Designation: E747 – 04 (Reapproved 2010)

Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology[1]

This standard is issued under the fixed designation E747; 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 practice[2] covers the design, material grouping classification, and manufacture of wire image quality indicators (IQI) used to indicate the quality of radiologic images.

1.2 This practice is applicable to X-ray and gamma-ray radiology.

1.3 This practice covers the use of wire penetrameters as the controlling image quality indicator for the material thickness range from 6.4 to 152 mm (0.25 to 6.0 in.).

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:*[3]

B139/B139M Specification for Phosphor Bronze Rod, Bar, and Shapes

B150M Specification for Aluminum Bronze, Rod, Bar, and Shapes [Metric] (Withdrawn 2002)[4]

B161 Specification for Nickel Seamless Pipe and Tube

B164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire

B166 Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and N06696), Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617), and Nickel-Iron-Chromium-Tungsten Alloy (UNS N06674) Rod, Bar, and Wire

E1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology

E1316 Terminology for Nondestructive Examinations

2.2 *Other Standards:*[5]

EN 462–1 Non-Destructive Testing—Image Quality of Radiographs-Part 1: Image Quality Indicators (Wire-Type)-Determination of Image Quality Value

3. Terminology

3.1 *Definitions*—The definitions of terms in Terminology E1316, Section D, relating to gamma and X-radiology, shall apply to the terms used in this practice.

4. Wire IQI Requirements

4.1 The quality of all levels of examination shall be determined by a set of wires conforming to the following requirements:

4.1.1 Wires shall be fabricated from materials or alloys identified or listed in accordance with 7.2. Other materials may be used in accordance with 7.3.

4.1.2 The IQI consists of sets of wires arranged in order of increasing diameter. The diameter sizes specified in Table 1 are established from a consecutive series of numbers taken in general from the ISO/R 10 series. The IQI shall be fabricated in accordance with the requirements specified in Figs. 1-8 and Tables 1-3. IQIs previously manufactured to the requirements of Annex A1 may be used as an alternate provided all other requirements of this practice are met.

4.1.3 Image quality indicator (IQI) designs other than those shown in Figs. 1-8 and Annex A1 are permitted by contractual agreement. If an IQI set as listed in Table 1 or Annex A1 is modified in size, it must contain the grade number, set identity, and essential wire. It must also contain two additional wires

[1] This practice is under the jurisdiction of ASTM Committee E07 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 Practice SE-747 in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The last approved version of this historical standard is referenced on www.astm.org.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

TABLE 1 Wire IQI Sizes and Wire Identity Numbers

SET A		SET B	
Wire Diameter in. (mm)	Wire Identity	Wire Diameter in. (mm)	Wire Identity
0.0032 (0.08)[A]	1	0.010 (0.25)	6
0.004 (0.1)	2	0.013 (0.33)	7
0.005 (0.13)	3	0.016 (0.4)	8
0.0063 (0.16)	4	0.020 (0.51)	9
0.008 (0.2)	5	0.025 (0.64)	10
0.010 (0.25)	6	0.032 (0.81)	11
SET C		SET D	
Wire Diameter in. (mm)	Wire Identity	Wire Diameter in. (mm)	Wire Identity
0.032 (0.81)	11	0.10 (2.5)	16
0.040 (1.02)	12	0.126 (3.2)	17
0.050 (1.27)	13	0.160 (4.06)	18
0.063 (1.6)	14	0.20 (5.1)	19
0.080 (2.03)	15	0.25 (6.4)	20
0.100 (2.5)	16	0.32 (8)	21

[A] The 0.0032 wire may be used to establish a special quality level as agreed upon between the purchaser and the supplier.

TABLE 2 Wire Diameter Tolerances, mm

Wire Diameter (d), mm	Tolerance, mm
$0.000 < d \leq 0.125$	±0.0025
$0.125 < d \leq 0.25$	±0.005
$0.25 < d \leq 0.5$	±0.01
$0.50 < d \leq 1.6$	±0.02
$1.6 < d \leq 4$	±0.03
$4.0 < d \leq 8$	±0.05

TABLE 3 Wire Diameter Tolerances, in.

Wire Diameter (d), in.	Tolerance, in.
$0.000 < d \leq 0.005$	±0.0001
$0.005 < d \leq 0.010$	±0.0002
$0.010 < d \leq 0.020$	±0.0004
$0.020 < d \leq 0.063$	±0.0008
$0.063 < d \leq 0.160$	±0.0012
$0.160 < d \leq 0.320$	±0.0020

that are the next size larger and the next size smaller as specified in the applicable set listed in Table 1.

4.1.4 Each set must be identified using letters and numbers made of industrial grade lead or of a material of similar radiographic density. Identification shall be as shown on Figs. 1-8 or Annex A1, unless otherwise specified by contractual agreement.

4.1.5 European standard EN 462-1 contains similar provisions (with nominal differences-see Table A1.1) for wire image quality indicators as this standard (E747). International users of these type IQI standards who prefer the use of EN 462-1 for their particular applications should specify such alternate provisions within separate contractual arrangements from this standard.

5. Image Quality Indicator (IQI) Procurement

5.1 When selecting IQI's for procurement, the following factors should be considered:

5.1.1 Determine the alloy group(s) of the material to be examined.

5.1.2 Determine the thickness or thickness range of the material(s) to be examined.

5.1.3 Select the applicable IQI's that represent the required IQI thickness(s) and alloy(s).

6. Image Quality Levels

6.1 The quality level required using wire penetrameters shall be equivalent to the 2-2T level of Practice E1025 for hole-type IQI's unless a higher or lower quality level is agreed upon between purchaser and supplier. Table 4 provides a list of various hole-type IQI's and the diameter of wires of corresponding equivalent penetrameter sensitivity (EPS) with the applicable 1T, 2T, and 4T holes in the IQI. This table can be used for determining 1T, 2T, and 4T quality levels. Appendix X1 gives the equation for calculating other equivalencies if needed.

6.2 In specifying quality levels, the contract, purchase order, product specification, or drawing should clearly indicate the thickness of material to which the quality level applies. Careful consideration of required quality levels is particularly important.

7. Material Groups

7.1 *General:*

7.1.1 Materials have been designated in eight groups based on their radiographic absorption characteristics: groups 03, 02, and 01 for light metals and groups 1 through 5 for heavy metals.

7.1.2 The light metal groups, magnesium (Mg), aluminum (Al), and titanium (Ti) are identified 03, 02, and 01 respectively, for their predominant alloying constituent. The materials are listed in order of increasing radiation absorption.

7.1.3 The heavy metal groups, steel, copper-base, nickel-base, and kindred alloys are identified 1 through 5. The materials increase in radiation absorption with increasing numerical designation.

7.1.4 Common trade names or alloy designations have been used for clarification of the pertinent materials.

7.1.5 The materials from which the IQI for the group are to be made are designated in each case and these IQI's are applicable for all materials listed in that group. In addition, any group IQI may be used for any material with a higher group number, provided the applicable quality level is maintained.

7.2 *Materials Groups:*

7.2.1 *Materials Group 01:*

7.2.1.1 Image quality indicators (IQI's) shall be made of titanium or titanium shall be the predominant alloying constituent.

7.2.1.2 Use on all alloys of which titanium is the predominant alloying constituent.

7.2.2 *Materials Group 02:*

7.2.2.1 Image quality indicators (IQI's) shall be made of aluminum or aluminum shall be the predominant alloying constituent.

7.2.2.2 Use on all alloys of which aluminum is the predominant alloying constituent.

7.2.3 *Materials Group 03:*

7.2.3.1 Image quality indicators (IQI's) shall be made of magnesium or magnesium shall be the predominant alloying constituent.

