Designation: E3388 – 23

Standard Practice for Determining Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy for High Energy Applications[1]

This standard is issued under the fixed designation E3388; 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 basic use of a gauge used to determine the image unsharpness and the basic spatial resolution of film radiographs or of digital images taken with CR imaging plates, digital detector arrays (DDA), or radioscopic systems (for example, with X-ray image intensifiers) for applications with Se-75, Ir-192, Co-60 and high energy sources with tube potentials ≥ 300 kV. The IQI may be used at lower tube potentials too, if the expected unsharpness is > 200 µm (SR_b^{image} or $SR_b^{detector}$ > 100 µm). For the measurement of lower unsharpness values, the usage of the gauge described in Practice E2002 is recommended.

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

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 The gauge described can be used effectively if the duplex wire IQI of Practice E2002 does not provide sufficient contrast resolution.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing

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 Radiography

E1316 Terminology for Nondestructive Examinations

E1815 Test Method for Classification of Film Systems for Industrial Radiography

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

2.2 *AIA/NAS Standard:*

NAS410 NAS Certification & Qualification of Nondestructive Test Personnel

2.3 *ASNT Standards:*

ANSI/ASNT CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

2.4 *CEN Standards:*

EN 462-5:1996 Non-destructive testing – Image quality of radiographs – Part 5: Image quality indicators (duplex plate type), determination of image unsharpness value, not an active standard, but still used as a reference in companies' procedures.

2.5 *ISO Standards:*[3]

ISO 9712 Non-destructive testing – Qualification and certification of NDT personnel

ISO/IEC 17050-1 Conformity assessment – Supplier's declaration of conformity – Part 1: General requirements

[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.

Current edition approved June 15, 2023. Published August 2023. DOI: 10.1520/E3388-23.

[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 International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org/iso/home/store.html.

ISO 19232-5 Non-destructive testing – Image quality of radiographs – Part 5: Determination of the image unsharpness value using duplex wire-type image quality indicators

3. Terminology

3.1 Definitions of terms applicable to this practice may be found in Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *basic spatial detector resolution – visual ($vSR_b^{detector}$), n*—determined with the duplex wire IQI directly on the detector with no object from the smallest number of the duplex plate pair, which is visually not separable in a film radiograph on a viewing station or on a monitor image for non-film applications.

3.2.2 *basic spatial image resolution – visual (vSR_b^{image}), n*—determined with the IQI on the object (side closest to X-ray source), beside the object or separately in the imaging plane from the smallest number of the duplex plate pair, which is visually not separable in a film radiograph on a viewing station or on a monitor image for non-film applications considering the magnification.

3.2.3 *detector unsharpness – interpolated ($iU_{detector}$), n*—two times the Basic Spatial Image Resolution – interpolated ($2 \times iSR_b^{detector}$)

3.2.4 *detector unsharpness – visual ($vU_{detector}$), n*—two times Basic Spatial Detector Resolution – visual ($2 \times vSR_b^{detector}$)

3.2.5 *duplex plate type image quality indicator, n*—duplex plate type IQI image quality indicator specifically designed to assess the image unsharpness and basic spatial image resolution of a radiograph or a digital image and composed of a series of pairs of plate elements made of high density metal.

3.2.6 *image unsharpness – interpolated (iU_{Im}), n*—two times the Basic Spatial Image Resolution – interpolated ($2 \times iSR_b^{image}$)

3.2.7 *image unsharpness – visual (vU_{Im}), n*—two times the Basic Spatial Image Resolution – visual ($2 \times vSR_b^{detector}$)

3.2.8 *linearized profile, n*—a graph, generated by an image processing software, which shows the pixel values, which are proportional to the radiation dose vs. a spatial position as, for example, duplex plate IQI length.

3.2.9 *linepair per mm (lp/mm) value, n*—determined from the duplex plate pair values, and corresponds to $1/U_{Im}$ (IQI on the object, beside the object or separately in the imaging plane) or $1/U_{detector}$ (IQI on the detector).

3.2.9.1 *Discussion*—The corresponding values are given in Table 1.

