.2 *Film Holders and Cassettes*—Film holders and cassettes shall be light-tight and shall be handled properly to reduce the likelihood that they may be damaged. They may be flexible vinyl, plastic, or any durable material; or, they may be made from metallic materials. In the event that light leaks into the film holder and produces images on the film extending into the area of interest, the film shall be rejected. If the film holder exhibits light leaks, it shall be repaired before reuse or discarded. Film holders and cassettes should be routinely examined to minimize the likelihood of light leaks.

6.3 *Intensifying Screens*:

6.3.1 *Lead-Foil Screens*:

6.3.1.1 Intensifying screens of the lead-foil type are generally used for all production radiography. Lead-foil screens shall be of the same approximate area dimensions as the film being used and they shall be in direct contact with the film during exposure.

6.3.1.2 For X-ray voltages between 200 kV and 1 MeV, front and rear screen thicknesses shall be a minimum of 0.005 in. (0.127 mm) thick. Below 200 kV, front screen thicknesses up to 0.005 in. and rear screen thicknesses of at least 0.005 in. should be used if they improve radiographic quality. For isotope and high-voltage X-radiography (greater than 1 MeV) increased thicknesses may be appropriate for improvements in radiographic quality and should be used accordingly. Intermediate screens (between multiloaded film) may be used if desired.

6.3.1.3 Sheet lead, with or without backing, used for screens should be visually examined for dust, dirt, oxidation, cracking or creasing, foreign material or other condition that could render undesirable nonrelevant images on the film.

6.3.2 *Fluorescent or Fluorometallic Screens*:

6.3.2.1 Fluorescent or fluorometallic screen may be used. However, they must be capable of demonstrating the required penetrameter (IQI) sensitivity.

6.3.2.2 *Screen Care*—All screens should be handled carefully to avoid dents, scratches, grease, or dirt on active surfaces. Screens that render false indications on radiographs shall be discarded or reworked to eliminate the artifact.

6.4 *Filters*—Filters shall be used whenever the contrast reductions caused by low-energy scattered radiation or the extent of undercut and edge burn-off occurring on production radiographs is of significant magnitude so as to cause failure to meet the quality level or radiographic coverage requirements stipulated by the job order or contract (see Guide E 94).

6.5 *Masking*—Masking material may be used, as necessary, to help reduce image degradation due to undercutting (see Guide E 94).

6.6 *Penetrameters (IQI)*—Unless otherwise specified by the applicable job order or contract, only those penetrameters that comply with the design and identification requirements specified in Practice E 747 or Practice E 1025 shall be used.

6.7 *Shims and Separate Blocks*—Shims or separate blocks made of the same or radiographically similar materials (as defined in Method E 142) may be used to facilitate penetrameter positioning. There is no restriction on shim or separate block thickness provided the penetrameter and area-of-interest density tolerance requirements of 9.7.6.2 are met.

6.8 *Radiographic Location and Identification Markers*—Lead numbers and letters are used to designate the part number

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

and location number. The size and thickness of the markers shall depend on the ability of the radiographic technique to image the markers on the radiograph. As a general rule, markers 1/16 in. (1.58 mm) thick will suffice for most low energy (less than 1 MeV) X-ray and Iridium-192 radiography; for higher energy radiography it may be necessary to use markers that are 1/8 in. (3.17 mm) or more thick.

6.9 *Radiographic Density Measurement Apparatus*—Either a transmission densitometer or a step-wedge comparison film shall be used for judging film density requirements. Step wedge comparison films or densitometer calibration, or both, shall be verified by comparison with a calibrated step-wedge film traceable to the National Institute of Standards and Technology.

7. Reagents and Materials

7.1 *Films*—Definite rules on selection of films cannot be given since choice depends on such factors as the required radiographic quality level and the maximum economically permissible exposure time. In any case, the films selected must be capable of demonstrating the required penetrameter (IQI) sensitivity.

NOTE 1—Test Method E 746 provides a method for determining the relative image quality response of industrial radiographic film and may be used as the basis for film selection.

8. Requirements

8.1 *Procedure Requirement*—Unless otherwise specified by the applicable job order or contract, radiographic examination shall be performed in accordance with a written procedure. Specific requirements regarding the preparation and approval of written procedures shall be dictated by a purchaser and supplier agreement. The procedure details should include at least those items stipulated in Appendix X1. In addition, a radiographic standard shooting sketch (RSS), Fig. X1.1, shall be prepared similar to that shown in Appendix X1 and shall be available for review during interpretation of the film.