TABLE 4 Wire Sizes Equivalent to Corresponding 1T, 2T, and 4T Holes in Various Hole Type Plaques

Plaque Thickness, in. (mm)	Plaque IQI Identification Number	Diameter of wire with EPS of hole in plaque, in. (mm)[A]		
		1T	2T	4T
0.005 (0.13)	5		0.0038 (0.09)	0.006 (0.15)
0.006 (0.16)	6		0.004 (0.10)	0.0067 (0.18)
0.008 (0.20)	8	0.0032 (0.08)	0.005 (0.13)	0.008 (0.20)
0.009 (0.23)	9	0.0035 (0.09)	0.0056 (0.14)	0.009 (0.23)
0.010 (0.25)	10	0.004 (0.10)	0.006 (0.15)	0.010 (0.25)
0.012 (0.30)	12	0.005 (0.13)	0.008 (0.20)	0.012 (0.28)
0.015 (0.38)	15	0.0065 (0.16)	0.010 (0.25)	0.016 (0.41)
0.017 (0.43)	17	0.0076 (0.19)	0.012 (0.28)	0.020 (0.51)
0.020 (0.51)	20	0.010 (0.25)	0.015 (0.38)	0.025 (0.63)
0.025 (0.64)	25	0.013 (0.33)	0.020 (0.51)	0.032 (0.81)
0.030 (0.76)	30	0.016 (0.41)	0.025 (0.63)	0.040 (1.02)
0.035 (0.89)	35	0.020 (0.51)	0.032 (0.81)	0.050 (1.27)
0.040 (1.02)	40	0.025 (0.63)	0.040 (0.02)	0.063 (1.57)
0.050 (1.27)	50	0.032 (0.81)	0.050 (1.27)	0.080 (2.03)
0.060 (1.52)	60	0.040 (1.02)	0.063 (1.57)	0.100 (2.54)
0.070 (1.78)	70	0.050 (1.27)	0.080 (2.03)	0.126 (3.20)
0.080 (2.03)	80	0.063 (1.57)	0.100 (2.54)	0.160 (4.06)
0.100 (2.50)	100	0.080 (2.03)	0.126 (3.20)	0.200 (5.08)
0.120 (3.05)	120	0.100 (2.54)	0.160 (4.06)	0.250 (6.35)
0.140 (3.56)	140	0.126 (3.20)	0.200 (5.08)	0.320 (8.13)
0.160 (4.06)	160	0.160 (4.06)	0.250 (6.35)	
0.200 (5.08)	200	0.200 (5.08)	0.320 (8.13)	
0.240 (6.10)	240	0.250 (6.35)		
0.280 (7.11)	280	0.320 (8.13)		

[A] Minimum plaque hole sizes were used as defined within Practice E1025.

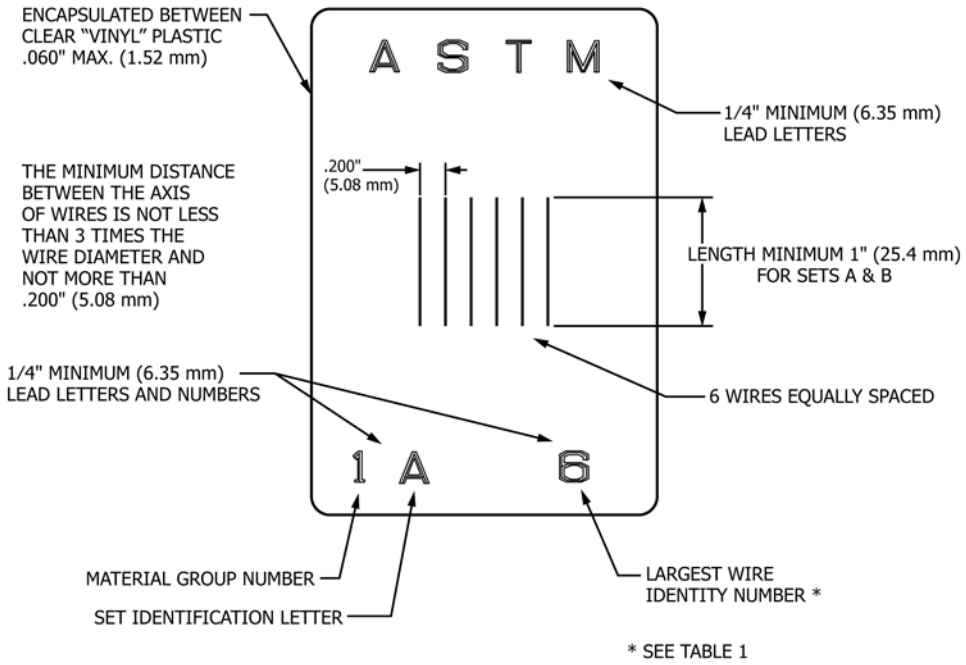


FIG. 1 Set A/Alternate 1

7.2.3.2 Use on all alloys of which magnesium is the predominant alloying constituent.

7.2.4 *Materials Group 1:*

7.2.4.1 Image quality indicators (IQI's) shall be made of carbon steel or Type 300 series stainless steel.

7.2.4.2 Use on all carbon steel, low-alloy steels, stainless steels, and manganese-nickel-aluminum bronze (Superston).[6]

[6] Superston is a registered trademark of Superston Corp., Jersey City, NJ.