4. Summary of Practice

4.1 When it is determined necessary to evaluate and measure the image or detector unsharpness or the basic spatial resolution of an imaging system or a detector separately and apart from contrast sensitivity measurements, a tool or gauge as described in this practice can be used. Conventional IQIs as described in Practices E747 and E1025 combine the contrast sensitivity and resolution measurements into an overall figure of merit. Such figures of merit may not be adequate to detect subtle changes in the imaging system's performance. For example, in a high-contrast image, unsharpness can increase with almost no noticeable effect upon the overall image contrast, but the contrast sensitivity for fine details will be reduced. 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 contrast. These

TABLE 1 Duplex Plate Number, Corresponding Image Unsharpness, Basic Spatial Resolution, Linepair Readings and Plate Widths and Spacings and its Tolerances[A]

NOTE 1—All unsharpness values are rounded to two digits after the dot. For conversion of the SR_b-values to µm, multiply values which are given in mm by 1000.

NOTE 2—If the IQI is located on the detector without object, the determined SR_b^{image} value is identical with the $SR_b^{detector}$ value and the image unsharpness U_{Im} corresponds to the inherent detector unsharpness $U_{detector}$.

Plate Material	Duplex Plate Number	Corresponding Unsharpness value U_{Im} (mm)	Corresponding Basic Spatial Resolution SR_b^{image} value (mm)[C]	Corresponding linepair value (lp/mm)	Plate Width and Spacing, d (mm)	Tolerance of Plate Width and Plate Spacing (mm)
W[B]	DP 10	0.20	0.100	5.00	0.10	±8 %
W	DP 9	0.26	0.130	3.85	0.13	
W	DP 8	0.32	0.160	3.13	0.16	
W	DP 7	0.40	0.200	2.50	0.20	
W	DP 6	0.50	0.250	2.00	0.25	±7 %
W	DP 5	0.64	0.320	1.56	0.32	
W	DP 4	0.80	0.400	1.25	0.40	
W	DP 3	1.00	0.500	1.00	0.50	
W	DP 2	1.26	0.630	0.79	0.63	±6 %
W	DP 1	1.60	0.800	0.63	0.80	

[A] This table is based on data provided by ISO 19232-5:2013. All unsharpness values are rounded to two digits after the dot.
[B] W = Tungsten.
[C] For conversion of the SR_b-values to µm, multiply values which are given in mm by 1000.

situations often develop and may go undetected until the system performance deteriorates below acceptable image quality limits.

5. Significance and Use

5.1 The gauge is intended to provide a means for measuring image or detector unsharpness and basic spatial image or detector resolution as independently as practicable from the imaging system and contrast sensitivity limitations. When the duplex plate gauge is positioned directly on the film or the digital detector instead on the test object, then the determined image unsharpness U_{Im} corresponds to the inherent film or detector unsharpness ($U_{detector}$) and the determined basic spatial image resolution SR_b^{image} corresponds to the basic spatial detector resolution $SR_b^{detector}$. SR_b^{image} provides a value which depends on the combined effect of detector unsharpness and geometric unsharpness.

5.2 *Basis of Application:*

5.2.1 The following items are subject to contractual agreement between the parties using or referencing this standard.

5.2.1.1 *Personnel Qualification*—Personnel performing examinations to this practice shall be qualified in accordance with NAS410, EN 4179, ANSI/ASNT CP 189, ISO 9712, or SNT-TC-1A and certified by the employer or certifying agency as applicable. Other equivalent qualification documents may be used when specified on the contract or purchase order. The applicable revision shall be the latest unless otherwise specified in the contractual agreement between parties.

5.2.1.2 If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Specification E543. The applicable edition of Specification E543 shall be specified in the contract.

6. Gauge Construction

6.1 The standard duplex plate IQI[4] shall be fabricated in accordance with Fig. 1, using the measures and tolerances given in Table 1.

6.2 The gauge shall consist of ten elements. Each element shall consist of a pair of plates of tungsten material. The ten elements are mounted in a rigid plastic holder as described in Fig. 1.

