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Standard Practice for Radiographic Examination Using Digital Detector Arrays[1]

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1. Scope

1.1 This practice establishes the minimum requirements for radiographic examination of metallic and nonmetallic materials using digital detector arrays (DDAs).

1.2 The stated requirements of this specification are based on the use of an X-ray generating source. Additionally, some of the tests and requirements may not be applicable to X-ray energy levels >450kV.

1.3 The requirements in this practice are intended to control the quality of radiographic examinations obtained using DDAs and are not intended to establish acceptance criteria for parts or materials.

1.4 This practice covers the radiographic examination with DDAs including DDAs described in Practice E2597/E2597M such as a device that contains a photoconductor attached to a Thin Film Transistor (TFT) read out structure, a device that has a phosphor coupled directly to an amorphous silicon read-out structure, and devices where a phosphor is coupled to a CMOS (complementary metal–oxide–semiconductor) array, or a CCD (charge coupled device) crystalline silicon read-out structure.

1.5 The requirements of this practice and Practice E2737 shall be used together. The requirements of Practice E2737 will provide the baseline evaluation and long term stability test procedures for the DDA system. The user of the DDA system shall establish a written procedure that addresses the specific requirements and tests to be used in their application and shall be approved by the Cognizant Radiographic Level 3 before examination of production hardware. This practice also requires the user to perform a system qualification suitable for its intended purpose and to issue a system qualification report (see 9.1).

1.6 The DDA shall be selected for an NDT application based on knowledge of the technology described in Guide E2736, and of the selected DDA properties provided by the manufacturer in accordance with Practice E2597/E2597M.

1.7 Techniques and applications employed with DDAs are diverse. This practice is not intended to be limiting or restrictive. Refer to Guides E94/E94M, E1000, and E2736, Terminology E1316, Practices E747 and E1025, and Federal Standards 21-CFR-1020.40 and 29-CFR-1910.96 for a list of documents that provide additional information and guidance.

1.8 *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]

E94/E94M Guide for Radiographic Examination Using Industrial Radiographic Film

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

E1000 Guide for Radioscopy

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

E1165 Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging

E1316 Terminology for Nondestructive Examinations

E1742/E1742M Practice for Radiographic Examination

E1817 Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)

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

E2339 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)

[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.

E2597/E2597M Practice for Manufacturing Characterization of Digital Detector Arrays
E2699 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Digital Radiographic (DR) Test Methods
E2736 Guide for Digital Detector Array Radiography
E2737 Practice for Digital Detector Array Performance Evaluation and Long-Term Stability
E2903 Test Method for Measurement of the Effective Focal Spot Size of Mini and Micro Focus X-ray Tubes

2.2 *AWS Documents:*[3]
AWS A2.4 Symbols for Welding and Nondestructive Testing

2.3 *Government Standards:*
NIST Handbook 114 General Safety Standard for Installations Using Non-Medical X-ray and Sealed Gamma Ray Sources, Energies up to 10 MeV[4]
21-CFR-1020.40 Safety Requirements of Cabinet X-ray Systems
29-CFR-1910.96 Ionizing Radiation
NCRP 144 Radiation Protection for Particle Accelerator Facilities

2.4 *Other Documents:*[5]
DICOM PS 3.14 Digital Imaging and Communications in Medicine (Dicom) Part 14: Grayscale Standard Display Function
ANSI/NCSL Z540-3 Requirements for the Calibration of Measuring and Test Equipment
ANSI/ASNT CP 189 Standard for Qualification and Certification of Nondestructive Testing Personnel
EN 4179 Aerospace Series - Qualification and Approval of Personnel for Non-destructive Testing
NAS 410 National Aerospace Standard Certification and Qualification of Nondestructive Testing Personnel
SNT-TC-1A Recommended Practice - Personnel Qualification and Certification in Nondestructive Testing
ISO 9712 Non-destructive Testing - Qualification and Certification of NDT personnel
ISO/CIE 19476 Characterization of the Performance of Illuminance Meters and Luminance Meters
SMPTE RP 133 Specifications for Medical Diagnostic Imaging Test Pattern for Television Monitors and Hard-copy Recording Cameras

3. Terminology

3.1 Definitions relating to the radiographic examination, which appear in Terminology E1316, shall apply to the terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bad pixel*—a pixel identified with a performance outside of the specification range for a pixel of a DDA as defined in Practice E2597/E2597M.