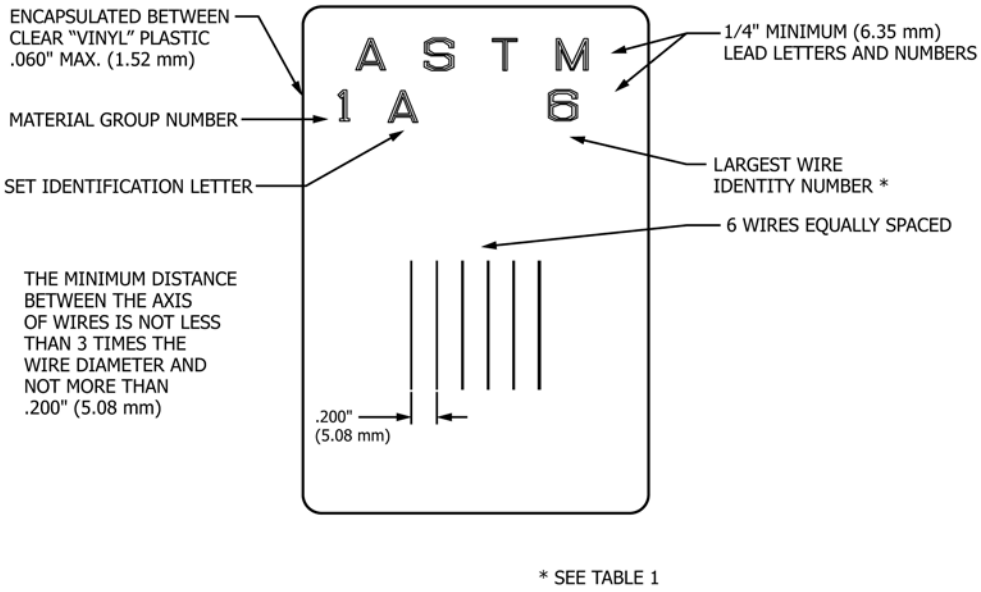


FIG. 2 Set A/Alternate 2

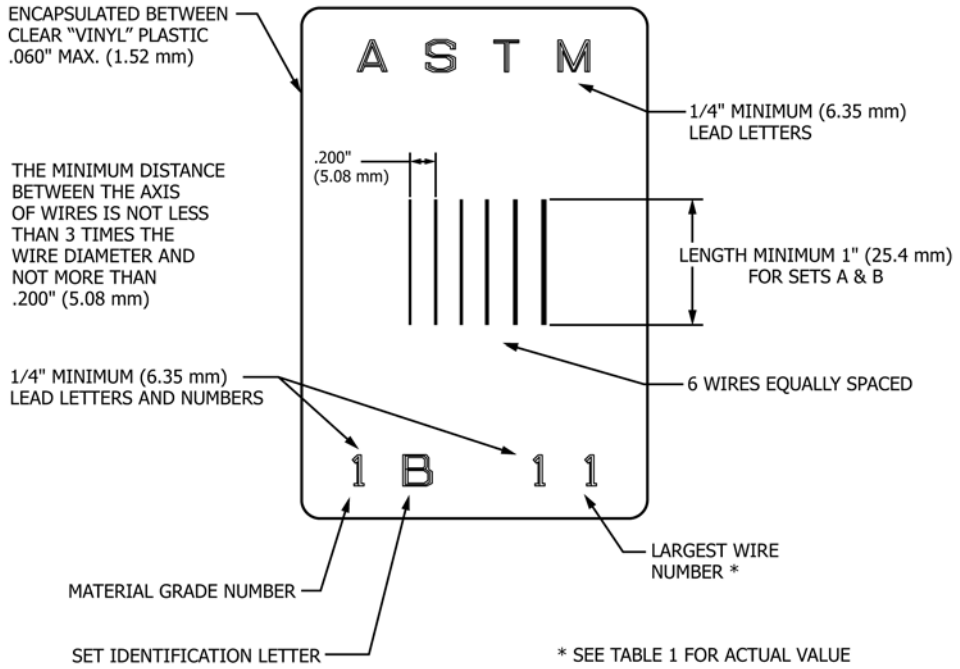


FIG. 3 Set B/Alternate 1

7.2.5 *Materials Group 2:*

7.2.5.1 Image quality indicators (IQI's) shall be made of aluminum bronze (Alloy No. 623 of Specification B150M) or equivalent, or nickel-aluminum bronze (Alloy No. 630 of Specification B150M) or equivalent.

7.2.5.2 Use on all aluminum bronzes and all nickel-aluminum bronzes.

7.2.6 *Materials Group 3:*

7.2.6.1 Image quality indicators (IQI's) shall be made of nickel-chromium-iron alloy (UNS No. N06600) (Inconel).[7] (See Specification B166).

7.2.6.2 Use on nickel-chromium-iron alloy and 18 % nickel-maraging steel.

[7] Inconel is a registered trademark of The International Nickel Co., Inc., Huntington, WV 25720.

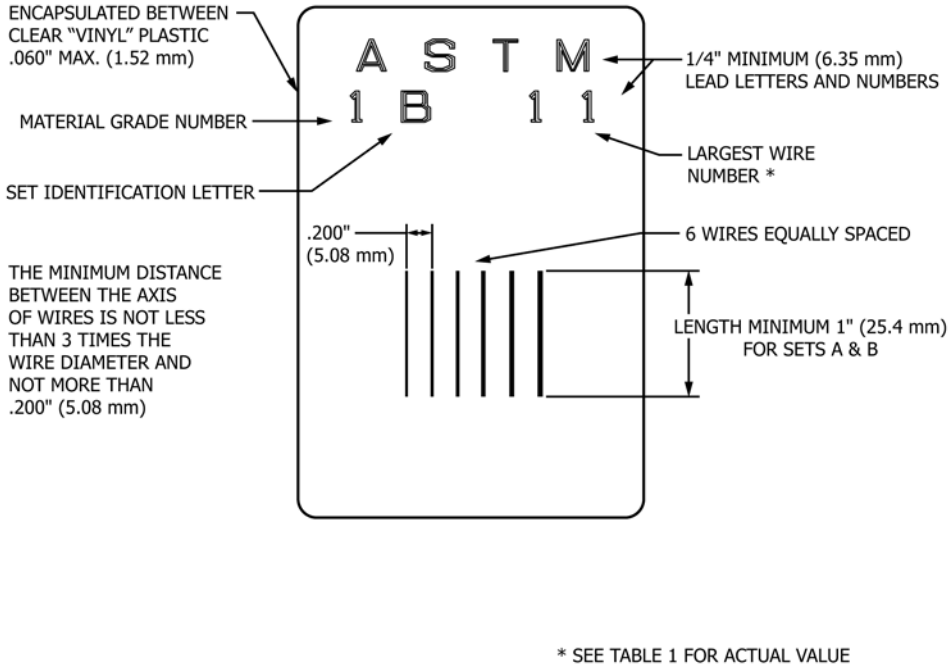


FIG. 4 Set B/Alternate 2

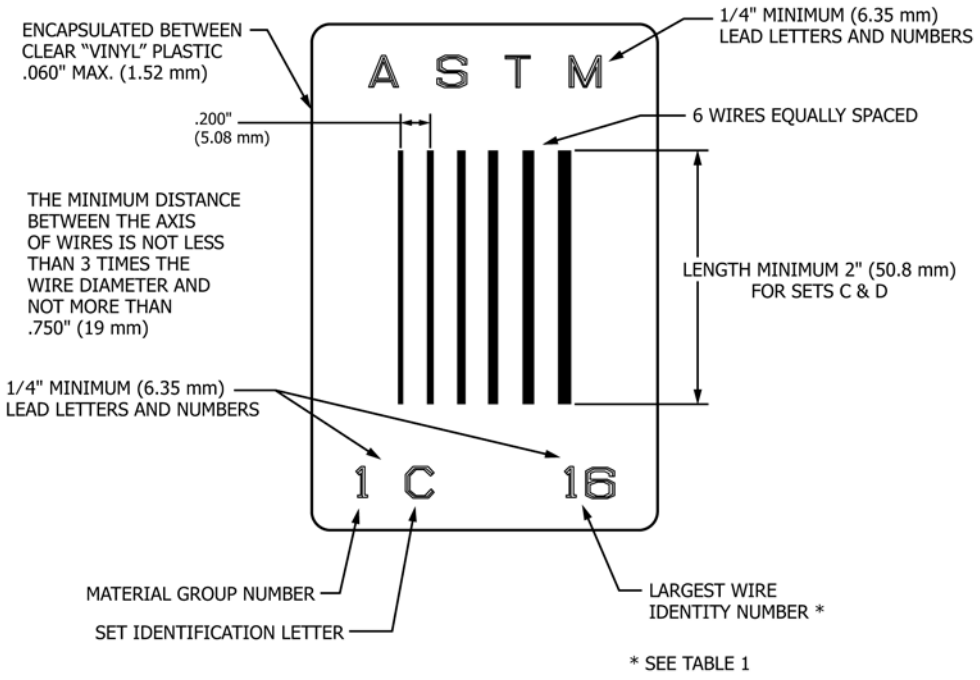


FIG. 5 Set C/Alternate 1

7.2.7 *Materials Group 4:*

7.2.7.1 Image quality indicators (IQI's) shall be made of 70 to 30 nickel-copper alloy (Monel)[8] (Class A or B of Specification B164) or equivalent, or 70 to 30 copper-nickel alloy (Alloy G of Specification B161) or equivalent.

7.2.7.2 Use on nickel, copper, all nickel-copper series, or copper-nickel series of alloys, and all brasses (copper-zinc alloys). Group 4 IQI's may include the leaded brasses since leaded brass increases in attenuation with increase in lead content. This would be equivalent to using a lower group IQI.

7.2.8 *Materials Group 5:*

7.2.8.1 Image quality indicators (IQI's) shall be made of tin bronze (Alloy D of Specification B139/B139M).

[8] Monel is a registered trademark of The International Nickel Co., Inc., Huntington,, WV 25720.

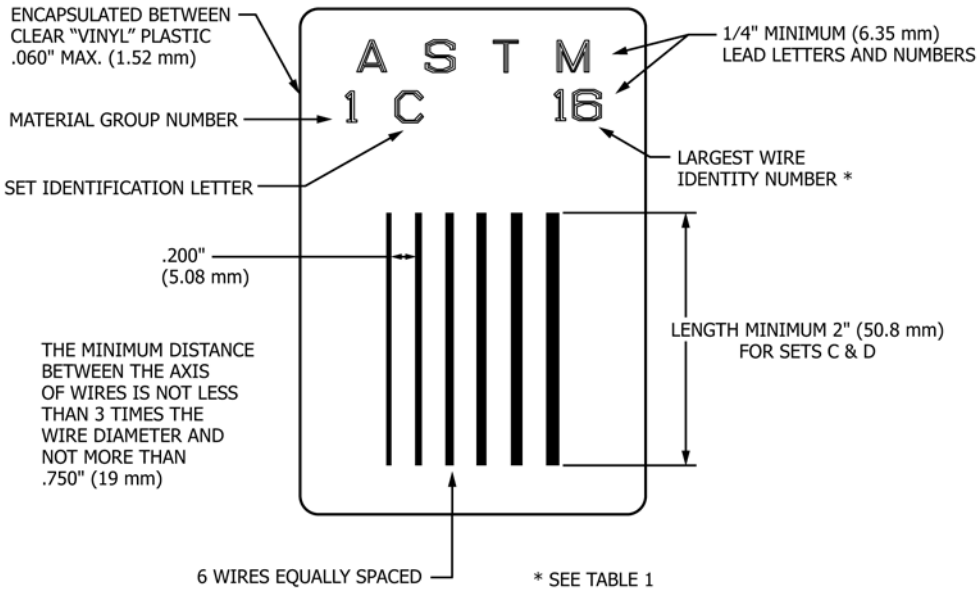


FIG. 6 Set C/Alternate 2

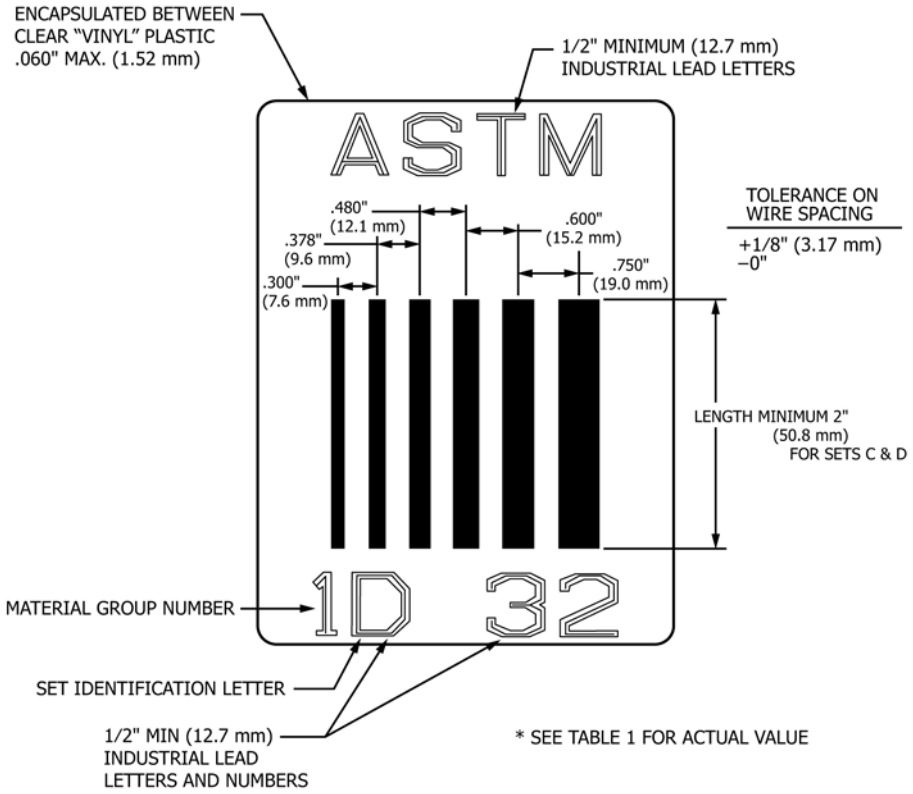


FIG. 7 Set D/Alternate 1

7.2.8.2 Use on tin bronzes including gun-metal and valve bronze, or leaded-tin bronze of higher lead content than valve bronze. Group 5 IQI's may include bronze of higher lead content since leaded bronze increases in attenuation with increase in lead content. This would be equivalent to using a lower group IQI.

NOTE 1—In developing the eight listed materials groups, a number of other trade names or other nominal alloy designations were evaluated. For the purpose of making this practice as useful as possible, these materials are listed and categorized, by group, as follows:

(*1*) *Group 2*—Haynes Alloy IN-100.[9]

(*2*) *Group 3*—Haynes Alloy No. 713C, Hastelloy D[10], G.E. Alloy SEL,

[9] All Haynes alloys are registered trademarks of Union Carbide Corp., New York, NY.

[10] All Hastelloys and Haynes Stellite alloys are registered trademarks of the Cabot Corp., Boston, MA.

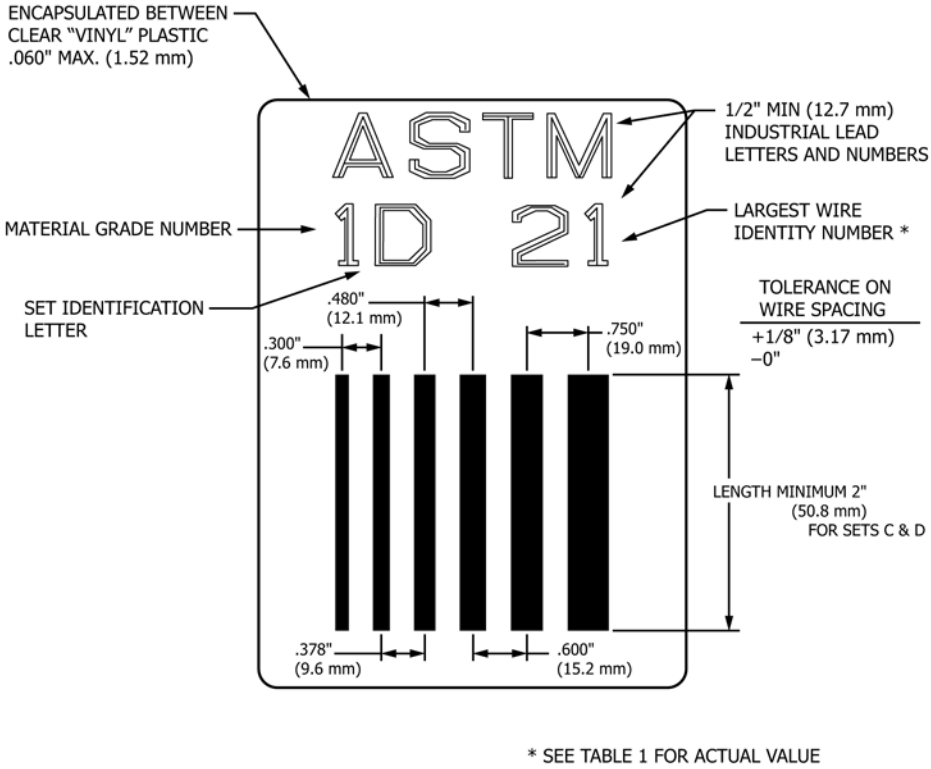


FIG. 8 Set D/Alternate 2

Haynes Stellite Alloy No. 21, GMR-235 Alloy, Haynes Alloy No. 93, Inconel X[7], Inconel 718, and Haynes Stellite Alloy No. S-816.

