Designation: E 1647 – ~~98a~~03

An American National Standard

Standard Practice for Determining Contrast Sensitivity in ~~Radioscopy~~ Radiology[1]

This standard is issued under the fixed designation E 1647; 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 covers the design and material selection of a contrast sensitivity measuring gage used to determine the minimum change in material thickness or density that may be imaged without regard to spatial resolution limitations.

1.2 This practice is applicable to transmitted-beam radiographic and radioscopic imaging systems utilizing X-ray and gamma ray radiation sources.

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.* For specific safety statements, see NIST/ANSI Handbook 114 Section 8, Code of Federal Regulations 21 CFR 1020.40 and 29 CFR 1910.96.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

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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 ~~747 Practice~~ 94 Guide for ~~the Design Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used For Radiology~~ Radiographic Examination[5]
E ~~1316 Terminology~~ 747 Practice for ~~Nondestructive Examination~~ the Design Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used For Radiology[5]
E 1025 Practice for Hole-Type Image Quality Indicators Used for Radiography[5]
E ~~1411 Practice~~ 1316 Terminology for Nondestructive Examination[5]
E 1411 Practice for Qualification of Radioscopic Systems[5]
E 2002 Practice for Determining Total Image Unsharpness in Radiology[5]

2.2 *Federal Standards:*

21 CFR 1020.40 Safety Requirements for Cabinet X-ray Systems[6]
29 CFR 1910.96 Ionizing Radiation[6]

2.3 *NIST/ANSI Standards:*

NIST/ANSI Handbook 114 General Safety Standard for Installations Using Non-Medical X-ray and Sealed Gamma Ray Sources, Energies to 10 MeV[7]

2.4 *Other Standard:*[8]

EN 462 – 5 Duplex Wire Image Quality Indicator
EN 13068–1 Radioscopic Testing-Part 1: Qualitative Measurement of Imaging Properties

3. Terminology

3.1 *Definitions*—Definitions of terms applicable to this test method may be found in Terminology E 1316.

4. Summary of Practice

4.1 It is often useful to evaluate the contrast sensitivity of a penetrating radiation imaging system separate and apart from spatial resolution measurements. Conventional image quality indicators (IQI's), such as Test Method E 747 wire and Practice E 1025 plaque IQIs, combine the contrast sensitivity and resolution measurements into an overall performance figure of merit, other methods such as included in Practice E 2002 do not address contrast specifically. Such figures of merit are often not adequate to detect subtle changes in imaging system performance. For example, in a high contrast image, spatial resolution can degrade with almost no noticeable effect upon overall image quality. Similarly, in an application in which the imaging system provides a very sharp image, contrast can fade with little noticeable effect upon the overall image quality. These situations often develop and may go unnoticed until the system performance deteriorates below acceptable image quality limits.

5. Significance and Use

5.1 The contrast sensitivity gage measures contrast sensitivity independent of the imaging system spatial resolution limitations. The thickness recess dimensions of the contrast sensitivity gage are large with respect to the spatial resolution limitations of most imaging systems. Four levels of contrast sensitivity are measured: 4 %, 3 %, 2 %, and 1 %.

5.2 The contrast sensitivity gage is intended for use in conjunction with a high-contrast resolution measuring gage, such as the EN 462 – 5 Duplex Wire Image Quality Indicator. Such gages measure spatial resolution essentially independent of the imaging system's contrast sensitivity. Such measurements are appropriate for the qualification and performance monitoring of radiographic and radioscopic imaging systems.

5.3 Radioscopic/radiographic system performance may be specified by combining the measured contrast sensitivity expressed as a percentage with the spatial resolution expressed in millimeters of unsharpness. For the EN 462 – 5 spatial resolution gage, the unsharpness is equal to twice the wire diameter. For the line pair gage, the unsharpness is equal to the reciprocal of the line-pair/mm value. As an example, an imaging system that exhibits 2 % contrast sensitivity and images the 0.1 mm EN 462 – 5 paired wires (equivalent to imaging 5 line-pairs/millimeter resolution on a line-pair gage) performs at a 2 %–0.2 mm sensitivity level. A standard method of evaluating overall radioscopic system performance is given in Practice E 1411 and in EN 13068–1.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.
[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.
[6] Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.
[7] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.
[8] Available from British Standards Institute, 2 Park Street, London, England W1A2B5.

6. Contrast Sensitivity Gage Construction and Material Selection

6.1 Contrast sensitivity gages shall be fabricated in accordance with Fig. 1, using the dimensions given in Table 1, Table 2, and Table 3.

6.2 The gage shall preferably be fabricated from the ~~test~~ examination object material. Otherwise, the following material selection guidelines are to be used:

6.2.1 Materials are designated in eight groupings, in accordance with their penetrating radiation absorption characteristics: groups 03, 02, and 01 for light metals and groups 1 through 5 for heavy metals.

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

6.2.3 The heavy metals group, steel, copper base, nickel base, and other alloys are identified 1 through 5. The materials increase in radiation absorption with increasing numerical designation.

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

6.3 The materials from which the contrast sensitivity gage is to be made is designated by group number. The gage is applicable to all materials in that group. Material groupings are as follows:

6.3.1 *Material Group 03*:

6.3.1.1 The gage shall be made of magnesium or a magnesium alloy, provided it is no more radio-opaque than unalloyed magnesium, as determined by the method outlined in 6.4.

6.3.1.2 Use for all alloys where magnesium is the predominant alloying constituent.

6.3.2 *Materials Group 02*:

6.3.2.1 The gage shall be made of aluminum or an aluminum alloy, provided it is no more radio-opaque than unalloyed aluminum, as determined by the method outlined in 6.4.

6.3.2.2 Use for all alloys where aluminum is the predominant alloying constituent.

6.3.3 *Materials Group 01*:

6.3.3.1 The gage shall be made of titanium or a titanium alloy, provided it is no more radio-opaque than unalloyed titanium, as determined by the method outlined in 6.4.

6.3.3.2 Use for all alloys where titanium is the predominant alloying constituent.

6.3.4 *Materials Group 1*:

6.3.4.1 The gage shall be made of carbon steel or Type 300 series stainless steel.

6.3.4.2 Use for all carbon steel, low-alloy steels, stainless steels, and magnesium-nickel-aluminum bronze (Superston[9]).

6.3.5 *Materials Group 2*:

6.3.5.1 The gage 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.

6.3.5.2 Use for all aluminum bronzes and all nickel aluminum bronzes.

6.3.6 *Materials Group 3*:

6.3.6.1 The gage shall be made of nickel-chromium-iron alloy (UNS No. N06600) (Inconel[10]). See Specification B 166.

6.3.6.2 Use for nickel-chromium-iron alloy and 18 % nickel-maraging steel.

6.3.7 *Materials Group 4*:

6.3.7.1 The gage shall be made of 70 to 30 nickel-copper alloy (Monel[11]) (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.

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

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

[11] 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.

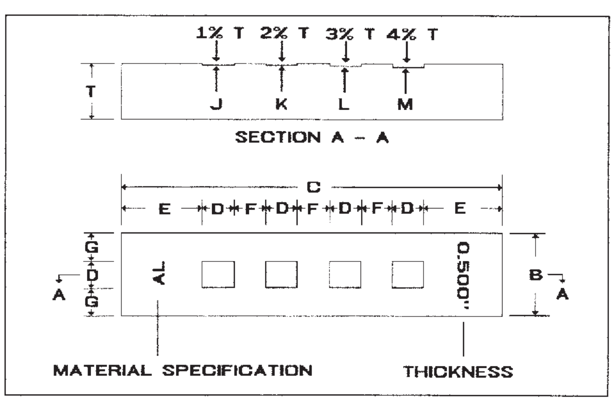

FIG. 1 General Layout of the Contrast Sensitivity Gage

TABLE 1 Design of the Contrast Sensitivity Gage

Gage Thickness	J Recess	K Recess	L Recess	M Recess
T	1 % of T	2 % of T	3 % of T	4 % of T

TABLE 2 Contrast Sensitivity Gage Dimensions

Gage Size	B DIM.	C DIM.	D DIM.	E DIM.	F,G DIM.
1	0.750 in.	3.000 in.	0.250 in.	0.625 in.	0.250 in.
	19.05 mm	76.20 mm	6.35 mm	15.88 mm	6.35 mm
2	1.500 in.	6.000 in.	0.500 in.	1.250 in.	0.500 in.
	38.10 mm	152.40 mm	12.70 mm	31.75 mm	12.7 mm
3	2.250 in.	9.000 in.	0.750 in.	1.875 in.	0.750 in.
	57.15 mm	228.60 mm	19.05 mm	47.63 mm	19.05 mm
4	3.000 in.	12.000 in.	1.000 in.	2.500 in.	1.000 in.
	76.20 mm	304.80 mm	25.40 mm	63.50 mm	25.4 mm

TABLE 3 Contrast Sensitivity Gage Application

Gage Size	Use on Thicknesses
1	Up to 1.5 in. (38.1 mm)
2	Over 1.5 in. (38.1 mm) to 3.0 in. (76.2 mm)
3	Over 3.0 in. (76.2 mm) to 6.0 in. (152.4 mm)
4	Over 6.0 in. (152.4 mm)

6.3.7.2 Use for nickel, copper, all nickel-copper series or copper-nickel series of alloys and all brasses (copper-zinc alloys) and all leaded brasses.

6.3.8 *Materials Group 5*:

6.3.8.1 The gage shall be made of tin-bronze (Alloy D of Specification B 139).

6.3.8.2 Use for tin bronzes including gun-metal and valve bronze and leaded-tin bronzes.

6.4 Where the material to be examined is a composite, ceramic, or other non-metallic material, or for some reason cannot be obtained to fabricate a gage, an equivalent material may be utilized, provided it is no more radio-opaque than the ~~test~~ examination object under comparable penetrating radiation energy conditions. To determine the suitability of a substitute material, radiograph identical thicknesses of both materials on one film using the lowest penetrating radiation energy to be used in the actual examination. Transmission densitometer readings for both materials shall be in the range from 2.0 to 4.0. If the radiographic density of the substitute material is within + 15 % to − 0 % of the ~~test~~ examination material, the substitute material is acceptable.

6.4.1 All contrast sensitivity gages shall be suitably marked by vibro-engraving or etching. The gage thickness and material type shall be clearly marked.

7. Imaging System Performance Levels

7.1 Imaging system performance levels are designated by a two-part measurement expressed as C(%) − U(mm). The first part of the expression C(%) refers to the depth of the shallowest flat-bottom hole that can be reliably and repeatably imaged. The second part of the expression refers to the companion spatial resolution measurement made with a resolution gage expressed in terms of millimeters unsharpness. Where contrast sensitivity is measured for both thin and thick section performance, the performance level is expressed as C_{min} (%)–C_{max} (%)–U(mm).

7.2 Each contrast sensitivity gage has four flat-bottom recesses that represent 1 %, 2 %, 3 %, and 4 % of the gage total thickness. The shallowest recess that can be repeatably and reliably imaged shall determine the limiting contrast sensitivity.

7.3 Contrast sensitivity measurements shall be made under conditions as nearly identical to the actual examination as possible. Penetrating radiation energy, image formation, processing, analysis, display, and viewing variables shall accurately simulate the actual examination environment.

8. Contrast Sensitivity Gage Measurement Steps (see Table 1)

8.1 The gage thickness *T* shall be within ±5 % of the ~~test~~ examination object thickness value at which contrast sensitivity is being determined.

8.2 The gage thickness tolerance shall be within ± 1 % of the gage design thickness *T* or 0.001 in., whichever is greater.

8.3 The gage recess depth tolerance shall be within ± 10 % of the design value for the shallowest recess or 0.001 in., whichever is greater.

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8.4 The gage recess inside and outside corner radius shall not exceed 0.062 in. To facilitate fabrication, the gage may be assembled from three individually machined components: (*1*) the machined center section containing the 1 % *T* , 2 % *T*, 3 % *T*, and 4 % *T* milled slots; (*2*) the front rail, and (*3*) the rear rail. The assemblage of the three components forms the complete gage similar to that shown in Appendix X1.

8.5 The gage dimensional tolerances shall be held to within ± 0.010 in. (0.25 mm) of the dimensions specified in Table 2.

9. Acceptable Performance Levels

9.1 Nothing in this test method practice implies a mandatory or an acceptable contrast sensitivity performance level. That determination is to be agreed upon between the supplier and user of penetrating radiation examination services.

9.2 The recess depths specified in Table 1 provide measurement points at 1 %, 2 %, 3 %, and 4 % that will accommodate many imaging system configurations. Other contrast sensitivity measurement points may be obtained by placing the gage on a shim made of the gage material. The resulting contrast sensitivity measurement expressed as a percentage is given by the following formula:

$$\% \text{ Contrast} = \frac{R}{T + S} \times 100 \qquad (1)$$

where:
R = recess depth,
S = shim thickness, and
T = gage thickness.

If other recess depths are required to document radioscopic or radiographic system performance, special contrast sensitivity gages may be fabricated by changing the recess depths specified in Table 1 to suit the need.

10. Performance Measurement Records

10.1 The results of the contrast sensitivity measurement should be recorded and maintained as a part of the initial qualification and performance monitoring records for the imaging system. Changes in contrast sensitivity can be an early indicator of deteriorating imaging system performance.

11. Precision and Bias

11.1 No statement is made about the precision or bias for indicating the contrast sensitivity of a radiologic (radiographic or radioscopic) system using the contrast sensitivity gage described by this test method. practice.

12. Keywords

12.1 contrast sensitivity gage; gamma ray; image formation; image processing; image quality indicator; line-pairs per millimeter; penetrating radiation; spatial resolution; X-ray

APPENDIX

(Nonmandatory Information)

X1. ASSEMBLING THE CONTRAST SENSITIVITY GAGE

X1.1 Suggested method of assembling the contrast sensitivity gage from a milled center section with front and rear rails

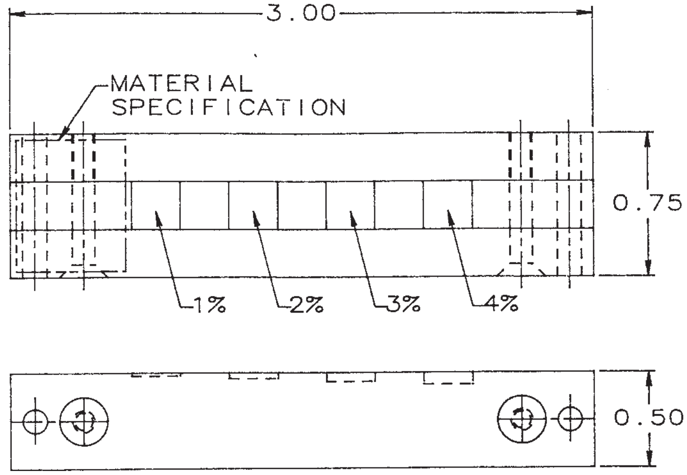

FIG. X1.1 Contrast Sensitivity Gage

attached to form the complete contrast sensitivity gage. The example shown (see Fig. X1.1~~)~~) is for use with a 0.500 in. thick ~~test~~ examination object.