6.3 The ratio of the plate height to width shall be 6 ± 10 %.

6.4 The gauge shall be identified by marking “ISO DP” (or “ISO 19232”), “Practice E3388” and a serial number”. Marking shall be performed by any suitable means.

6.5 The gauge manufacturer shall provide a certificate of conformance with each gauge. Each IQI should be delivered with a declaration of conformity according to ISO/IEC 17050-1. For identification, the IQI should be numbered and marked by the producer.

[4] The sole source of supply of the IQI shown in Fig. 1, known to the committee at this time, is KOWOTEST GmbH, Solinger Strasse 186, 40764 Langenfeld, fax: +49 2173-22335, eMail: info@kowotest.de. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

7. Application

7.1 A radiograph shall be made or an image displayed on a monitor with the duplex plate placed on the source side of the item being examined. The gauge may be placed beside the object, or separately in the imaging plane. The duplex plate IQI should be aligned, as closely as possible, normal to the axis of the radiation beam. The radiation shall be directed along the gap between the plate pairs. The angle between the direction of the radiation and the gap of interest shall be ≤ 2.5°.

NOTE 1—If the IQI is placed directly on the detector, the inherent detector unsharpness $U_{detector}$ and the basic spatial detector resolution $SR_b^{detector}$ are measured.

7.2 The evaluation of the duplex plate pair images is based on a visual evaluation by an operator of films on a viewing station or images on a monitor or by measurement with a profile function if digital images are available. The image unsharpness U_{Im} or detector unsharpness $U_{detector}$ is given by $2d$, where d is the corresponding width of the duplex plates and is also the plate spacing distance (see Fig. 1). The value of d is considered as the basic spatial resolution of the image or detector, depending on the IQI location (this means: IQI on the object, beside the object, separately in the imaging plane or on the detector). The term $1/(2d)$ is considered as linepair/mm value.

NOTE 2—It is recommended to use the duplex plate IQI always with a shim, close to the source or in front or behind the IQI, to avoid that unfiltered radiation exposes the detector, because the X-ray spectrum changes significantly depending on the thickness and material of the object and shim, which can influence the result of the measurement.