(*3*) *Group 4*—Hastelloy Alloy F, Hastelloy Alloy X, and Multimeter Alloy Rene 41.

(*4*) *Group 5*—Alloys in order of increasing attenuation: Hastelloy Alloy B, Hastelloy Alloy C, Haynes Stellite Alloy No. 31, Thetaloy, Haynes Stellite No. 3, Haynes Alloy No. 25. Image quality indicators (IQI's) of any of these materials are considered applicable for the materials that follow it.

NOTE 2—The committee formulating these recommendations recommend other materials may be added to the materials groups listed as the need arises or as more information is gained, or that additional materials groups may be added.

7.3 *Method for Other Materials:*

7.3.1 For materials not herein covered, IQI's of the same materials, or any other material, may be used if the following requirements are met. Two blocks of equal thickness, one of the material to be examined (production material) and one of the IQI material, shall be radiographed on one film by one exposure at the lowest energy level to be used for production. Transmission densitometer measurements of the radiographic image of each material shall be made. The density of each image shall be between 2.0 and 4.0. If the image density of the IQI material is within 1.00 to 1.15 times (–0 % to + 15 %) the image density of the production material, IQI's made of that IQI material may be used in radiography of that production material. The percentage figure is based on the radiographic density of the IQI material.

7.3.2 It shall always be permissible to use IQI's of similar composition as the material being examined.

8. Image Quality Indicator (IQI) Certification

8.1 Documents shall be provided by the IQI manufacturer attesting to the following:

8.1.1 IQI identification alternate, if used.

8.1.2 Material type.

8.1.3 Conformance to specified tolerances for dimensional values.

8.1.4 ASTM standard designation, for example, ASTM E747—(year designation) used for manufacturing.

9. Precision and Bias

9.1 *Precision and Bias*—No statement is made about the precision or bias for indicating the quality of images since the results merely state whether there is conformance to the criteria for success specified in this practice.

10. Keywords

10.1 density; image quality level; IQI; radiologic; radiology; X-ray and gamma radiation

ANNEX

(Mandatory Information)

A1. ALTERNATE IQI IDENTIFICATION

A1.1 The use of IQI's with identifications as shown on Figs. A1.1-A1.9 and as listed in Table A1.1 is permitted as an acceptable alternate provided all other requirements of Practice E747 are satisfied.

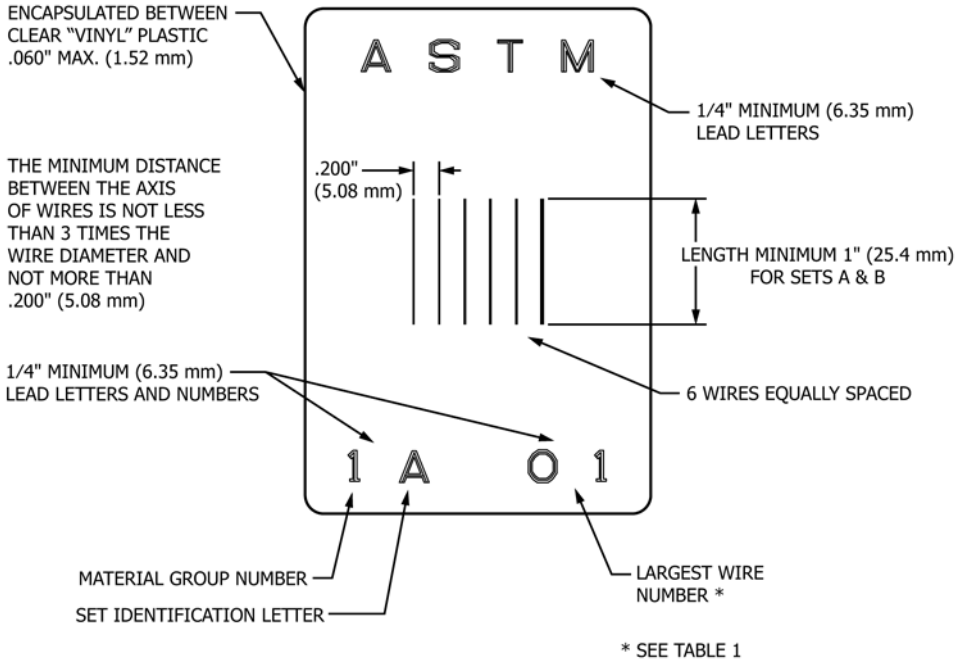


FIG. A1.1 Set A/Alternate 1

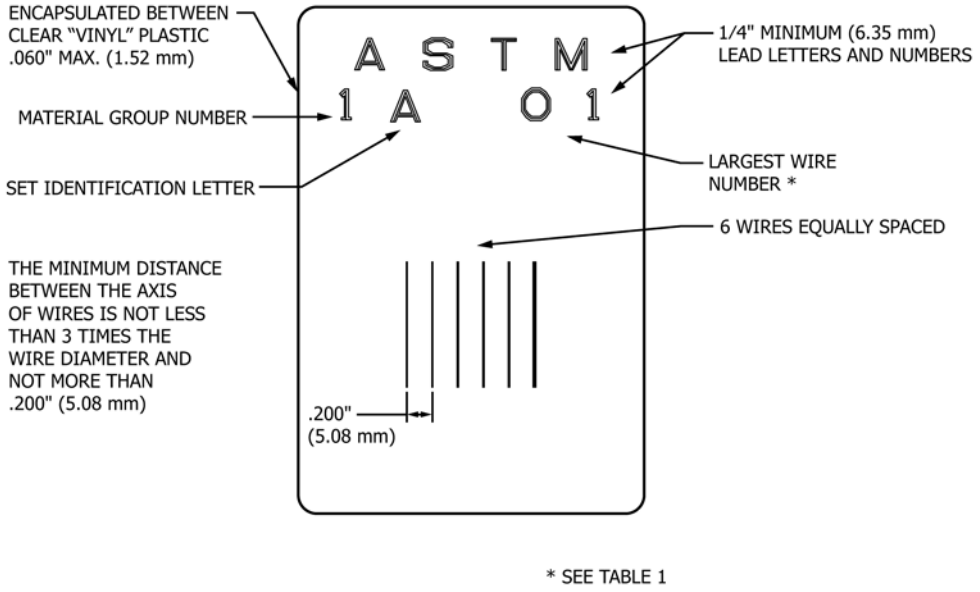


FIG. A1.2 Set A/Alternate 2

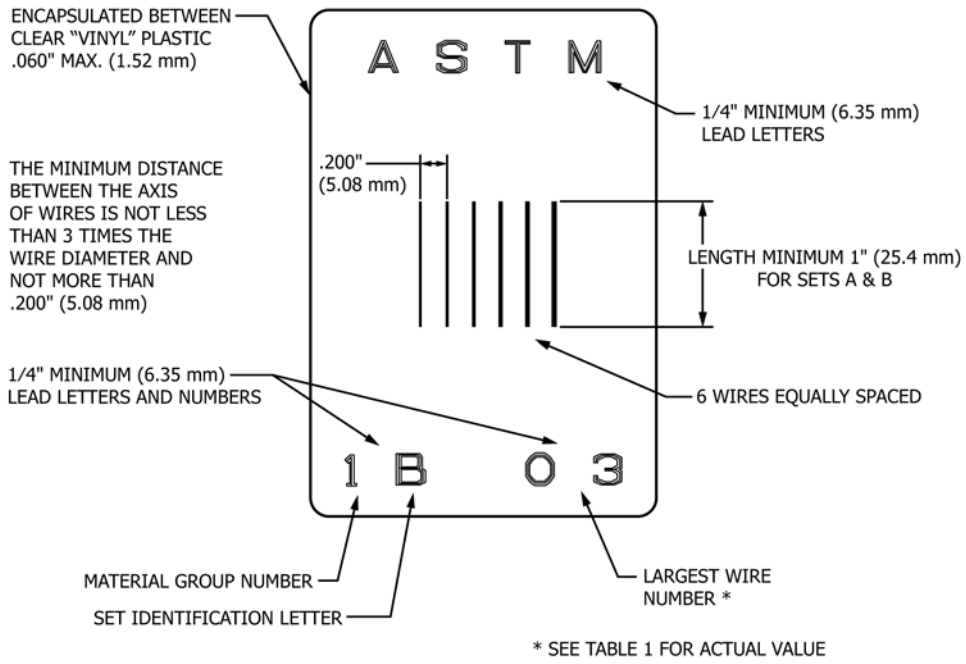


FIG. A1.3 Set B/Alternate 1

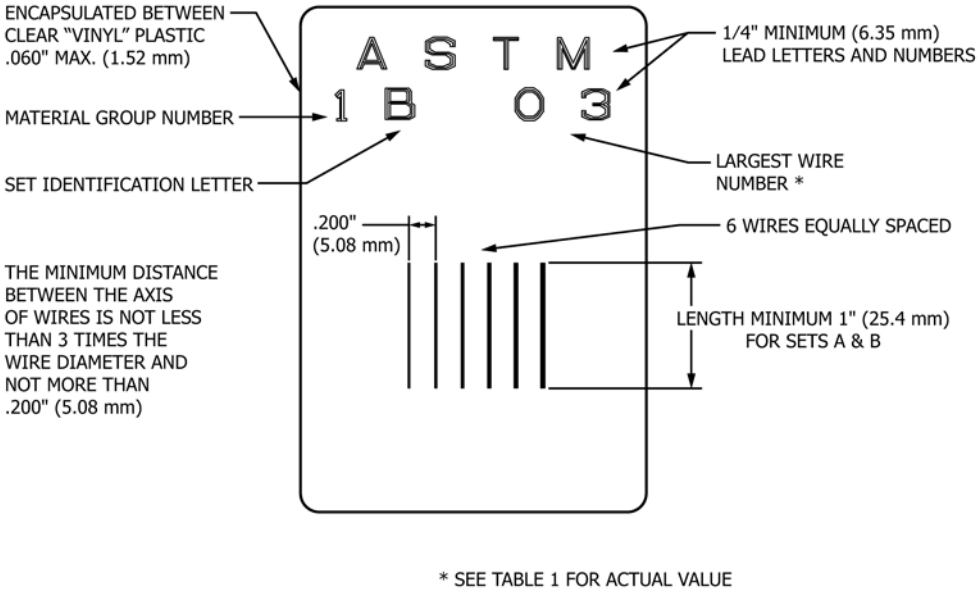


FIG. A1.4 Set B/Alternate 2

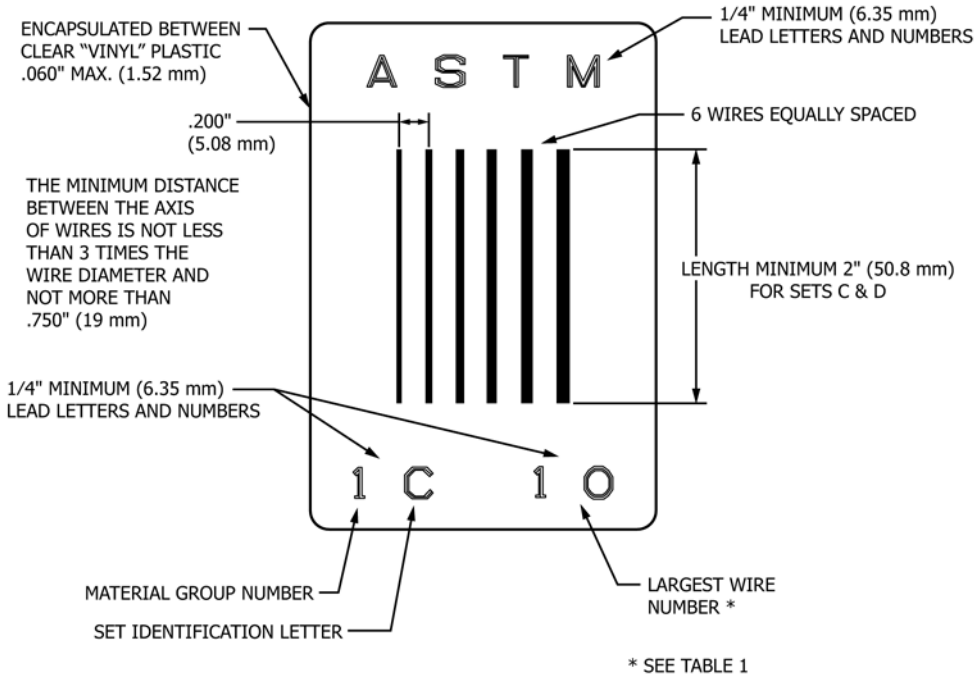


FIG. A1.5 Set C/Alternate 1

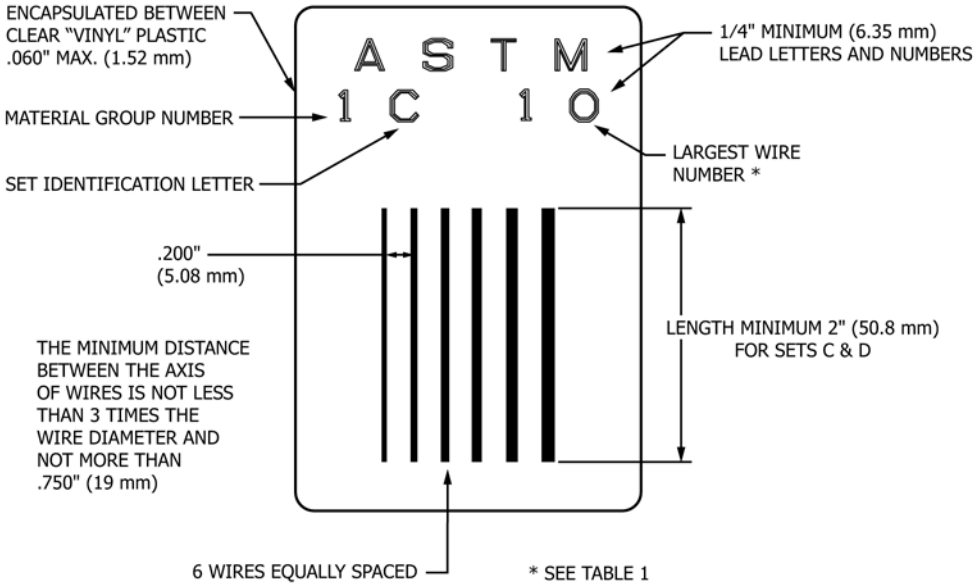


FIG. A1.6 Set C/Alternate 2

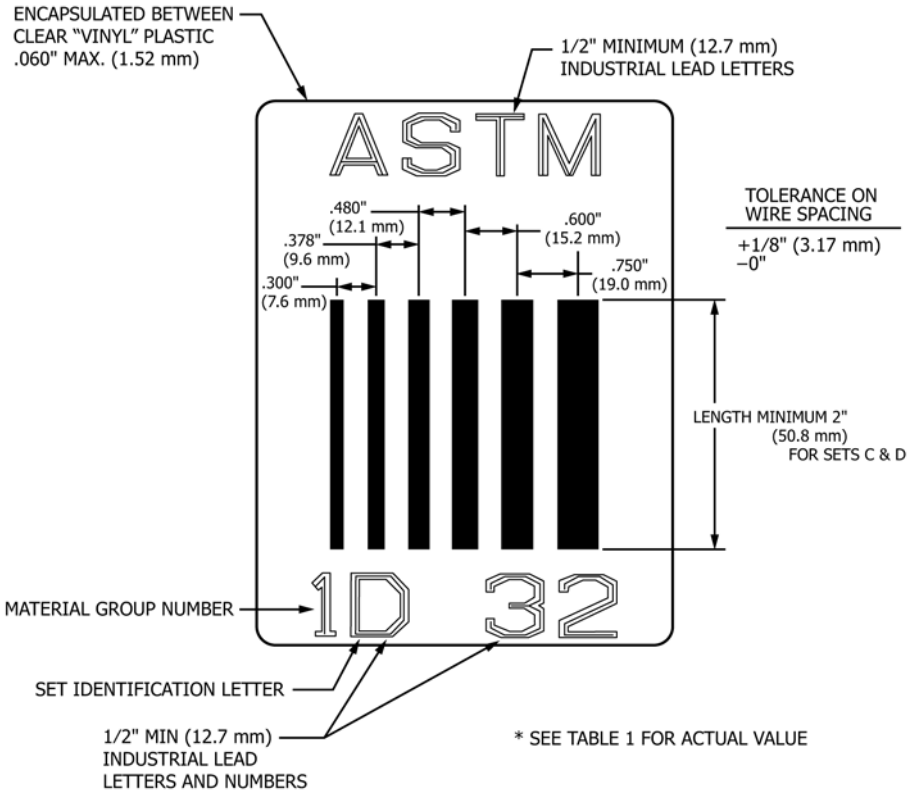


FIG. A1.7 Set D/Alternate 1

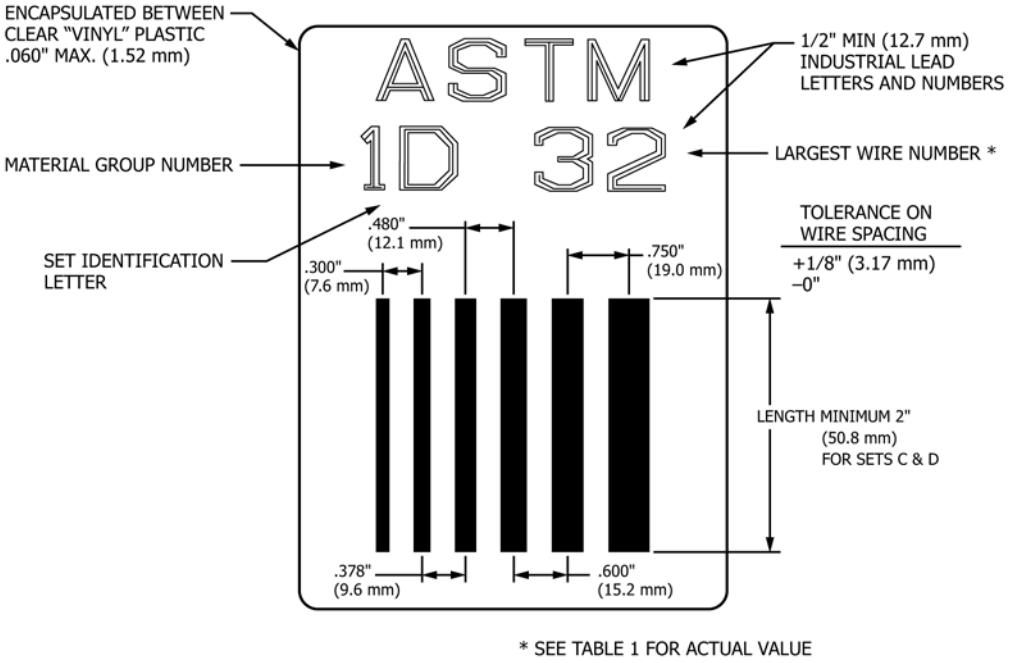
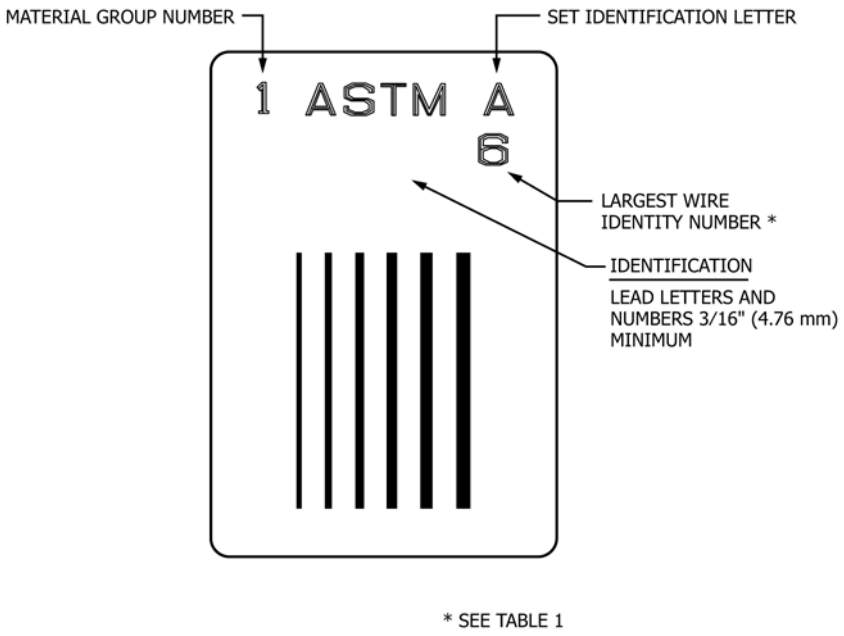


FIG. A1.8 Set D/Alternate 2



NOTE 1—All other IQI requirements as shown on Figs. 1-8 or Figs. A1.1-A1.8 apply.

FIG. A1.9 Alternate Identification Locations and Letter, Number Size-Typical All Sets (A, B, C, D)

TABLE A1.1 Penetrameter Sizes
Wire Diameter in. (mm)

SET A	ASTM Wire Identity	CEN Alternate Wire No. EN 462-1[A]	SET B	ASTM Wire Identity	CEN Alternate Wire No. EN 462-1[A]
0.0032(0.08)	1	W 17	0.010(0.25)	6	W 12
0.0040(0.1)	2	W 16	0.013(0.33)	7	W 11
0.0050(0.13)	3	W 15	0.016(0.41)	8	W 10
0.0063(0.16)	4	W 14	0.020(0.51)	9	W 9
0.0080(0.2)	5	W 13	0.025(0.64)	10	W 8
0.010(0.25)	6	W 12	0.032(0.81)	11	W 7
SET C	**ASTM Wire Identity**	**CEN Alternate Wire No. EN 462-1[A]**	**SET D**	**ASTM Wire Identity**	**CEN Alternate Wire No. EN 462-1[A]**
0.032(0.81)	11	W 7	0.100(2.5)	16	W 2
0.040(1.02)	12	W 6	0.126(3.2)	17	W 1
0.050(1.27)	13	W 5	0.160(4.06)	18	...
0.063(1.6)	14	W 4	0.20(5.1)	19	...
0.080(2.03)	15	W 3	0.25(6.4)	20	...
0.100(2.50)	16	W 2	0.32(8.1)	21	...

[A]As governed under provisions of paragraph 4.1.5 of this practice.

APPENDIX

(Nonmandatory Information)

X1. CALCULATING OTHER EQUIVALENTS

X1.1 The equation to determine the equivalencies between wire and (hole type) IQI's is as follows:

$$F^{3}d^{3}l = T^{2}H^{2}(\pi/4)$$

where:

F = form factor for wire, 0.79,
d = wire diameter, in. (mm),
l = effective length of wire, 0.3 in. (7.6 mm),
T = plaque thickness, in. (mm), and
H = diameter of hole, in. (mm).

X1.2 It should be noted that the wire and plaque (hole type) IQI sensitivities cannot be related by a fixed constant.

X1.3 Figs. X1.1 and X1.2 are conversion charts for hole type IQI's containing 1T and 2T holes to wires. The sensitivities are given as a percentage of the specimen thickness.

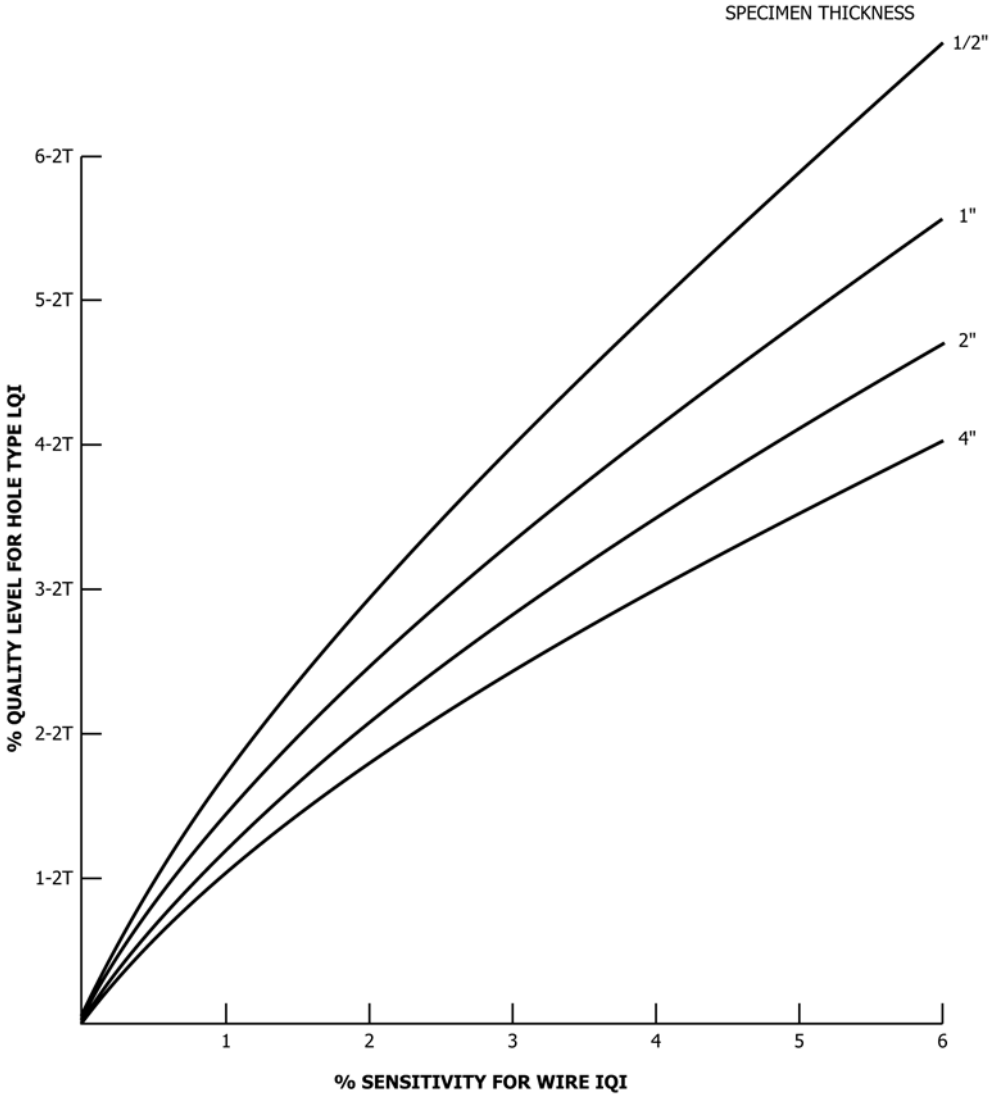


FIG. X1.1 Conversion Chart for 2-T Quality Level Holes to % Wire Sensitivity

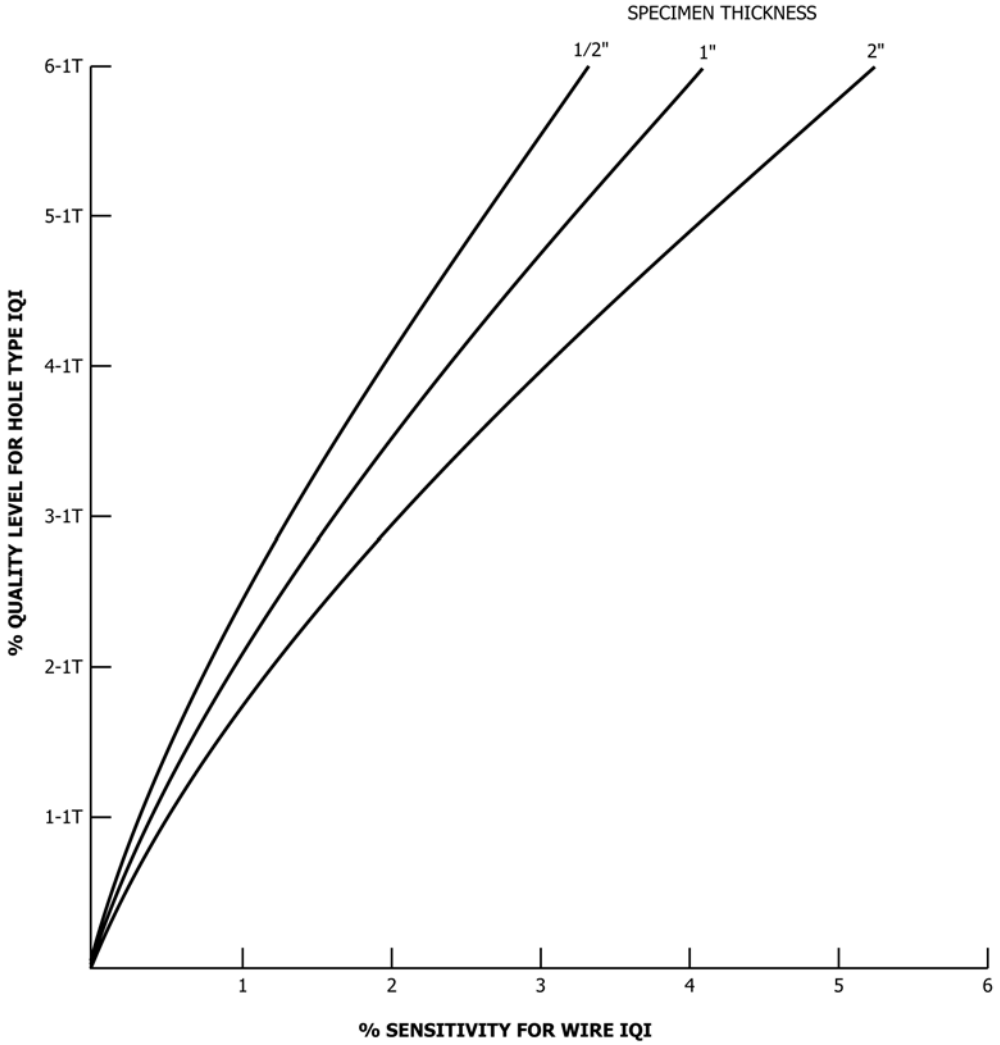


FIG. X1.2 Conversion Chart for 1-T Quality Level Holes to % Wire Sensitivity