Designation: E 1025 – 98

An American National Standard

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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# Standard Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology[1]

This standard is issued under the fixed designation E 1025; 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 hole-type 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 The values stated in inch-pound units are to be regarded as standard.

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. Referenced Documents

2.1 *ASTM Standards:*

B 139 Specification for Phosphor Bronze Rod, Bar, and Shapes[3]

B 150 Specification for Aluminum Bronze Rod, Bar, and Shapes[3]

B 161 Specification for Nickel Seamless Pipe and Tube[4]

B 164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire[4]

B 166 Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, and N06690) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire[4]

E 1316 Terminology for Nondestructive Examinations[5]

## 3. Terminology

3.1 *Definitions*—The definitions of terms relating to gamma and x-radiology in Terminology E 1316, Section D, shall apply to the terms used in this practice.

## 4. Hole-Type IQI Requirements

4.1 Image quality indicators (IQIs) used to determine radiologic-image quality levels shall conform to the following requirements.

4.1.1 *Standard Hole-Type IQIs*:

4.1.1.1 Image quality indicators (IQIs) shall be fabricated from materials or alloys identified or listed in accordance with 7.3. Other materials may be used in accordance with 7.4.

4.1.1.2 Image quality indicators (IQIs) shall dimensionally conform to the requirements of Fig. 1.

4.1.1.3 Both the rectangular and the circular IQI shall be identified with number(s) made of lead or a material of similar radiation opacity. The number shall be bonded to the rectangular IQI's and shall be placed adjacent to circular IQI's to provide identification of the IQI on the image. The identification numbers shall indicate the thickness of the IQI in thousandths of an inch, that is, a number 10 IQI is 0.010 in. thick, a number 100 IQI is 0.100 in. thick, etc. Additional identification requirements are provided in 7.2.

4.1.1.4 Alloy-group identification shall be in accordance with Fig. 2. Rectangular IQI's shall be notched. Image quality indicators (IQI's) shall be vibrotooled or etched as specified.

4.1.2 *Modified Hole-Type IQI*:

4.1.2.1 The rectangular IQI may be modified in length and width as necessary for special applications, provided the hole size(s) and IQI thickness conform to Fig. 1.

4.1.2.2 The IQI's shall be identified as specified in 4.1.1.3, except that the identification numbers may be placed adjacent to the IQI if placement on the IQI is impractical.

4.1.2.3 When modified IQI's are used, details of the modification shall be documented in the records accompanying the examination results.

## 5. 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 and alloy(s).

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[1] This practice is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on Radiographic Practice and Penetrameters.

Current edition approved July 10, 1998. Published December 1998. Originally published as E 1025 – 84. Last previous edition E 1025 – 95.

[2] For ASME Boiler and Pressure Vessel Code applications see related Practice SE-1025 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 02.01.

[4] *Annual Book of ASTM Standards*, Vol 02.04.

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



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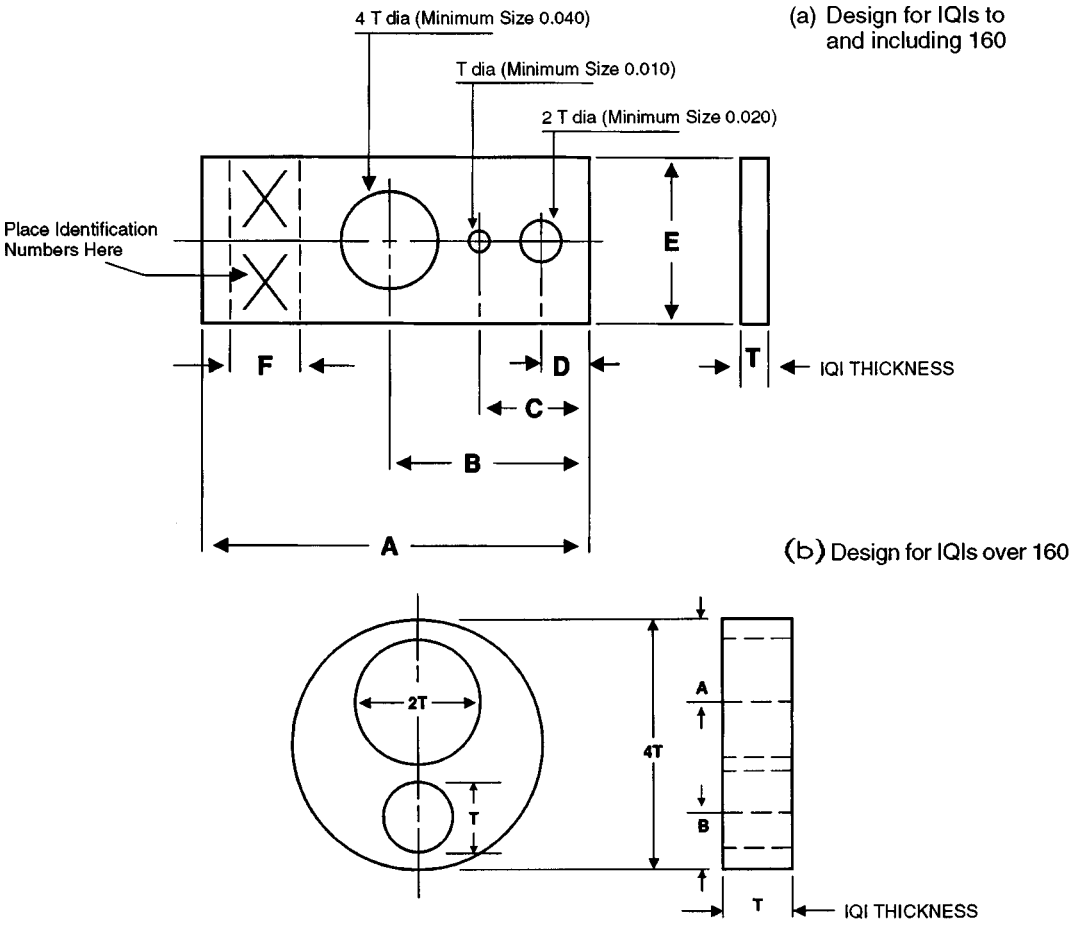