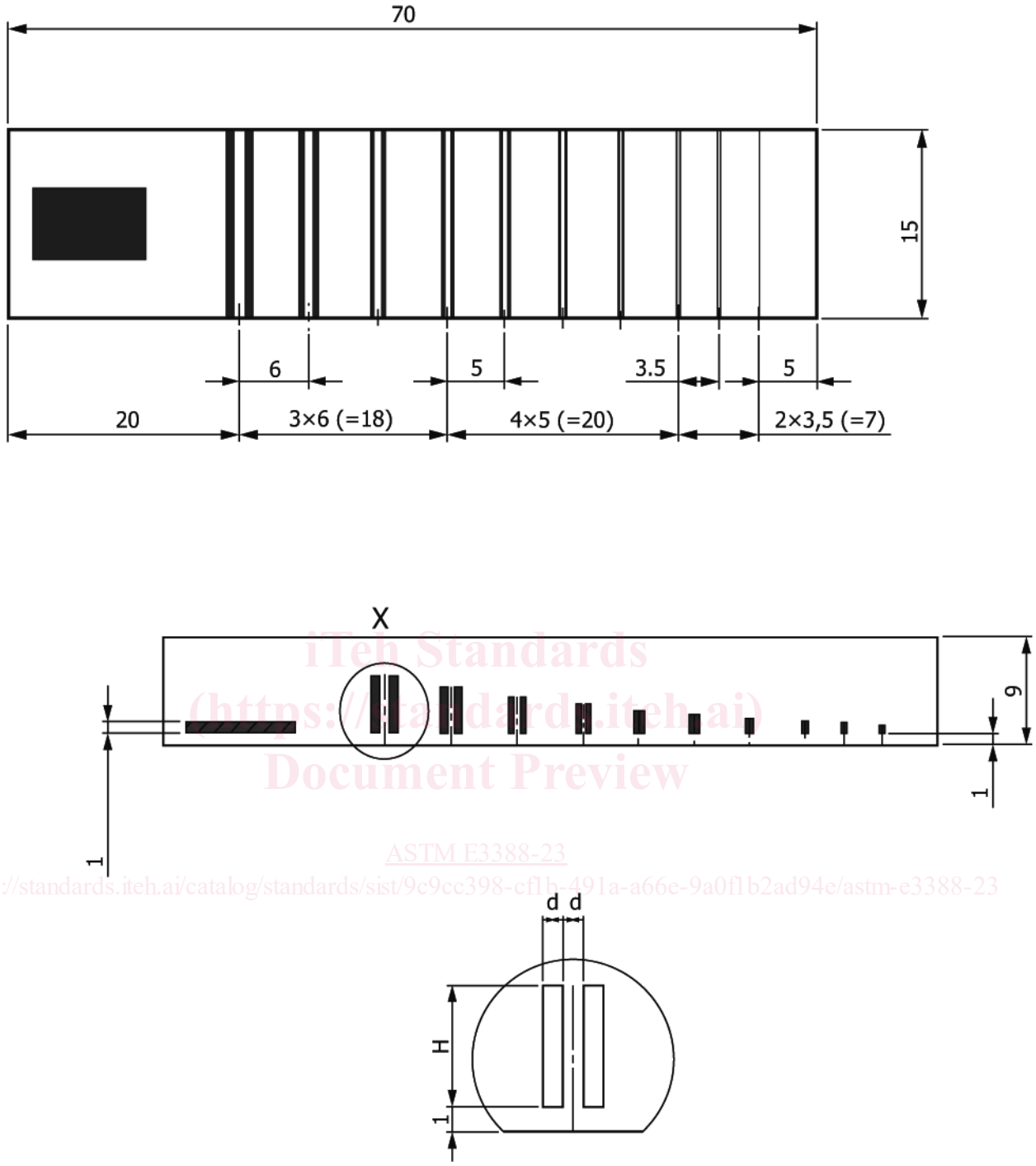
7.2.1 *Visual Evaluation*—If the image of the duplex plate IQI is evaluated visually, it shall be examined using magnification up to four times on film or on a monitor image. The element with smallest plate number (that is, pair of plates), of which the image of the adjacent plates has just merged into single form without an identifiable space between the images of the two adjacent plates, is taken as the limit of visual discernibility for radiography and analog radioscopy.

NOTE 3—The visual determination of the first unresolved plate pair may depend on the signal-to-noise ratio (SNR) of analog radioscopic systems, or may depend on the film system class and tube kV or used gamma source, respectively.

7.2.1.1 The resulting visual basic spatial resolution value shall be documented as “visual SR_b^{image}- or visual $SR_b^{detector}$-value” or vSR_b^{image} or $vSR_b^{detector}$. The resulting visual unsharpness value shall be documented as “visual U_{Im}-value or visual $U_{detector}$-value” or vU_{Im} or $vU_{detector}$.

7.2.2 *Evaluation of Digital Images with Profile Function*—If digital images are evaluated with a profile function the element with smallest plate number, of the duplex plate pair, which is separable by a profile function with less than 20 % modulation depth, is taken as the limit of discernibility for digital radiography. See Fig. 2. The profile function shall be evaluated from linearized pixel profiles.

7.2.2.1 The duplex plate IQI shall be positioned at an angle of approximately 2° to 5° towards the pixel line or column orientation as shown in Fig. 2a in order to reduce aliasing effects in the digital images.

