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AEROSPACE MATERIAL SPECIFICATION

SAE AMS-STD-2175

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Submitted for recognition as an American National Standard

Castings, Classification and Inspection of

NOTICE

This document has been taken directly from U.S. Military Standard MIL-STD-2175A and contains only minor editorial and format changes required to bring it into conformance with the publishing requirements of SAE technical standards. The initial release of this document is intended to replace MIL-STD-2175A. Any part numbers established by the original specification remain unchanged.

The original Military Standard was adopted as an SAE standard under the provisions of the SAE Technical Standards Board (TSB) Rules and Regulations (TSB 001) pertaining to accelerated adoption of government specifications and standards. TSB rules provide for (a) the publication of portions of unrevised government specifications and standards without consensus voting at the SAE Committee level, and (b) the use of the existing government specification or standard format.

Under Department of Defense policies and procedures, any qualification requirements and associated qualified products lists are mandatory for DOD contracts. Any requirement relating to qualified products lists (QPL's) has not been adopted by SAE and is not part of this technical report.

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TABLE

APPENDIX

1. SCOPE:

1.1 Purpose:

The purpose of this military standard is to prescribe the non-destructive testing acceptance criteria for the inspection of metal castings that are classified (see 1.3) in accordance with this standard.

1.2 Applicability:

1.2.1 Casting methods: This standard is intended to apply to all casting methods except high pressure die castings (such as the ones covered by ASTM B 85, “Aluminum Alloy Die Castings”).

1.2.2 Casting Alloys: This standard applies to casting alloys that fall under one of the alloy families covered in tables 6 through 14 of this standard. Alloys that do not belong to any of the alloy families covered in tables 6 through 14 may be inspected to this standard in accordance with 5.3.3.2.

1.3 Classification:

Castings that are inspected in accordance with this standard are classified by classes and applicable grades. This class governs the frequency of inspection (see 6.4), while the grade controls the quality of the casting.

1.3.1 Classes: For design information only, castings are classified as follows:

a. Class 1. A casting, the single failure of which would endanger the lives of operating personnel, or cause the loss of a missile, aircraft, or other vehicle.

b. Class 2. A casting, the single failure of which would result in a significant operational penalty. In the case of missiles, aircraft, and other vehicles, this includes loss of major components, unintentional release or inability to release armament stores, or failure of weapon installation components.

c. Class 3. Castings not included in Class 1 or Class 2 and having a margin of safety of 200 percent or less.

d. Class 4. Castings not included in Class 1 or Class 2 and having a margin of safety greater than 200 percent.

1.3.2 Grades: Castings, or sections of a casting, shall be of grades A, B, C or D as shown in Tables 6 through 14 for radiographic requirements, and table 4 for magnetic particle and liquid penetrant requirements. For design information only, definitions for the grades are shown below:

a. Grade A - The highest quality grade of casting, or area of a casting, with minimum allowable discontinuities and very difficult to produce except in local areas.

b. Grade B - The second highest quality grade of casting, or area of a casting, which allows slightly more discontinuities than grade A, and difficult to produce, except in local areas.

c. Grade C - A high quality grade of casting, or area of a casting, that can be consistently produced.

d. Grade D - The lowest quality grade of a casting, or area of a casting, that is easily produced and is used primarily for low stress or noncritical areas adjacent to the higher graded areas.

2. APPLICABLE DOCUMENTS:

The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

2.1 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-I-25135 Inspection Materials, Penentrants

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification
MIL-STD-453 Inspection, Radiographic
MIL-STD-6866 Inspection, Liquid Penetrant

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings
ASTM E 186 Reference Radiographs for Heavy-walled (2 to 4.5 in. (51 to 114 mm)) Steel Castings
ASTM E 192 Reference Radiographs of Investment Steel Castings for Aerospace Applications
ASTM E 272 Reference Radiographs of High-Strength Copper-Base and Nickel-Copper Alloy Castings
ASTM E 280 Reference Radiographs for Heavy-walled (4.5 to 12 in. (114 to 305 mm)) Steel Castings
ASTM E 310 Reference Radiographs for Tin Bronze Castings
ASTM E 446 Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness
ASTM E 1255 Radioscopic Real-Time Examination
ASTM E 1444 Magnetic Particle Examination

3. DEFINITIONS:

3.1 Alloy:

A metallic substance composed of two or more elements which possesses properties different from those of its constituents.

3.2 Casting:

An object at or near finished shape obtained by filling a mold with molten metal and allowing it to solidify.

3.3 Chaplet:

Metal core support which is used in the mold cavity and which fuses into the casting.

3.4 Cold shut:

An imperfect junction between two flows of metal in a mold caused by the surface of the streams of metal chilling too rapidly, or in effect, being chilled to the extent that fusion does not occur. This discontinuity may have the appearance of a crack or seam with smooth or rounded edges.

3.5 Contracting agency:

A prime contractor, subcontractor, or government agency procuring castings.

3.6 Defect:

A discontinuity or condition in a casting which exceeds allowable limits. Defects are, by definition, unacceptable.

3.7 Diffraction:

A pattern of light or dark areas in a casting radiograph, due to grain structure, which is not detrimental to the casting.

3.8 Discontinuity:

An interruption in the normal physical structure or configuration of a part such as cracks, inclusions, and porosity, which may or may not affect the usefulness of a part.

3.9 Foreign materials:

Appear as isolated, irregular, or elongated variations of radiographic film density, corresponding to variations in thickness of material, or to cavities. They may be due to the presence of sand, slag, oxide, dross, or metal of different density. External foreign material would, of course, be detected by visual inspection. In radiographic inspection, the distinguishing factor between inclusions and foreign material is that the foreign material indications occur over a larger area while the inclusion indications are singular indications of one inclusion.

3.10 Gas holes:

Round or elongated, smooth-edged voids occurring individually, in clusters, or distributed throughout the casting. They are generally caused by trapped air or gases rejected from the metal during solidification.

3.11 Gas porosity:

Minute voids usually distributed throughout the entire casting. They are generally caused by trapped air or gases rejected from the metal during solidification.

3.12 Hot tear:

Hot tears appear as ragged dark lines of variable width and with no definite line of continuity. Hot tears may exit in groups starting at a surface. They usually result from uneven cooling associated with abrupt changes in wall thickness, and they are formed upon solidification of the molten metal.

3.13 Inclusions:

Inclusions are particles of foreign material such as sand or slag that are embedded in the cast metal.

3.14 Insert:

A piece of steel used to locally increase the rate of heat removal during solidification. It is also called an internal chill.

3.15 Misruns:

A misrun is caused by a failure of the molten metal to completely fill the mold. It appears on the radiograph as prominent darkened areas of variable dimensions with a definite and smooth outline.

3.16 Penetrameter or Image Quality Indicator (IQI):

A strip of metal that is radiographically similar to the metal being tested, representing a percentage of object thickness and provided with a combination of steps, holes or wires. When placed in the path of X-rays or gamma rays, its image provides a check on the radiographic technique employed.

3.17 Radiographic quality level:

The ability of the radioraphic procedure to demonstrate a certain IQI sensitivity based on the perception of the IQI holes or wires.

3.18 Segregation:

A concentration of alloying elements in specific regions of the casting, usually the result of the primary crystallization of one phase with the subsequent concentration of other elements in the remaining liquid.

3.19 Shrinkage:

The term shrinkage, as used in this standard, refers to a network of small voids due to grain boundary solidification phenomena. It is different than the larger and singular voids caused by solidification shrinkage on a large scale, as defined in 3.20 (shrinkage cavity). Shrinkage is usually categorized as either dendritic, filamentary, feathery, or sponge. It is usually below the surface but may extend to the surface. In radiographic inspection, depending on the category, shrinkage may appear as dark irregular patches, as dark feathery streaks, or as a lacy or honeycombed darkened area with a diffuse outline. In penetrant inspection, dendritic shrinkage (sometimes called “microshrinkage”), and sponge shrinkage, are often indistinguishable from each other and appear as a sponge-like cluster of tiny pin holes or spotty irregular areas with feathery outlines. In magnetic particle inspection shrinkage may appear as a jagged area or irregular patch of magnetic particles.

3.20 Shrinkage cavity:

Shrinkage cavities occur when insufficient feeding of a section results in a continuous cavity within the section. Shrinkage cavities appear on the radiograph as dark areas that are indistinctly outlined and have irregular dimensions.

3.21 Surface irregularities:

In radiographic inspection, they are any images corresponding to an irregularity visible on the surface. In visual inspection they are any interruptions, either positive (raised) or negative (depressed) from the normal cast surface.

3.22 Visual inspection:

Inspection of casting surfaces to determine conformance to the requirements for surface roughness, surface irregularities, dimensions, or any visible surface discontinuities.

4. GENERAL REQUIREMENTS:

4.1 Personnel qualification:

Personnel performing penetrant, magnetic particle or radiographic inspections as required by this standard shall be qualified and certified in accordance with MIL-STD-410 for the applicable method being used.

4.2 Inspection sequence:

It is the responsibility of the contractor to perform appropriate inspections as necessary and in the proper sequence during processing to assure freedom from harmful discontinuities in the final product. The intent of inspections during processing is to detect flaws which would be detrimental to the final product at the earliest stage in processing so as to minimize the cost of rejected or scrapped castings. The inspection sequence for liquid penetrant, magnetic particle, and radiographic inspections shall be as specified in ASTM-E-1444, MIL-STD-453, and MIL-STD-6866 or as otherwise specified by the design activity on the engineering drawing, applicable specification, or other contractual or engineering documentation.

4.3 Discontinuity removal:

If it is determined that rejectable discontinuities shall subsequently be removed by machining on machining stock surfaces, or by blending on as-cast surfaces, then those discontinuities need not be cause for rejection provided reinspection is performed after the material removal to verify that the discontinuity was removed, and the dimensional tolerance requirements of the casting are satisfied.

4.4 Classification of castings:

4.4.1 Determination of classes and grades: The design activity shall establish the class and grade(s) for each casting design (see 1.3). Sections of a casting may be of varying grades depending on the applied stresses to that portion of a casting. Particular attention should be given to areas that contain, or will eventually contain, stress risers after machining (such as sharp internal corners, holes, or notches). If the grade of casting is not indicated on the drawing or other contractual document, grade C shall apply, except for class 4 castings, where grade D shall apply.

4.4.2 Class 1 casting requirements: All areas of class 1 castings shall be of a quality equivalent to, or better than, grade C, except that all highly stressed areas of a class 1 casting shall be of a quality equivalent to, or better than, grade B.

4.5 Inspection Lot:

An inspection lot, for the purposes of visual, liquid penetrant, magnetic particle, and radiographic inspection shall be as defined in the casting (material) specification, engineering drawing, or purchase order. If not specified in any of the above documents, an inspection lot shall be defined as all castings of the same part number, of one alloy, produced using the same processing parameters of the casting procedure, and submitted for inspection as a single group.

5. DETAIL REQUIREMENTS:

5.1 Outline of inspections:

5.1.1 Visual inspection: Visual inspection shall be performed in accordance with, and evaluated to the acceptance criteria of 5.3.1. Sampling shall be in accordance with 5.2.1 (see 6.4).

5.1.2 Magnetic particle and liquid penetrant inspection: Magnetic particle and liquid penetrant inspection shall be performed in accordance with, and evaluated to the acceptance criteria of 5.3.2. Sampling shall be in accordance with 5.2.2 (see 6.4).

5.1.3 Radiographic inspection: Radiograhic inspection shall be performed in accordance with, and evaluated to the acceptance criteria of 5.3.3. Sampling shall be in accordance with 5.2.3 (see 6.4).

5.2 Sampling:

5.2.1 Visual inspection: Each casting shall be examined visually.

5.2.2 Magnetic particle and penetrant inspection: Each casting shall be subjected to either magnetic particle or penetrant inspection, as may be appropriate (see 5.3.2), except that class 4 castings shall be sample inspected in accordance with table 1, unless 100 percent inspection is required by the engineering drawing, casting specification or purchase order.

5.2.3 Radiographic inspection: Sampling inspection and inspection coverage shall be as indicated below:

a. Class 1 castings - Each casting shall be completely examined.

b. Class 2 castings - Castings shall be selected in accordance with table 1 and completely examined.

c. Class 3 castings - Castings shall be selected in accordance with table 2 and completely examined.

d. Class 4 castings - Radiographic examination is not required unless otherwise specified in the casting drawing, specification, contract, or purchase order. If radiographic examination is specified and no sampling is specified, table II shall apply.

5.3 Inspection methods and acceptance criteria:

5.3.1 Visual inspection: Each casting shall be 100% visually inspected. Visual inspection should be performed in areas with an ambient lighting range of no less than 75 foot-candles. Castings shall be free of foreign materials, and shall not contain any cracks, hot tears, cold shuts, and negative core seams (also called parting line below flush). In addition, visual inspections shall be performed to determine conformance to the criteria specified on the engineering drawing, specification, or agreed upon observational standards (see 6.8).

5.3.1.1 Surface roughness: Dimensions and surface roughness shall conform to the engineering drawing requirements. Surface roughness requirements specified on the engineering drawing (for example 63 Ra) do not preclude the presence of acceptable liquid penetrant or magnetic particle indications. Visual and tactile comparison with commercially available observational standards may be used to determine conformance to surface roughness requirements.

5.3.1.2 Gate, riser, and parting line projections: If allowance limits for gate, riser, or parting line projections are not specified on the engineering drawing or casting (material) specification, then the maximum limit for gates, risers and parting lines shall be in accordance with table 3.

5.3.1.3 Surface pits and raised metal: Allowable surface pits and raised metal (also called positive metal), other than gates, risers and parting lines, that are not specifically controlled by the engineering drawing or agreed upon observational standards shall be allowed as specified below:

a. For sand castings, surface pits are acceptable if they have smooth rounded contours and do not cause the casting to fall outside the dimensional requirements of the engineering drawing. Raised metal that has a jagged or irregular surface, or which causes the casting to fall outside of the dimensional requirements of the engineering drawing, shall be removed or blended to conform to the dimensional and surface roughness requirements of the engineering drawing.

b. For investment and permanent mold castings, random raised metal shall be limited to a height of 0.015-0.030 inch by 0.125 by 0.125 inch and no more than one per square inch. Random surface pits shall be limited to 0.030-0.060 inch in diameter and 0.030 inch in depth and no more than one per square inch. Smaller surface pits or raised metal may be present at random provided they do not interfere with the function of the part.

5.3.2 Magnetic particle and liquid penetrant inspection:

5.3.2.1 Inspection method for ferromagnetic materials: Class 1, 2 and 3 castings and sample castings of class 4 ferromagnetic materials shall be magnetic particle inspected. Magnetic particle inspection shall be in accordance with ASTM E 1444. If necessary, and when approved by the contracting agency, liquid penetrant inspections may be performed in lieu of magnetic particle inspection on ferromagnetic materials if their size or complex shape prohibits adequate inspection with magnetic particle inspection. The surface quality of the castings shall conform to 5.3.2.3. All precipitation hardening stainless steels shall be penetrant inspected in accordance with 5.3.2.2. (due to the possibility of delta ferrite stringers), unless otherwise prohibited by the contracting agency.

5.3.2.2 Inspection method for nonferromagnetic materials: Class 1, 2 and 3 castings and sample castings of class 4 nonferromagnetic material shall be penetrant inspected in accordance with MIL-STD-6866. The design activity shall specify, on the engineering drawing or other applicable documents, the sensitivity level of the penetrant materials to be used in accordance with the classification of MIL-I-25135. If no sensitivity level is specified, the inspection facility shall determine the appropriate sensitivity level for the inspection procedure in accordance with MIL-STD-6866, or the company process specification. The surface quality of the castings shall conform to 5.3.2.3. Penetrant materials which exhibit excessive fluorescent background which could mask or obscure relevant discontinuities on the as-cast surface shall not be used.

5.3.2.3 Magnetic particle and liquid penetrant acceptance criteria: If the design activity does not specify their own magnetic particle or liquid penetrant acceptance criteria on the engineering drawing, then the surface quality of each grade designation shall conform to table 4.

5.3.3 Radiographic inspection:

5.3.3.1 Radiographic inspection method: Radiographic inspection shall be in accordance with MIL-STD-453. THe use of nonfilm radiographic techniques (radioscopy) is permitted provided the method used is sufficiently sensitive to resolve the required radiographic quality level. Radioscopic inspection shall be in accordance with ASTM E 1255. However, prior approval shall be obtained from the contracting agency on the detailed inspection, evaluation and quality control procedures.

5.3.3.2 Radiographic reference standards: Radiographic standards shall be as required in ASTM E 155, ASTM E 186, ASTM E 192, ASTM E 272, ASTM E 280, ASTM E 310 and ASTM E 446. For alloy types where reference radiographs are specifically covered, the reference radiographic shall be of the same alloy family as the casting. For alloys not specifically included in the alloy family covered by the ASTM reference radiographic standards, the design activity shall either select an ASTM standard representative of the quality required, or develop their own radiograhic standards containing details comparable to an ASTM standard.

5.3.3.3 Radiographic acceptance criteria: The design activity shall specify on the drawing or other document the radiographic grade(s) for classes 1, 2 and 3 castings designs. The design activity may specify radiographic grade(s) for class 4 casting designs. Either the castings, or areas of the castings, shall be in accordance with the requirements for the applicable grades of tables 6 through 14 of this standard.

5.4 Reinspection:

5.4.1 Reinspection of rejected lots: When an inspection lot is rejected on the basis of a sampling plan, regardless of the inspection method, it may be resubmitted for 100 percent inspection and defective castings removed from the lot per 5.4.2. For lots of class 2 and class 3 castings which were rejected in a radiographic inspection sampling plan, each part shall be completely examined upon reinspection, whereas for class 4 castings, only the areas where the rejectable discontinuities were found need to be inspected.

5.4.2 Individual casting rejection: Individual casting rejection shall apply in those instances where all castings in the lot are inspected and any individual casting is found defective in visual, penetrant, magnetic particle, or radiographic inspection. Only the defective casting needs to be rejected, and individual castings meeting the requirements of this standard may be accepted.

6. NOTES:

(This section contains guidance information of a general or explanatory nature that may be helpful, but is not mandatory)

6.1 Intended use:

This standard prescribes acceptance criteria for surface inspections and radiographic inspections applied to metal castings. This standard is not intended to apply to high pressure die castings. Acceptance criteria for die castings may be based on standards and guidelines developed by the American Society for Testing and Materials (ASTM), and the North American Die Casting Association (formerly the American Die Casting Institute (ADCI)). Examples are ASTM B 505 and ADCI “Q”, “E”, and “M” series standards.

6.2 Issue of DoDISS:

When this standard is used in acquisition, the issue of the DoDISS to be applicable to this solicitation must be cited in the solicitation.

6.3 Data requirements:

The following Data Item Descriptions (DID’s) must be listed, as applicable, on the Contract Data Requirements List (DD Form 1423) when this standard is applied in a contract, in order to obtain the data, except where DOD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

Reference Paragraph(s)	DID Number	DID Title	Suggested Tailoring
Appendix A	DI-MISC-80653	Test Reports	Use contractor format

6.4 Sampling:

The following is included as a quick check to aid in identifying the sampling requirements specified herein for the different inspection methods as they apply to each class:

a. Class 1. For castings classified as class 1, all castings in the lot are inspected by the methods specified in this standard.

b. Class 2. For castings classified as class 2, all castings in the lot are inspected by the methods specified in this standard, except for radiographic inspection, in which case the castings are sampled per table 1.

6.4 (Continued):

c. Class 3. For castings classified as class 3, all castings in the lot are inspected by the methods specified in this standard, except for radiographic inspection, in which case the castings are sampled per table 2.

d. Class 4. For castings classified as class 4, all castings in the lot are inspected by visual inspection, while castings are sampled in accordance with table 1 for penetrant or magnetic particle inspection. Radiographic examination is not required unless specified on the engineering drawing, specification, contract, or purchase order.

6.5 Cross reference:

The class of castings defined in paragraph 1.3 corresponds to those defined in MIL-C-6021H as shown below:

MIL-C-6021H designation	MIL-C-6021G description
Class 1	Class 1, Class 1A
Class 2	Class 1, Class 1B
Class 3	Class 2, Class 2A
Class 4	Class 2, Class 2B

6.6 Radiographic quality grades for machined areas:

Castings that have been found acceptable per the ASTM radiographic standards often times have internal discontinuities (such as shrinkage, porosity, and inclusions) exposed after machining. One way to help alleviate this problem is to quantify (in terms of size) the ASTM reference radiographic discontinuities so that their size on the surface may be approximated. Once this has been done, the engineer or designer should be able to determine if the discontinuities allowed in the radiographic grade will be permissible on the surface. If they are not permissible, then the area that is machined should be zoned to a more stringent radiographic grade.

6.7 Productibility considerations:

The class assigned to the casting should represent a realistic value for the functional requirements, do not assign a class 1 casting for a class 2 function. Casting design coupled with foundry practice can make overly severe soundness requirements impractical for a manufacturer to satisfy. Caution should be exercised in specifying the grade of maximum permissible radiographic discontinuity level and surface quality requirements to be met in a casting.

6.8 Observational standards:

Observational standards for visual inspection may include sample castings with known discontinuities. Assistance with the visual inspection criteria for steel castings may be obtained by reference to ASTM A 802 and MSS SP-55. MSS SP-55 contains reference photographs that illustrate various types and degrees of surface discontinuities, while ASTM A 802 contains plates that model actual discontinuities and surface roughness. The full titles of ASTM A 802 and MSS SP-55 are shown below:

a. ASTM A 802 "Steel Castings, Surface Acceptance Standards, VIsual Examination": (Copies may be obtained from the ASTM address given in section 2).

b. MSS SP-55 "Quality Standard for Steel Castings for Valves, Flanges, and Fittings and other Piping Components (Visual Method)" (Copies may be obtained from the Manufacturer's Standardization Society of the Valve and Fittings Industry, 127 Park Street, N.E., Vienna, VA 22180

6.9 Ultrasonic inspection of thick castings:

Class 1 and Class 2 castings have a section thickness of 4.50 inches and greater should also be inspected by ultrasonic methods due to the loss of radiographic sensitivity in the thicker sections. It should be noted that ultrasonic examination and radiography are not directly comparable. Therefore, the design activity would need to specify, on the engineering drawing, the appropriate document for ultrasonic inspection along with the appropriate quality level of acceptance criteria contained within that document. One document that could be specified is:

a. ASTM A 609 "Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof"

6.10 Subject term (key word) listing:

Liquid penetrant testing
Nondestructive testing
Magnetic particle testing
Radiographic testing

PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE "B"

TABLE 1. Sampling, radiographic inspection of class 2 castings, and magnetic particle and liquid penetrant inspection of class 4 castings

Lot size 1/	Sample size 2/	Lot size	Sample size
2-5	All	27-36	10
6-8	5	37-51	11
9-11	6	52-82	12
12-15	7	83-162	13
16-20	8	163-971	14
21-26	9	972 and over	15

1/ See 4.5 for lot definition.
2/ Acceptance number is 0.

TABLE 2. Sampling, radiographic inspection of Class 3 castings

Lot size 1/	Sample size 2/	Lot size	Sample size
2-4	All	18-27	7
5-6	4	28-48	8
7-11	5	49 and over	9
12-17	6		

1/ See 4.5 for lot definition.
2/ Acceptance number is 0.

TABLE 3. Maximum allowable gate, riser, and parting line projections

Casting weight lb.	Nonmachined surface (in.)	Machined surface (in.)
up to 10	.031	.062
over 10 thru 25	.047	.062
over 25 thru 50	.062	.094
over 50	.125	.188

TABLE 4. Maximum allowable discontinuity size and distribution (in inches) for magnetic particle (MT) and liquid penetrant (PT) inspection 1/, 2/, 3/, 4/
(T = Thickness of casting section.)

Discontinuity type		Grade A	Grade B	Grade C	Grade D
Random individual discontinuities (Gas holes, inclusions, discrete shrinkage cavities) 5/, 6/ (nonlinear)		1/4 T or the sizes shown below, whichever is less	1/3 T or the sizes shown below, whichever is less	1/3 T or the sizes shown below, whichever is less	1/2 T or the sizes shown below, whichever is less
	surface	0.03 dia	0.05 dia	0.09 dia	0.12 dia
	subsurface (MT only)	0.05 dia	0.09 dia	0.12 dia	0.15 dia
Cracks, hot tears, cold shuts, or through wall indications		- - - - - - - - - - - - - - - - None Allowed - - - - - - - - - - - - - - - -			
Microshrinkage or shrinkage sponge 7/		0	0.12 dia	0.38 dia	0.75 dia
Microshrinkage or shrinkage sponge 1/, 4/ (linear)		0	0	0.12	0.25
Number of allowable discontinuities within a 2 X 2 inch area	Random individual 8/ discontinuities	2	3	4	4
	Microshrinkage shrinkage-sponge	0	1	1	1

See next page for notes.

Notes for table 4.

1/ Linear discontinuities (length to width ratio of 3 to 1 or greater) are not allowed except under the following circumstances:

(a) Linear dendritic shrinkage, or linear shrinkage sponge indications shall be evaluated in accordance with this table and shall not be allowed to break over an edge, extend through a wall, or be located in internal corners of fillet radii.

(b) In magnetic particle inspection, discontinuities 0.030 inches or less in length need not be evaluated for linearity. In penetrant examination, discontinuities 0.015 inches or less in length need not be evaluated for linearity.

2/ Discontinuities that are visible under white light without the use of penetrant or magnetic particles may be evaluated to the criteria of this table.

3/ Size limits shown are for actual discontinuity size and not bleed out. Indications may be inspected by measuring their size after wiping with a solvent dampened cloth, cotton swab, or brush. Immediately evaluate the discontinuity for size as soon as the solvent has evaporated.

4/ For rounded indications exhibiting excessive penetrant bleedout, or doubtful indications of microshrinkage or shrinkage sponge, disposition may be based on the radiographic acceptance criteria after x-raying the part. Linear microshrinkage, or linear shrinkage sponge shall only be acceptable after verification by radiography.

5/ For random individual discontinuities, the minimum resolvable size shall be 0.030 inches for magnetic particle inspection and 0.015 inches for penetrant inspection. Discontinuities smaller than these sizes shall be considered non-interpretable.

6/ For grade A, any two random individual discontinuities shall be separated by a distance of at least three times the maximum dimension of the larger discontinuity. For grades B, C, and D random individual discontinuities shall be separated by a distance equal to twice the maximum dimension of the larger discontinuity. However, if the total length of the discontinuities that violate this spacing requirement does not exceed the maximum length permitted for a single discontinuity, then these discontinuities shall be considered as one and shall not be cause for rejection.

7/ Microshrinkage is also called dendritic shrinkage.

8/ The limits for random individual discontinuities do not apply if the discontinuities are smaller than one-half their maximum allowable size and they meet the minimum spacing requirement of note 6/.

TABLE 5. Notes for tables 6 through 14

(1)	An area of like size to the reference radiograph shall be the unit area by which the production radiograph is evaluated. If the production radiograph shows a discontinuity that is equal to or better than the severity level of the reference radiograph, the casting shall be acceptable. If the production radiograph shows a discontinuity of greater severity than the reference radiograph, the casting shall be rejected.
(2)	When two or more types of discontinuities are present (in an area equal to the reference radiographic plate area) to an extent equal to the maximum permissible severity level for each type, the casting shall be rejected.
(3)	Numbers in the tables are ASTM radiographic plate numbers for a particular type and severity of discontinuity. A low number indicates fewer, smaller discontinuities while a higher number indicates more numerous, larger discontinuities.
(4)	The smallest resolvable indication size, below which indications are considered non-interpretable, shall be 0.015 inches.
(5)	Gas holes, sand spots, and inclusions allowed by these tables (even those smaller than the maximum allowable size) shall be cause for rejection when closer than twice their maximum dimension to an edge. Exceptions to this note based on the class and grade of the casting are shown below: 1/ Class 1 No exceptions from note 5. Class 2 No exceptions from note 5 for Grade A and Grade B areas, or other areas that are specified critical or highly stressed. Otherwise, the note 5 discontinuities are acceptable if they are separated from the edge by a distance, equal to, or greater than, the discontinuity's maximum dimension. Class 3 Gas holes, sand spots, and inclusions, of the maximum size allowed by these tables, shall be cause for rejection if they are closer than one diameter of their maximum dimension to an edge. This does not apply to gas holes, sand spots, and inclusions smaller than the maximum allowable size. Class 4 Edge of part discontinuities are acceptable if they are not crack-like, linear, or round with protruding linear indications. 1/ The term "edge" refers to the outer boundary of the radiographic image of the casting. This interpretation need only be made in the standard exposures (views) defined by the approved radiographic technique. Additional radiographic exposures, to determine the distance from the surface of each gas hole, sand spot, or inclusion in other orientations, are not required.

TABLE 6. Maximum permissible radiographic severity levels for discontinuities in aluminum castings per ASTM E 155. 3/, 4/, 5/

Discontinuity	Grade A		Grade B		Grade C		Grade D	
	Inch		Inch		Inch		Inch	
	1/4	3/4	1/4	3/4	1/4	3/4	1/4	3/4
Gas holes	None		1	1	2	2	5	5
Gas porosity (round)	None		1	1	3	3	7	7
Gas porosity (elongated)	None		1	2	3	4	5	5
Shrinkage cavity	None		1	NA 2/	2	NA 2/	3	NA 2/
Shrinkage (sponge)	None		1	1	2	2	4	3
Foreign material (less dense material)	None		1	1	2	2	4	4
Foreign material (more dense material)	None		1	1	2	1	4	3
Cracks 1/	None		None		None		None	
Cold shuts 1/	None		None		None		None	
Surface irregularity 1/	Not to exceed drawing tolerance							
Core shift 1/	Not to exceed drawing tolerance							

1/ No reference radiographic plates available.
2/ Not available, use the 1/4 inch reference radiographic plate thickness with a severity level 2 units greater than the one shown for the 1/4 inch column.
3/ ASTM E 155 Volume I reference radiographic plates.
4/ For feature thicknesses greater than two inches, the 3/4 inch reference radiographic plates may be used.
5/ See table 5 for additional notes that apply to this table.

TABLE 7. Maximum permissible radiographic severity levels for discontinuities in magnesium castings per ASTM E 155. 3/, 4/, 5/

Discontinuity	Grade A		Grade B		Grade C		Grade D	
	Inch		Inch		Inch		Inch	
	1/4	3/4	1/4	3/4	1/4	3/4	1/4	3/4
Gas holes	None		1	1	3	2	4	4
Microshrinkage (feathery)	None		1	1	4	4	7	7
Microshrinkage (sponge)	None		1	1	3	4	7	8
Foreign material (less dense material)	None		2	2	3	3	4	4
Foreign material (more dense material)	None		1	1	2	2	3	3
Cracks 1/	None		None		None		None	
Cold shuts 1/	None		None		None		None	
Surface irregularity 1/	Not to exceed drawing tolerance							
Core shift 1/	Not to exceed drawing tolerance							
	APPLICABLE TO ALL THICKNESSES							
Reacted sand inclusions	1		3		4		6	
Gravity segregation	1		2		3		4	
Eutectic segregation								
(a) Microshrinkage type	None		4		5		6	
(b) Pipe shrink type	None		None		None		1/3 of size on plate	
(c) Hot tear type	None		same as size on plate		same as size on plate		twice the size on plate	
Oxide Inclusions	None		1/3 of size on plate		1/2 of size on plate		same as size on plate	
Eutectic depletion - Flow line	None		same as size on plate		twice the size on plate		Any length 2/	

1/ No reference radiographic plates available.
2/ No other types of discontinuities are allowed to be contained with it in an area of like size to the reference radiographic plate.
3/ ASTM E 155 Volume I and II reference radiograph numbers.
4/ For feature sizes greater than 2 inches, the 3/4 inch reference radiographic plates may be used.
5/ See table 5 for additional notes that apply to this table.

TABLE 8. Maximum permissible radiographic severity levels for discontinuities in investment steel castings 1 in. (25.4 mm) wall or less per ASTM E 192. 5/ 6/

Discontinuity	Grade A Inch 1/8	3/8	3/4	Grade B Inch 1/8	3/8	3/4	Grade C Inch 1/8	3/8	3/4	Grade D Inch 1/8	3/8	3/4
Gas holes	1	1	1	3	3	3	5	5	5	7 1/	7 2/	7
Foreign material (more dense)				Use "foreign material (less dense) limits								
Shrinkage cavity	None	None	None	None	None	1	None	None	3	1	2	5
Shrinkage sponge	1	1	1	2 3/	1	1	4	4	5	6	6	7
Shrinkage, dendritic	1	1	1	2	2	2	4	4	4	6	6	6
Shrinkage, filamentary	None	None	None	None	None	1	None	None	2	None	None	3
Foreign material (less dense)	1	1	1	3	3	3	5	6	6	6	7	7
Cold shut	----------			----------			None allowed			----------		
Hot tear	----------			----------			None allowed			----------		
Cold crack	----------			----------			None allowed			----------		
Misrun	----------			----------			None allowed			----------		
Core shift	----------			----------			Not to exceed drawing tolerance			----------		
Mold buckle, positive	----------			----------			Not to exceed drawing tolerance			----------		
Mold buckle, negative	----------			----------			Not to exceed drawing tolerance			----------		
Mold ridge	----------			----------			Not to exceed drawing tolerance			----------		
Excess metal in cracked core	----------			----------			Not to exceed drawing tolerance			----------		
Surface irregularities	----------			----------			Not to exceed drawing tolerance			----------		

1/ Excluding the single largest gas hole.
2/ Excluding the crack-like discontinuities emitting from the gas holes.
3/ Excluding bottom half of the standard reference film.
4/ NA - Not available.
5/ See table 5 for additional notes that apply to this table.
6/ "None" as used in this table means that the discontinuity is not allowed.

TABLE 9. Maximum permissible radiographic severity levels for discontinuities in heavy walled steel castings 2 - 4.5 in. (51 - 114 mm) per ASTM E 186. 1/

Code or Category	Discontinuities	Grade A	Grade B	Grade C	Grade D
A	Gas porosity	None	1	2	3
B	Sand/slag inclusions	None	1	2	4
C	Shrinkage type 1	None	2	3	5
C	Shrinkage type 2	None	2	3	4
C	Shrinkage type 3	None	2	3	4
D	Crack	None	None	None	None
E	Hot Tear	None	None	None	None
F	Insert	None	None	None	None

1/ See table 5 for additional notes that apply to this table.