3.2.2 *basic spatial resolution detector ($iSR_b^{detector}$)*—the smallest geometrical detail, which can be resolved by a digital detector without geometric magnification as defined in Practice E2597/E2597M.

3.2.3 *cluster kernel pixel (CKP)*—a bad pixel, as defined in Practice E2597/E2597M, that does not have five or more good pixels as neighbors and is therefore not correctable.

3.2.4 *Cognizant Radiographic Level 3*—the certified Level 3 Radiographer holding final technical responsibility for the radiographic facility and staff.

3.2.5 *compensation principle*—the practice of permitting an examination scenario where the total image unsharpness fails to meet the required value, but the image quality exceeds the required value by at least one quality level. See Guide E2736 for additional information regarding this term.

3.2.6 *component*—the part(s) or element of a system assembled or processed to the extent specified by the drawing, purchase order, or contract.

3.2.7 *contrast-to-noise ratio (CNR)*—quotient of the difference in the mean values of the intensity (signal) in an area in the object subtracted from the mean value of the intensity of the background, and standard deviation of the intensity (noise). The CNR depends on the radiation dose and quality, thickness/attenuation of the object and the DDA system properties.

3.2.8 *digital driving level (DDL)*—for computer graphics display boards, the digital value that corresponds to a particular monochrome grayscale level. A particular DDL "drives out" a particular visible shade of gray. For example, in an 8-bit display, a DDL assumes 256 values from 0 to 255.

3.2.9 *effective pixel size*—Effective pixel size is equal to $iSR_b^{detector}$.

3.2.10 *energy*—a property of radiation that determines the penetrating ability. In x-ray radiography, energy machine rating is determined by kilo electron volts (keV), million electron volts (MeV). In gamma ray radiography, energy is a characteristic of the source used.

3.2.11 *ghosting*—residual signal or image from a prior exposure in a current image. Signal or image can be negative or positive and may affect interpretation of the image.

3.2.12 *grayscale*—2^N signal levels for N-bit system.

3.2.13 *like section*—a separate section of material that is similar in shape and cross section to the component or part being radiographically examined, and is made of the same or radiographically similar material.

3.2.14 *material group*—materials that have the same predominant alloying elements and which can be examined using the same IQI. A listing of common material groups is given in Practice E1025.

3.2.15 *mean gray level*—the average of all the pixel gray levels in a given region of interest.

3.2.16 *NDT facility*—the facility or entity performing the radiographic examination.

3.2.17 *pixel value*—one of 2^N signal levels for an N-bit digital system

[3] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.
[4] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.
[5] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.

3.2.18 *relevant cluster*—a grouping of bad pixels with at least one cluster kernel pixel (CKP) in the grouping.

3.2.19 *window width and level*—contrast (window width) and brightness (window level) adjustment of a digital image by changing how the Gray levels translate into displayed brightness levels.

4. Significance and Use

4.1 This practice establishes the basic parameters for the application and control of the digital detector array radiographic method. This practice is written so it can be specified on the engineering drawing, specification, or contract. It will require a detailed procedure delineating the technique or procedure requirements and shall be approved by the Cognizant Engineering Organization (CEO).

5. Basis of Application

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

5.1.1 *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.

5.1.2 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. Environment and Safety

6.1 The premises and equipment shall present no hazards to the safety of personnel or property. NCRP 144, and/or NIST Handbook 114 may be used as guides to ensure that radiographic procedures are performed so that personnel shall not receive a radiation dosage exceeding the maximum permitted by the city, state, or national codes.