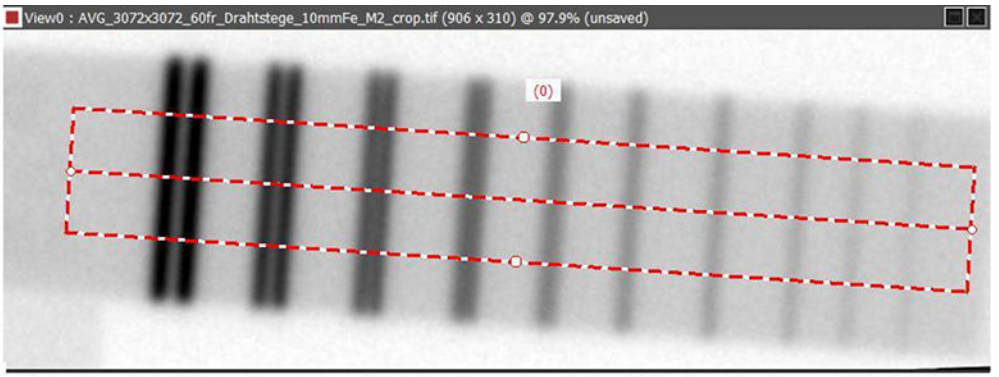


KEY:
X – Duplex plate IQI
H – Height of duplex plates
d – Plate width and Plate spacing

FIG. 1 Unsharpness Duplex Plate Gauge

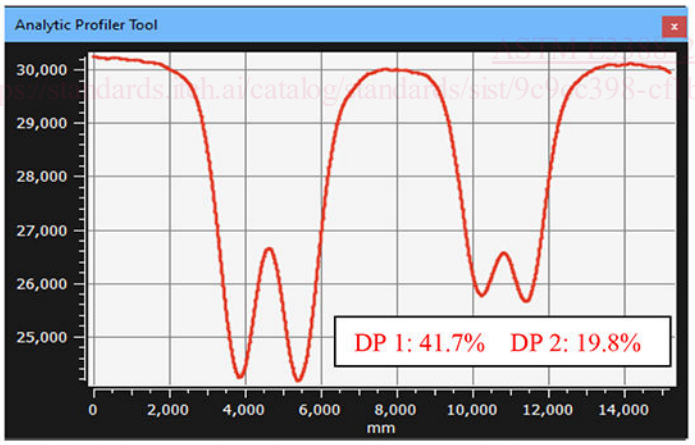
7.2.2.2 The image unsharpness or the basic spatial resolution of digital images is based on the determination of the first duplex plate pair (smallest number) with less than 20 % modulation depth (dip).

7.2.2.3 The measurement shall be done with a profile function of an image processing software across the middle area of the IQI image, integrating along the plates of about 30 % to 60 % of the duplex plates' length in order to obtain a

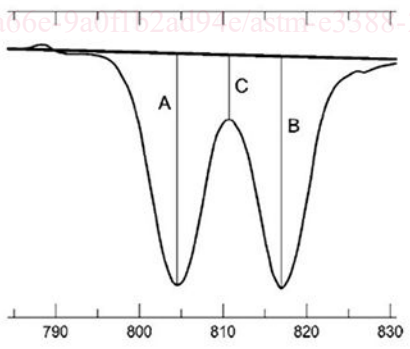


a) Image of duplex plate IQI as shown in a digital radiograph with indicated profile line and its integration window with 10 plate pairs from DP1 –10

b) Profile of a duplex plate IQI, averaged from profile lines, covering 30% to 60% of the plate length.



c) Zoomed profile of plate pair DP 1 and DP 2



d) Scheme of the calculation of the dip value in % with
Dip = 100 *(A + B – 2c)/(A + B)

NOTE 1—The lowest plate-pair value shall be determined, which has a modulation depth (dip) < 20 %. The modulation depth is determined in the profile function as shown in Fig. 2c-d. The first "unsharp" plate pair in Fig. 2c is DP 2. The resulting values are corresponding to Table 1: SR_b^{image} = 0.63 mm and U_{Im} = 1.26 mm.

FIG. 2 Plate-pair Image Analysis for Calculation of Basic Spatial Resolution (SR_b^{image}) and Image Unsharpness (U_{Im}) of Digital Images.

robust repeatable value, but shall use a minimum of an 11 pixel width line profile (or the average of 11 single width line profiles) to avoid variability along the length of the plates (Fig. 2b, c).

7.2.2.4 The resulting basic spatial resolution value shall be documented as "SR_b^{image}"- or "$SR_b^{detector}$"-value. The resulting unsharpness value shall be documented as U_{Im} or $U_{detector}$. The image unsharpness (U_{Im}) is calculated from SR_b^{image} by: