Designation: E1647 – 16

Standard Practice for Determining Contrast Sensitivity in Radiology[1]

This standard is issued under the fixed designation E1647; 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 gauge used to determine the minimum change in material thickness or density that may be imaged without regard to unsharpness limitations.

1.2 This practice is applicable to transmitted-beam radiographic imaging systems (film, radioscopy, computed radiography, and digital detector array image detectors) utilizing X-ray and gamma ray radiation sources.

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

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]

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

B150/B150M Specification for Aluminum Bronze Rod, Bar, and Shapes

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

E747 Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology

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

E1255 Practice for Radioscopy

E1316 Terminology for Nondestructive Examinations

E1411 Practice for Qualification of Radioscopic Systems

E1734 Practice for Radioscopic Examination of Castings

E1742 Practice for Radiographic Examination

E2002 Practice for Determining Total Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy

E2445 Practice for Performance Evaluation and Long-Term Stability of Computed Radiography Systems

2.2 *Federal Standards:*[3]

21 CFR 1020.40 Safety Requirements for Cabinet X-ray Systems

29 CFR 1910.96 Ionizing Radiation

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[4]

2.4 *ISO Standard:*[5]

ISO 19232–5 Duplex Wire Image Quality Indicator

2.5 *Other Standards:*

EN 462 – 5 Duplex Wire Image Quality Indicator (withdrawn, replaced by ISO 19232–5)[6]

EN 13068–1 Radioscopic Testing-Part 1: Qualitative Measurement of Imaging Properties[6]

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[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 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] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

[4] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

3. Terminology

3.1 *Definitions*—Definitions of terms applicable to this test method may be found in Terminology E1316.

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 unsharpness measurements. Conventional image quality indicators (IQI's), such as Test Method E747 wire and Practices E1025 or E1742 plaque IQIs, combine the contrast sensitivity and resolution measurements into an overall performance figure of merit, other methods such as included in Practice E2002 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, unsharpness can increase 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 gauge measures contrast sensitivity independent of the imaging system spatial resolution limitations. The thickness recess dimensions of the contrast sensitivity gauge are large with respect to the unsharpness limitations of most imaging systems. Four levels of contrast sensitivity are measured: 4 %, 3 %, 2 %, and 1 %.

5.2 The contrast sensitivity gauge is intended for use in conjunction with a high-contrast resolution measuring gauge, such as Practice E2002, ISO 19232 – 5 Duplex Wire Image Quality Indicator[7], or a line-pair gauge. Such gauges measure system unsharpness 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 with film, realtime devices, Computed Radiography (CR) and Digital Detector Arrays (DDA).

5.3 Radioscopic/radiographic system performance may be specified by combining the measured contrast sensitivity expressed as a percentage with the unsharpness expressed in millimetres of unsharpness. For the duplex wire image quality indicator, the unsharpness is equal to twice the wire diameter. For the line pair gauge, 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 paired wires of the duplex wire IQI (equivalent to imaging 5 line-pairs/millimeter resolution on a line-pair gauge) performs at a 2 %–0.2 mm sensitivity level. A standard method of evaluating overall radioscopic system performance is given in Practice E1411 and in EN 13068–1. A conversion table from duplex wire read out to lp/mm can be found in Practice E2002. For CR system performance evaluation, this contrast sensitivity gauge is used in Practice E2445.

[7] The former version of the duplex wire gauge with the mark EN-462 may also be used.

6. Contrast Sensitivity Gauge Construction and Material Selection

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

6.2 The gauge shall preferably be fabricated from the 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 as 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 as 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 gauge is to be made is designated by group number. The gauge is applicable to all materials in that group. Material groupings are as follows:

6.3.1 *Materials Group 03:*

6.3.1.1 The gauge 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 gauge 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.

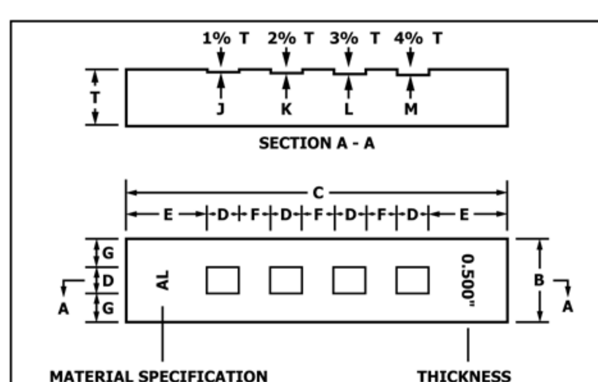

FIG. 1 General Layout of the Contrast Sensitivity Gauge

TABLE 1 Design of the Contrast Sensitivity Gauge

Gauge 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 Gauge Dimensions

Gauge 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 Gauge Application

Gauge 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)

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

6.3.3 *Materials Group 01:*

6.3.3.1 The gauge 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 gauge 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[8]).

6.3.5 *Materials Group 2:*

6.3.5.1 The gauge shall be made of aluminum bronze (Alloy No. 623 of Specification B150/B150M) or equivalent or nickel-aluminum bronze (Alloy No. 630 of Specification B150/B150M) 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 gauge shall be made of nickel-chromium-iron alloy (UNS No. N06600) (Inconel[9]). See Specification B166.

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 gauge shall be made of 70 to 30 nickel-copper alloy (Monel[10]) (Class A or B of Specification B164) or equivalent, or 70 to 30 copper-nickel alloy, (Alloy G of Specification B161) or equivalent.

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 gauge shall be made of tin-bronze (Alloy D of Specification B139/B139M).

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 gauge, an equivalent material may be utilized, provided it is no more radio-opaque than the examination object under comparable penetrating radiation energy conditions. To determine the suitability of a substitute material, radiographs or digital images of identical thicknesses of both materials shall be evaluated. Using film, both material shall be 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 optical density of the substitute material is within + 15 % to 0 % of the examination material, the substitute material is acceptable. When using a non-film technique (Radioscopy, CR, or DDA), both materials shall be in the same image using the lowest penetrating radiation energy to be used in the actual examination. The gray values shall be in the range of 20 % to 60 % of saturation gray level (positive image with higher gray values for less material thickness). If the gray value of the substitute material is within + 15 % to 0 % of the examination material, the substitute material is acceptable.

6.4.1 All contrast sensitivity gauges shall be suitably marked by vibro-engraving or etching. The gauge 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 system unsharpness measurement made with a resolution gauge expressed in terms of millimetres 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) (see Practices E1255 and E1734).

7.2 Each contrast sensitivity gauge has four flat-bottom recesses that represent 1 %, 2 %, 3 %, and 4 % of the gauge 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,

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

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

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

processing, analysis, display, and viewing variables shall accurately simulate the actual examination environment.

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

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

8.2 The gauge thickness tolerance shall be within ± 1 % of the gauge design thickness T or 0.001 in. (0.025 mm), whichever is greater.

8.3 The gauge recess depth tolerance shall be within ± 10 % of the design value for the shallowest recess or 0.001 in. (0.025 mm), whichever is greater.

8.4 The gauge recess inside and outside corner radius shall not exceed 0.062 in. (1.57 mm). To facilitate fabrication, the gauge 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 gauge similar to that shown in Appendix X1.

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

9. Acceptable Performance and Performance Levels

9.1 Nothing in this practice implies a mandatory or an acceptable contrast sensitivity performance. The determination of performance levels 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 gauge on a shim made of the gauge material. The resulting contrast sensitivity measurement expressed as a percentage is given by the following formula:

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

where:

R = recess depth,
S = shim thickness, and
T = gauge thickness.

If other recess depths are required to document radioscopic or radiographic system performance, special contrast sensitivity gauges 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 gauge described by this practice.

12. Keywords

12.1 contrast sensitivity gauge; gamma ray; image formation; image processing; image quality indicator; line-pairs per millimeter; penetrating radiation; unsharpness; X-ray

APPENDIX

(Nonmandatory Information)

X1. ASSEMBLING THE CONTRAST SENSITIVITY GAUGE

X1.1 Suggested method of assembling the contrast sensitivity gauge from a milled center section with front and rear rails attached to form the complete contrast sensitivity gauge. The example shown (see Fig. X1.1) is for use with a 0.500-in. (12.7-mm) thick examination object.

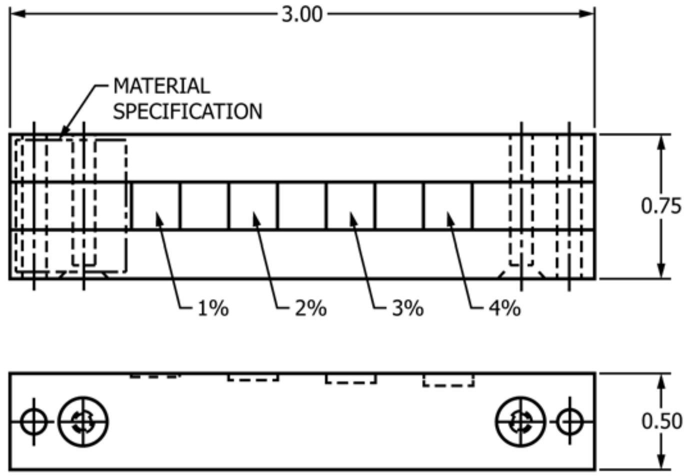

FIG. X1.1 Contrast Sensitivity Gauge