NOTE 1—All dimensions in inches (Note 6).
NOTE 2—Tolerances for IQI thickness and hole diameter.
NOTE 3—*XX* identification number equals *T* in .001 inches.
NOTE 4—IQIs No. 1 through 9 are not 1*T*, 2*T*, and 4*T*.
NOTE 5—Holes shall be true and normal to the IQI. Do not chamfer.
NOTE 6—To convert inch dimensions to metric, multiply by 25.4.

| Identification Number *T* (Note 3) | A | B | C | D | E | F | Tolerances (Note 2) |
|---|---|---|---|---|---|---|---|
| 1–4 | 1.500 ±0.015 | 0.750 ±0.015 | 0.438 ±0.015 | 0.250 ±0.015 | 0.500 ±0.015 | 0.250 ±0.030 | ±10% |
| 5–20 | 1.500 ±0.015 | 0.750 ±0.015 | 0.438 ±0.015 | 0.250 ±0.015 | 0.500 ±0.015 | 0.250 ±0.030 | ±0.0005 |
| 21–50 | ... | ... | ... | ... | ... | ... | ±0.0025 |
| Over 50–160 | 2.250 ±0.030 | 1.375 ±0.030 | 0.750 ±0.030 | 0.375 ±0.030 | 1.000 ±0.030 | 0.375 ±0.030 | ±0.005 |
| Over 160 | 1.330T ±0.005 | 0.830T ±0.005 | ... | ... | ... | ... | ±0.010 |

**FIG. 1 IQI Design**

NOTE 1—This practice does not recommend or suggest specific IQI sets to be procured. Section 5 is an aid in selecting IQI's based on specific needs.

## 6. Image Quality Levels

6.1 Image quality levels are designated by a two part expression *X-YT*. The first part of the expression *X* refers to the IQI thickness expressed as a percentage of the specimen thickness. The second part of the expression *YT* refers to the diameter of the hole and is expressed as a multiple of the IQI thickness, *T*. The image quality level 2-2*T* means that the IQI thickness *T* is 2 % of the specimen thickness and that the diameter of the IQI imaged hole is 2 × the IQI thickness.

NOTE 2—Image Quality Indicators (IQI's) less than number 10 have hole sizes 0.010, 0.020, and 0.040 in. diameter regardless of the IQI



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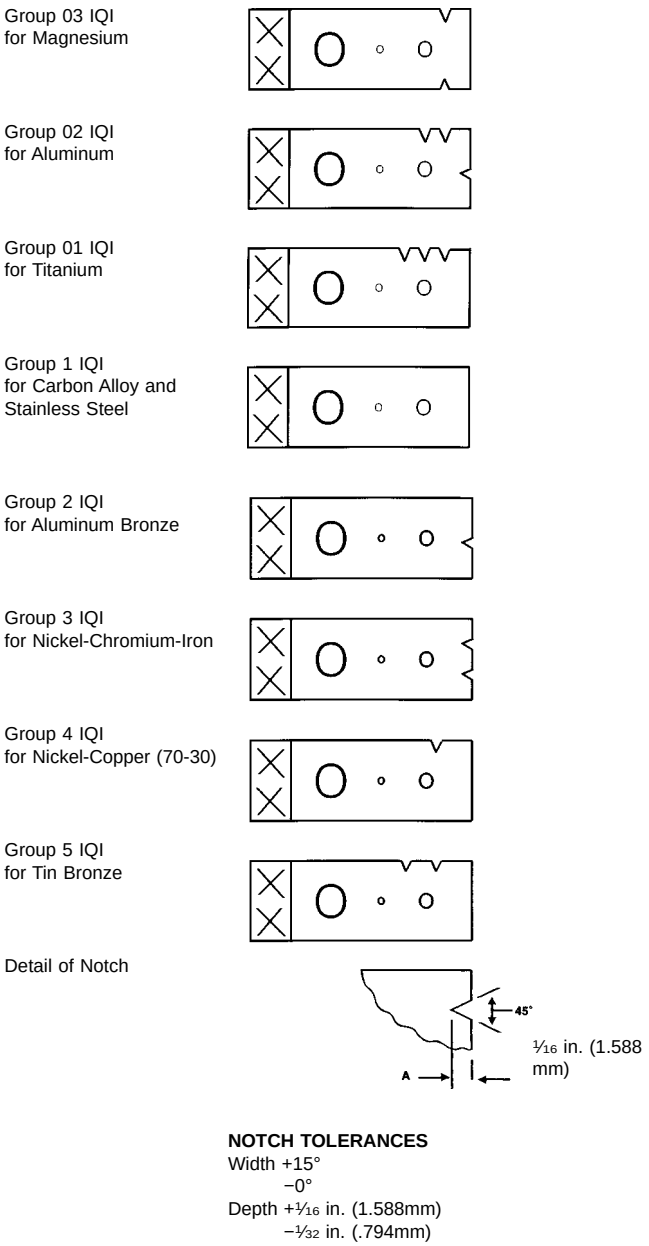


**FIG. 2 Rectangular IQI Notch Identification and Material Grouping**

thickness. Therefore, IQI's less than number 10 do not represent the quality levels specified in 6.1 and Table 1. The equivalent sensitivity can be computed from data furnished in Appendix X1.

6.2 Typical image quality level designations are shown in Table 1. The level of inspection specified should be based on service requirements of the product. Care should be taken in specifying image quality levels 2-1*T*, 1-1*T*, and 1-2*T* by first determining that these levels can be maintained in production.

6.3 In specifying image quality levels, the contract, purchase order, product specification, or drawing should state the proper two-part expression and clearly indicate the thickness of the metal to which the level refers. In place of a designated two–part expression, the IQI number and minimum discernible hole size shall be specified.

## 7. Material Groups

7.1 *General*:

**TABLE 1 Typical Image Quality Levels**

| Image Quality Levels | IQI Thickness | Minimum Preceptible Hole Diameter | Equivalent IQI Sensitivity, %[A] |
|---|---|---|---|
| **Standard Image Quality Levels** | | | |
| 2-1*T* | 1/50 (2 %) of Specimen Thickness | 1*T* | 1.4 |
| 2-2*T*[B] | | 2*T* | 2.0 |
| 2-4*T* | | 4*T* | 2.8 |
| **Special Image Quality Levels** | | | |
| 1-1*T* | 1/100 (1 %) of Specimen Thickness | *1T* | 0.7 |
| 1-2*T* | | 2*T* | 1 |
| 4-2*T* | 1/25(4 %) of Specimen Thickness | 2*T* | 4 |

[A]Equivalent IQI sensitivity is that thickness of the IQI, expressed as a percentage of the part thickness, in which the 2*T* hole would be visible under the same conditions.

[B]For *Level* 2-2*T Radiologic*—The 2*T* hole in an IQI, 1/50(2 %) of the specimen thickness, is visible.

7.1.1 Materials have been designated in eight groups based on their radiation 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 (A1), 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.

NOTE 3—These groups were established experimentally at 180 kV on 3/4-in. (19-mm) thick specimens. They apply from 125 kV to the multivolt range.

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 *Identification System*:

7.2.1 A notching system has been designated for the eight groups of IQI's and is shown in Fig. 2.

7.2.2 For circular IQI's, a group designation shall be vibro-tooled or chemically etched on the IQI to identify it by using the letter" G" followed by the group number, that is, G4 for a Group 4 IQI. For identification of the group on the image, corresponding lead characters shall be placed adjacent to the circular IQI, just as is done with the lead numbers identifying the thickness. The identification is shown in Fig. 3.

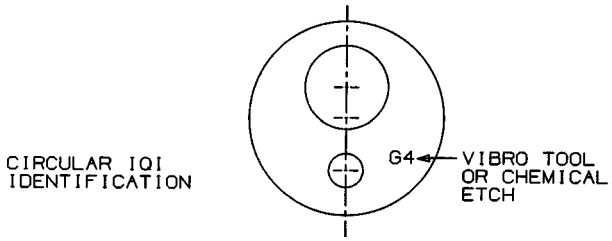


**FIG. 3 Circular IQI Identification**



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7.3 *Materials Groups*:

7.3.1 *Materials Group* 03:

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

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

7.3.2 *Materials Group* 02:

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

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

7.3.3 *Materials Group* 01:

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

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

7.3.4 *Materials Group* 1:

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

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

7.3.5 *Materials Group* 2:

7.3.5.1 Image quality indicators (IQI's) shall be made of aluminum bronze (Alloy No. 623, of Specification B 150 or equivalent, or nickel-aluminum bronze (Alloy No. 630 of Specification B 150) or equivalent.

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

7.3.6 *Materials Group* 3:

7.3.6.1 Image quality indicators (IQI's) shall be made of nickel-chromium-iron alloy (UNS No. NO6600) (Inconel).[7] (See Specification B 166.)

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

7.3.7 *Materials Group* 4:

7.3.7.1 Image quality indicators (IQI's) shall be made of 70 to 30 nickel-copper alloy (Monel)[8] (Class A or B of Specification B 164) or equivalent, or 70 to 30 copper-nickel alloy, (Alloy G of Specification B 161) or equivalent.

7.3.7.2 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 be used on the leaded brasses, since leaded brass increases in attenuation with increase in lead content. This would be equivalent to using a lower group IQI.

7.3.8 *Materials Group* 5:

7.3.8.1 Image quality indicators (IQI's) shall be made of tin bronze (Alloy D of Specification B 139).

7.3.8.2 Use on tin bronzes including gun-metal and valve bronze, leaded-tin bronze of higher lead content than valve bronze. Group 5 IQI's may be used on 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 4—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, Haynes Stellite Alloy No. 21,[10] 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. IQIs of any of these materials are considered applicable for the materials that follow it.

NOTE 5—The committee formulating these recommendations, recommended 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.

7.4 *Radiographic Method for Other Materials*:

7.4.1 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 readings for both materials shall be read from the film and shall be between 2.0 and 4.0 (radiographic) density for both materials. If the radiographic image density of the material from which the IQI's are to be fabricated is within +15 to −0 % of the radiographic image density of the production material, the IQI material may be used to fabricate IQI's for examination of the production material. The percentage figure is based on the radiographic density of the IQI material.

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

## 8. IQI Certification

8.1 Records shall be available that attest to the conformance of the material type, grouping (notches), and dimensional tolerances of the IQI's specified by this practice.

## 9. Precision and Bias

9.1 *Precision and Bias*—No statement is made about the precision or bias for indicating the quality of radiographs 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

[6] Superston is a registered trademark of Superston Corp., Jersey City, NJ.
[7] Inconel is a registered trademark of The International Nickel Co., Inc., Huntington, WV 25720.
[8] Monel is a registered trademark of The International Nickel Co., Inc., Huntington, WV 25720.
[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 Cabot Corp., Boston, MA.



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# APPENDIX

**(Nonmandatory Information)**

## X1. EQUIVALENT IQI (PENETRAMETER) SENSITIVITY (EPS)[11]

X1.1 To find the equivalent IQI sensitivity (percent), the hole size (diameter in inches), of the IQI thickness (inches), for a section thickness (inches), the following computations may be used:

where:

$$\alpha = \frac{100}{X}\sqrt{\frac{TH}{2}},$$

$\alpha$ = equivalent IQI sensitivity, %,
$X$ = section thickness to be examined, in.,
$T$ = IQI Thickness, in., and
$H$ = hole diameter, in.

X1.2 Alternate method for determining EPS using Fig. X1.1 Nomograph:

Example:
Given:

$$X = 0.5 \text{ in.}, \quad (X1.1)$$
$$T = 0.005 \text{ in., and}$$
$$H = 0.0625 \text{ in.}$$

Solution:

$$A = \frac{100T}{X} = \frac{100 \times 0.005}{0.5} = 1.0\ \% \quad (X1.2)$$

$$B = \frac{100H}{X} = \frac{100 \times 0.0625}{0.5} = 12.5\ \% \quad (X1.3)$$

X1.3 Proceed to the nomograph (Fig. X1.1) and draw a line joining the 1.0 % Value A and the 12.5 % Value B and look on the center percent scale where the line crosses it and read the answer—2.5 %. Thus under the given conditions, equivalent IQI (penetrameter) sensitivity (EPS) is 2.5 %.

[11] O'Connor, D. T., and Criscuolo, E. L., "The Quality of Radiographic Inspection," *ASTM Bulletin*, ASTM, Vol 213, 1956, p. 52.



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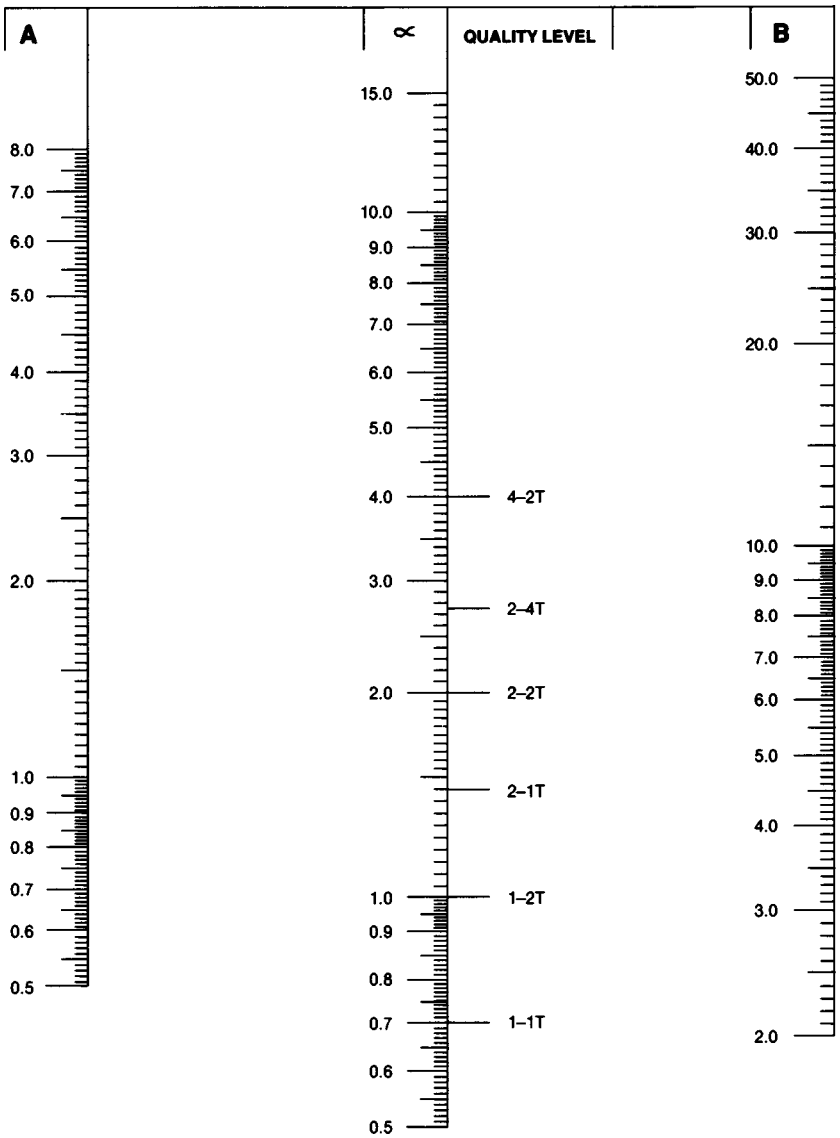


*Definitions:*

*A* equals the visible IQI (penetrameter) plaque thickness (*T*) expressed as a percentage of the section (object) thickness to be radiographed in (inches).

*B* equals the diameter of the smallest IQI (penetrameter) hole (*H*) for which the image is visibly expressed as a percentage of the section (object) thickness to be radiographed in (inches).

NOTE 1—The nomograph is used for computing equivalent IQI sensitivity from *T* (*T* equals penetrameter thickness) inches and *H* (*H* equals hole diameter) inches. Draw a straight line joining the values on any two scales, and look on the third scale where the line crosses and read the answer. Due to normal reproduction methods in producing the nomograph, some small error (that is, less than 5 %) may occur. If more accurate results are required, the formula in Appendix X1 should be used.

**FIG. X1.1 Equivalent I.Q.I (Penetrameter) Sensitivity Nomograph**

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