8.2 *Radiographic Coverage*—Unless otherwise specified by a purchaser and supplier agreement, the extent of radiographic coverage shall be the maximum practical volume of the casting. Areas that require radiography shall be designated as illustrated in Figs. X1.2 and X1.3 of Appendix X1. When the shape or configuration of the casting is such that radiography is impractical, these areas shall be so designated on drawings or sketches that accompany the radiographs. Examples of casting geometries and configurations that may be considered impractical to radiograph are illustrated in Appendix X2.

8.3 *Radiographic Film Quality*—All radiographs shall be free of mechanical, chemical, handling-related, or other blemishes which could mask or be confused with the image of any discontinuity in the area of interest on the radiograph. If any doubt exists as to the true nature of an indication exhibited by the film, the radiograph shall be retaken or rejected.

8.4 *Radiographic Quality Level*—The applicable job order or contract shall dictate the requirements for radiographic quality level. (See Practice E 1025 or Practice E 747 for guidance in selection of quality level.)

8.5 *Acceptance Level*—Radiographic acceptance levels and associated severity levels shall be stipulated by the applicable contract, job order, drawing, or other purchaser and supplier agreement.

8.6 *Radiographic Density Limitations*—Radiographic density in the area of interest shall be within 1.5 to 4.0 for either single or superimposed viewing.

8.7 *Film Handling*:

8.7.1 *Darkroom Facilities*—Darkroom facilities should be kept clean and as dust-free as practical. Safelights should be those recommended by film manufacturers for the radiographic materials used and should be positioned in accordance with the manufacturer's recommendations. All darkroom equipment and materials should be capable of producing radiographs that are suitable for interpretation.

8.7.2 *Film Processing*—Radiographic film processing shall be controlled in accordance with Guide E 999.

8.7.3 *Film Viewing Facilities*—Viewing facilities shall provide subdued background lighting of an intensity that will not cause troublesome reflections, shadows, or glare on the radiograph. The viewing light shall be of sufficient intensity to review densities up to 4.0 and be appropriately controlled so that the optimum intensity for single or superimposed viewing of radiographs may be selected.

8.7.4 *Storage of Radiographs*—When storage is required by the applicable job order or contract, the radiographs should be stored in an area with sufficient environmental control to preclude image deterioration or other damage. The radiograph storage duration and location after casting delivery shall be as agreed upon between purchaser and supplier. (See Guide E 1254 for storage information.)

9. Procedure

9.1 *Time of Examination*—Unless otherwise specified by the applicable job order or contract, radiography may be performed prior to heat treatment and in the as-cast, rough-machined, or finished-machined condition.

9.1.1 *Penetrameter (IQI) Selection*—Unless otherwise specified in the applicable job order or contract, penetrameter (IQI) selection shall be based on the following: if the thickness to be radiographed exceeds the design thickness of the finished piece, the penetrameter (IQI) size shall be based on a thickness which does not exceed the design thickness of the finished piece by more than 20 % or 1/4 in. (6.35 mm), whichever is greater. In no case shall the penetrameter (IQI) size be based on a thickness greater than the thickness to be radiographed.

9.2 *Surface Preparation*—The casting surfaces shall be prepared as necessary to remove any conditions that could mask or be confused with internal casting discontinuities.

9.3 *Source-to-Film Distance*—Unless otherwise specified in the applicable job order or contract, geometric unsharpness (Ug) shall not be greater than one percent of the maximum part thickness being interpreted on the radiograph, or 0.070 in. (1.8 mm), whichever is less. Geometric unsharpness values shall be determined as specified in Guide E 94.

9.4 *Direction of Radiation*—The direction of radiation shall be governed by the geometry of the casting and the radiographic coverage and quality requirements stipulated by the applicable job order or contract. Whenever practicable, place the central beam of the radiation perpendicular to the surface of the film. Appendix X2 provides examples of preferred source

and film orientations and examples of casting geometries and configurations on which radiography is impractical or very difficult.

9.5 *Back-Scattered Radiation Protection*:

9.5.1 *Back-Scattered Radiation*—(secondary radiation emanating from surfaces behind the film, that is, walls, floors, etc.) serves to reduce radiographic contrast and may produce undesirable effects on radiographic quality. A ⅛-in. (3.17 mm) lead sheet placed behind the film generally furnishes adequate protection against back-scattered radiation.

9.5.2 To detect back-scattered radiation, position a lead letter "B" (approximately ¼ in. (3.17 mm) thick by ½ in. (12.7 mm) high) on the rear side of the film holder. If a light image (lower density) of the lead letter "B" appears on the radiograph, it indicates that more back-scatter protection is necessary. The appearance of a dark image of the lead letter "B" should be disregarded unless the dark image could mask or be confused with rejectable casting defects.

9.6 *Penetrameter (IQI) Placement*—Place all penetrameters (IQI) being radiographed on the source side of the casting. Place penetrameters (IQI's) in the radiographic area of interest, unless the use of a shim or separate block is necessary, as specified in 9.7.6.

9.7 *Number of Penetrameters (IQI's)*:

9.7.1 One penetrameter (IQI) shall represent an area within which radiographic densities do not vary more than + 30 % to − 15 % from the density measured through the body of the penetrameter (IQI).

9.7.2 When the film density varies more than − 15 % to + 30 %, two penetrameters (IQI's) used as follows will be acceptable: if one penetrameter (IQI) shows acceptable sensitivity representing the most dense portion of the exposure, and the second penetrameter (IQI) shows acceptable sensitivity representing the least dense portion of the exposure, then these two penetrameters (IQI's) shall qualify the exposure location within these densities, provided the density requirements stipulated in 8.6 are met.

9.7.3 For cylindrical or flat castings where more than one film holder is used for an exposure, at least one penetrameter (IQI) image shall appear on each radiograph. For cylindrical shapes, where a panoramic type source of radiation is placed in the center of the cylinder and a complete or partial circumference is radiographed using at least four overlapped film holders, at least three penetrameters (IQIs) shall be used. On partial circumference exposures, a penetrameter (IQI) shall be placed at each end of the length of the image to be evaluated on the radiograph with the intermediate penetrameters (IQIs) placed at equal divisions of the length covered. For full circumferential coverage, three penetrameters (IQIs) spaced 120° apart shall be used, even when using a single length of roll film.

9.7.4 When an array of individual castings in a circle is radiographed, the requirements of 9.7.1 or 9.7.2, or both, shall prevail for each casting.

9.7.5 If the required penetrameter (IQI) sensitivity does not show on any one film in a multiple film technique (see 9.11), but does show in composite (superimposed) film viewing, interpretation shall be permitted only by composite film viewing for the respective area.

9.7.6 When it is not practicable to place the penetrameter(s) (IQI) on the casting, a shim or separate block conforming to the requirements of 6.7 may be used.

9.7.6.1 The penetrameter (IQI) shall be no closer to the film than the source side of that part of the casting being radiographed in the current view.

9.7.6.2 The radiographic density measured adjacent to the penetrameter (IQI) through the body of the shim or separate block shall not exceed the density measured in the area of interest by more than 15 %. The density may be lighter than the area of interest density, provided acceptable quality level is obtained and the density requirements of 8.6 are met.

9.7.6.3 The shim or separate block shall be placed at the corner of the film holder or close to that part of the area of interest that is furthest from the central beam. This is the worst case position from a beam angle standpoint that a discontinuity would be in.

9.7.6.4 The shim or separate block dimensions shall exceed the penetrameter (IQI) dimensions such that the outline of at least three sides of the penetrameter (IQI) image shall be visible on the radiograph.

9.7.7 *Film Side Penetrameter (IQI)*—In the case where the penetrameter (IQI) cannot be physically placed on the source side and the use of a separate block technique is not practical, penetrameters (IQI's) placed on the film side may be used. The applicable job order or contract shall dictate the requirements for film side radiographic quality level (see 8.4).

9.8 *Location Markers*—The radiographic image of the location markers for the coordination of the casting with the film shall appear on the film, without interfering with the interpretation, in such an arrangement that it is evident that the required coverage was obtained. These marker positions shall be marked on the casting and the position of the markers shall be maintained on the part during the complete radiographic cycle. The RSS shall show all marker locations.

9.9 *Radiographic Identification*—A system of positive identification of the film shall be provided. As a minimum, the following shall appear on the radiograph: the name or symbol of the inspecting laboratory, the date, the casting identification number, and whether it is an original or subsequent exposure.

9.10 *Subsequent Exposure Identification*—All repair radiographs after the original (initial) shall have an inspection status designation that indicates the reason. Subsequent radiographs made by reason of a repaired area shall be identified with the letter "R" followed by the respective repair cycle (that is, R-1 for the first repair, R-2 for the second repair, etc.). Subsequent radiographs that are necessary as a result of additional surface preparation should be identified by the letters "REG."

9.11 *Multiple Film Techniques*—Two or more films of equal or different speeds in the same cassette are allowed, provided prescribed quality level and density requirements are met (see 9.7.2 and 9.7.5).

9.12 *Radiographic Techniques*:

9.12.1 *Single Wall Technique*—Except as provided in 9.12.2, radiography shall be performed using a technique in which the radiation passes through only one wall.

9.12.2 *Double Wall Technique*—For castings with an inside

diameter of 4 in. or less, a technique may be used in which the radiation passes through both walls and both walls are viewed for acceptance on the same film. An adequate number of exposures shall be taken to ensure that required coverage has been obtained.

9.13 **Safety**—Radiographic procedures shall comply with applicable city, state, and federal regulations.

10. Radiograph Evaluation

10.1 **Film Quality**—Verify that the radiograph meets the quality requirements specified in 8.3, 8.4, 8.6, 9.5.2 and 9.7.

10.2 **Film Evaluation**—Determine the acceptance or rejection of the casting by comparing the radiographic image to the agreed upon acceptance criteria (see 8.5).

11. Reference Radiographs

11.1 Reference Radiographs E 155, E 186, E 192, E 272, E 280, E 310, E 446, E 505, E 689, and E 802 are graded radiographic illustrations of various casting discontinuities. These reference radiographs may be used to help establish acceptance criteria and may also be useful as radiographic interpretation training aids.

12. Report

12.1 The following radiographic records shall be maintained as agreed upon between purchaser and supplier:

12.1.1 Radiographic standard shooting sketch,

12.1.2 Weld repair documentation,

12.1.3 Film,

12.1.4 Film interpretation record containing as a minimum:

12.1.4.1 Disposition of each radiograph (acceptable or rejectable),

12.1.4.2 If rejectable, cause for rejection (shrink, gas, etc.),

12.1.4.3 Surface indication verified by visual examination (mold, marks, etc.), and

12.1.4.4 Signature of the film interpreter.

13. Precision and Bias

13.1 No statement has been made about either the precision or bias of this test method since the result merely states whether there is conformance to the criteria for success specified in the procedure.

14. Keywords

14.1 castings; gamma-ray; nondestructive testing; radiographic; radiography; x-ray

APPENDIXES

(Nonmandatory Information)

X1. RADIOGRAPHIC STANDARD SHOOTING SKETCH (RSS)

X1.1 The radiographic standard shooting sketch (RSS) provides the radiographic operator and the radiographic interpreter with pertinent information regarding the examination of a casting. The RSS is designed to standardize radiographic methodologies associated with casting inspection; it may also provide a means of a purchaser and supplier agreement, prior to initiation of the inspection on a production basis. The use of a RSS is advantageous due to the many configurations associated with castings and the corresponding variations in techniques for inspection of any particular one. The RSS provides a map of location marker placement, directions for source and film arrangement, and instructions for all other parameters associated with radiography of a casting. This information serves to provide the most efficient method for controlling the quality and consistency of the resultant radiographic representations.

X1.2 The RSS usually consists of an instruction sheet and sketch(es) of the casting: the instruction sheet specifies the radiographic equipment, materials, and technique-acceptance parameters for each location; the sketch(es) illustrate(s) the location, orientation, and the source and film arrangement for each location. Figs. X1.1-X1.3 of this appendix provide a typical instruction sheet and sketch sheets. As a minimum, the RSS should provide the following information. All spaces shall be filled in unless not applicable; in those cases, the space shall be marked NA.

X1.2.1 The instruction sheet should provide the following:

X1.2.1.1 Company preparing RSS and activity performing radiography.

X1.2.1.2 Casting identification including:

(a) Drawing number,

(b) Casting identification number,

(c) Descriptive name (for example, pump casting, valve body, etc.),

(d) Material type and material specification,

(e) Heat number, and

(f) Pattern number.

X1.2.1.3 Surface condition at time of radiography (as cast, rough machined, finished machined).

X1.2.1.4 Spaces for approval (as applicable).

X1.2.1.5 *Radiographic Technique Parameters for Each Location*:

(a) Radiographic location designation,

(b) Source type and size,

(c) Finished thickness,

(d) Thickness when radiographed,

(e) Penetrameters,

(f) Source to film distance,

(g) Film type and quantity,

GENERAL INFORMATION					CASTING IDENTIFICATION		
COMPANY PREPARING RSS					DRAWING NO.	REVISION	PIECE NO.
COMPANY PERFORMING RT					DESCRIPTION: BODY		
FOUNDRY CASTING IDENTIFICATION METHOD: STAMPED [X] ETCHED [ ] AT RT LOCATION 9-10					MATERIAL: NI-CU	MATERIAL SPEC.	
SURFACE CONDITION WHEN RT'D: AS CAST [ ] ROUGH MACH'D [X] FINISH MACH'D [ ]					PATTERN NO.	HEAT NO.	

RSS APPROVAL			
SUPPLIER		CUSTOMER	
1.	DATE	1.	DATE
2.	DATE	2.	DATE

SAMPLE

RT PARAMETERS								
VIEWS	1-2 thru 4-1	5-6 thru 7-8	9-10	11-12	13			
SOURCE TYPE	IRID 192	→	→	→	→			
FINISHED THICKNESS	13/16"	3/4"	5/8"-2-1/2	5/8"-2 3/8	3/4"-2 3/8			
THICKNESS WHEN RT'D	15/16"	7/8"	3/4"-2 5/16	3/4"-2-1/2	7/8"-2-1/2			
PENETRAMETER(S)	I7	I7	I5 - 45	I5 - 50	I7 - 50			
SOURCE TO FILM DISTANCE	30"	→	→	→	→			
FILM TYPE	I	→	I & 2	→	→			
FILM SIZE	5 X 7	→	8 X I0	→	→			
QUALITY LEVEL	2-2T	→	→	→	→			
ACCEPTANCE STANDARD	ASTM E-272	→	→	→	→			
SEVERITY LEVEL	2	→	→	→	→			

NOTES	REVISIONS					
	REV.	DESCRIPTION	APPROVAL SUPPLIER BY	SUPPLIER DATE	CUSTOMER BY	CUSTOMER DATE
	A	ORIGINAL ISSUE	—	—	—	—

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FIG. X1.1 Sample Radiographic Standard Shooting Sketch (RSS)

(h) Film size,

(i) Required penetrameter (IQI) quality level,

(j) Radiographic acceptance standard, and

(k) Applicable radiographic severity level.

X1.2.2 The sketch(es) should provide the following:

X1.2.2.1 Location marker placement.

X1.2.2.2 Location of foundry's identification pad or symbol on the casting.

X1.2.2.3 Designation of areas that require radiography (as applicable).

X1.2.2.4 Designation of areas that are considered impractical or very difficult to radiograph (see 1.2 and 8.2).

X1.2.2.5 Radiographic source and film arrangement and radiation beam direction for each location.

NOTE X1.1—The RSS should designate the involved locations and stipulate that the technique for those locations is typical, for sections of the casting on which a continuing series of locations are to be radiographed with the same basic source and film arrangement for each location.

X1.2.3 Fig. X1.1 of this appendix provides a sample RSS that has been developed for a typical production application, and Figs. X1.2 and X1.3 provide sample RSS sketches that have been developed for a typical production application.

X1.2.4 The RSS may not provide what is considered to be the most effective means of technique control for all radiographic activities, but, in any event, some means of technique standardization should be employed. As a general rule, it is a beneficial practice for the supplier to solicit purchaser approval of the radiographic methodology prior to performing production radiography. This generally entails the demonstration of the adequacy of the methodology by submitting the proposed technique parameters and a corresponding set of pilot radiographs to the purchaser for review. Purchaser approval of the technique shall be addressed in the applicable job order or contract.

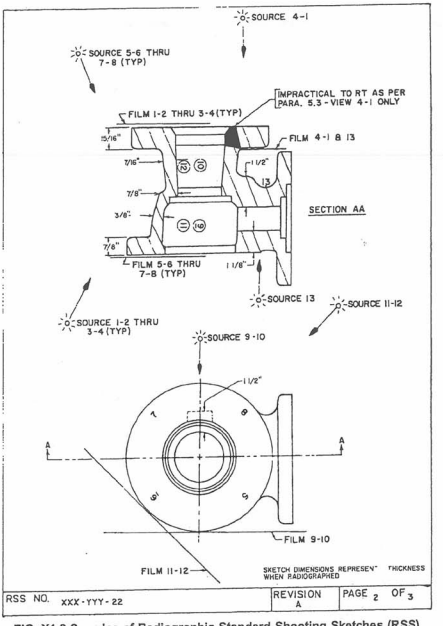


FIG. X1.2 Samples of Radiographic Standard Shooting Sketches (RSS) Views Illustrating Layout and Source and Film Placement

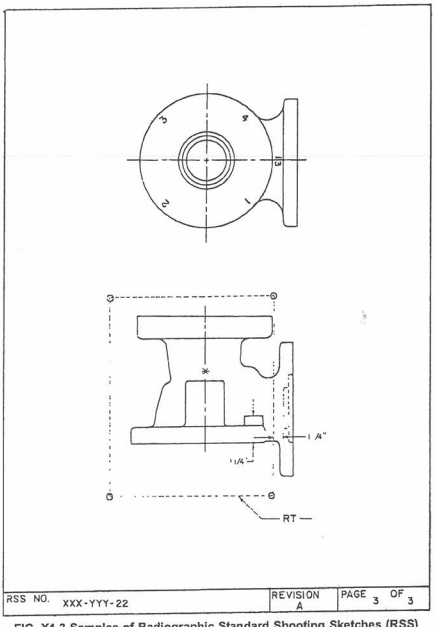
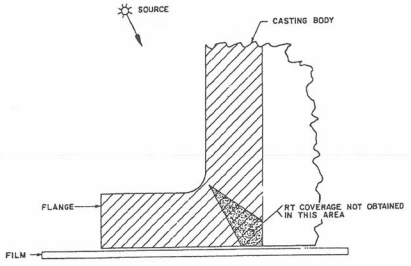


FIG. X1.3 Samples of Radiographic Standard Shooting Sketches (RSS) Views Illustrating Layout and Extent of Coverage

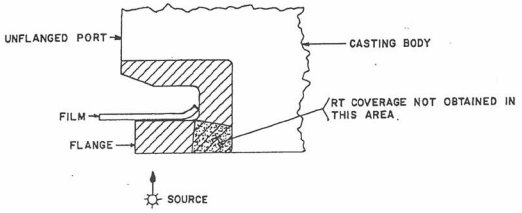
X2. PREFERRED SOURCE AND FILM ALIGNMENT FOR FLANGE RADIOGRAPHY AND EXAMPLES OF AREAS THAT ARE CONSIDERED IMPRACTICAL TO RADIOGRAPH

X2.1 Preferred Source and Film Alignment for Flange Radiography—The effective use of radiography for assessing material soundness in casting areas where a flange joins a body is somewhat limited by the source and film alignment that the geometric configuration of these areas require. The following figures describe source and film alignments that can be employed and discusses the limits and benefits of each.



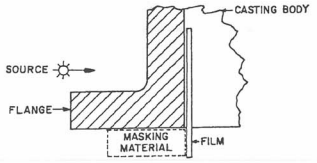
NOTE 1—For general application, this alignment provides the most effective compromise of quality radiography and maximum obtainable coverage.

FIG. X2.1 Preferred Source and Film Alignment



NOTE 1—This alignment provides a suitable alternative when other casting appendages (bosses, flanges, etc.) project into the radiation path as illustrated in Fig. X2.2 when this alignment is used, additional losses in coverage (as opposed to Fig. X2.1) should be expected and noted accordingly on the applicable RSS.

FIG. X2.2 Permissible Source and Film Alignment when Fig. X2.1 Cannot Be Applied Due to Casting Geometry



NOTE 1—This alignment is permissible if the radiation source energy and film multi-load capabilities are sufficient to afford compliance with the technique requirements stipulated herein. This alignment will generally require the use of filters or masking to reduce the influence of radiation that undercuts the thicker areas and reduces overall radiographic quality.

FIG. X2.3 Allowable Source Film Alignment as Governed by Source Energy and Multi-Film Load Acceptable Density Latitude

X3. EXAMPLES OF AREAS THAT ARE CONSIDERED TO BE IMPRACTICAL TO RADIOGRAPH

X3.1 Certain casting geometry configuration are inaccessible for conventional source and film arrangements that will provide meaningful radiographic results. These areas generally involve the juncture of two casting sections. The following illustrations provide typical examples of such areas.

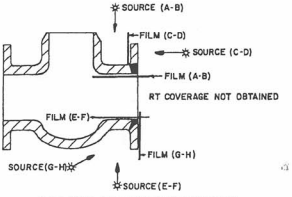


FIG. X3.1 Areas Involving Flanges

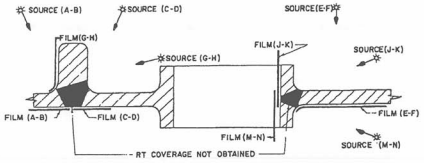


FIG. X3.2 Areas Involving Other Junctures