6.2 Environmental conditions conducive to human comfort and concentration will promote examination efficiency and reliability. A proper examination environment will take into account temperature, humidity, dust, lighting, access, and noise.

6.3 Dust and dirt need to be kept to a minimum and the image display face needs to be cleaned often to prevent interference with interpretation.

7. Equipment

7.1 Different examination system configurations are possible. It is important that the user understands the advantages and limitations of each (see Practice E2597/E2597M and Guide E2736). The provider and the user of the examination system should be fully aware of the capabilities and limitations of each system proposed.

7.2 The DDA cannot be operated without computing hardware and software for image acquisition, image display and image storage/retrieval.

7.2.1 The software shall be capable of acquiring images frame by frame from the DDA and integrating, or averaging the frames, or both.

7.2.2 The software shall perform an image calibration to correct the inhomogenities of the detector and to determine and correct bad pixels (that is, bad pixel map). Bad pixels are defined in Practice E2597/E2597M.

7.2.3 The software to display resulting imagery from a DDA shall have the following capabilities at a minimum:

7.2.3.1 *Line Profile*—A line profile function capable of displaying the pixel values (PVs) along a user defined line as a graph. The line profile tool should also be capable of adjusting the line width where the values of the line profile are averaged from multiple parallel lines of equivalent length.

7.2.3.2 *Region of Interest Tool*—A histogram type tool capable of displaying the PVs of a user defined Region of Interest (ROI) as a graph. The ROI tool shall also display the size of the ROI (in other words, x pixels by y pixels), and as a minimum, the statistical mean and standard deviation of the ROI PVs.

7.2.3.3 *Negative/Positive Image Display*—Display images in either negative or positive gray scale (negative or inverse).

7.2.3.4 *Linearized Pixel Values*—The software shall be capable of performing calculations using linearized pixel values as a function of dose.

7.2.3.5 *Digital Image Magnification (Zoom)*—Adjust and display the digital magnification level, as well as display the image at 1:1 pixel mapping (in other words, each pixel of the image is mapped to an image display monitor pixel).

7.2.3.6 *Image Pan*—Capability to pan the image.

7.2.3.7 *Window Width and Window Level (Window/Level)*—Adjust window width (contrast) and window level.

7.2.3.8 *Size Measurement Tool*—Perform measurements for distance or sizing of discontinuities. The software shall be capable of calibrating the measuring tool to a reference standard.

7.2.3.9 A tool or tools capable of performing area measurements.

7.2.3.10 *Image Format*—Lossy compression shall not be allowed for images that are used for final product disposition. For systems that are not DICONDE compliant, TIFF images are recommended.

7.2.3.11 The software shall be capable of saving a copy of the radiographic image with image processing applied.

7.2.3.12 For systems that are DICONDE compliant the software shall be capable of storing images in accordance with Practices E2339 and E2699.

7.3 For systems used in the examination of castings, as well as other examinations where reference radiographs are used, the software shall have the ability to direct the viewing properties of the production image and a reference radiograph image in accordance with the applicable ASTM or other digital reference radiograph standard or specification.

7.4 *The Digital Detector Array (DDA):*

7.4.1 Only DDAs shall be used in practice as established in Guide E2736.

7.4.2 Users shall comply with the manufacturers' requirements of temperatures and humidity conditions for both operation and shipping.

7.4.3 The DDA shall be calibrated using the manufacturers' recommendation both for frequency of calibration and the method used. Other calibration methods are allowed as long as approved by the CEO.

7.4.4 The user shall ensure that all exposures are within the linear operating range of the DDA, using either information obtained from the manufacturer or data obtained by the user/CEO.

7.5 Image display monitors used for interpretation shall meet the following requirements as a minimum. Alternate image displays or requirements may be used with CEO approval.

7.5.1 The minimum brightness as measured off the image display monitor screen at maximum Digital Driving Level (DDL) shall be 250 cd/m^2.

7.5.2 The minimum contrast as determined by the ratio of the image display monitor screen brightness at the maximum DDL compared to the screen brightness at the minimum DDL shall be 250:1.

7.5.3 The image display monitor shall be capable of displaying linear patterns of alternating pixels at full contrast in both the horizontal and vertical directions without aliasing.

7.5.4 The image display monitor shall be free of discernable geometric distortion.

7.5.5 The image display monitor shall be free of screen flicker, characterized by high frequency fluctuation of high contrast image details.

7.5.6 The image display monitor shall be capable of displaying a 5 % DDL block against a 0 % DDL background and simultaneously displaying a 95 % DDL block against a 100 % background in a manner clearly perceptible to the user. An image display test pattern, in accordance with the requirements of SMPTE RP 133, shall be configured for the system display resolution and aspect ratio. Alternate test patterns may be used provided they include the features described in SMPTE RP 133 required to perform the quality tests specified in this practice.

7.5.7 The image display monitor shall be capable of discriminating the horizontal and vertical low contrast (1 %) modulation patterns at the display center and each of the four corner locations.

7.5.8 The image display monitor shall be capable of displaying no less than 256 unique shades of gray.

7.6 *Image Quality Indicators (IQI):*

7.6.1 IQIs shall be in accordance with a recognized standard or approved by the Cognizant Engineering Organization. Hole plate type indicators shall comply with Practice E1025 or Practice E1742/E1742M, Annex 1. Wire type indicators shall be in accordance with Practice E747 and correlated to the hole type penetrameters in accordance with Practice E747.

7.6.2 The IQI shall be constructed from material in the same material group (see Practice E1025) as the material to be radiographically examined. If an IQI material of the same material group is not available, a material that is radiographically less dense shall be used.

7.6.3 Representative quality indicators (RQIs) may be used if approved by the Cognizant Engineering Organization. RQIs shall be in accordance with the requirements of Practice E1817.

7.6.4 The IQIs shall be procured or fabricated to the requirements of Practice E1025, Practice E1742/E1742M (Annex 1), or Practice E747 with a manufacturer's certification of compliance with respect to alloy and dimensions. Users shall visually inspect IQIs for damage and cleanliness in accordance with Appendix X1.

7.7 *Radiation Sources:*

7.7.1 *X-Radiation Sources*—Selection of appropriate X-ray voltage and current levels is dependent upon variables regarding the specimen being examined (material type and thickness) and exposure time. The suitability of these exposure parameters shall be demonstrated by attainment of the required radiographic quality level and compliance with all other requirements stipulated herein.

7.7.2 *Gamma Radiation Sources*—Isotope sources that are used shall be capable of demonstrating the required radiographic quality level.

7.8 *Photometers or Light Meters*—Photometers or light meters used for determining display monitor brightness and contrast and ambient background light, shall meet the requirements of ANSI/NCSL Z540-3 or ISO/CIE 19476.

8. Equipment Monitoring Requirements

8.1 The image display monitor shall be checked in accordance with Appendix X1.

8.1.1 *Image Viewing Stations*—Image viewing stations shall be arranged to exclude any objectionable illuminance that could cause a reflective glare from the display monitor and shall have light controls to achieve ambient (background) lighting levels of no greater than 30 lux.

8.1.2 Ambient light shall be measured at the viewing surface with the display monitor off.

8.2 Radiographic images shall be free of visible bad pixels or other artifacts which may interfere with image interpretation (see Practices E2597/E2597M and E2737).

8.3 Detailed schedule and tests for monitoring the DDA performance over time shall be performed in accordance with Practice E2737.

8.4 The user shall adopt the manufacturer's recommendations for DDA gain, offset and bad pixel identification and calibration, methodology and the frequency thereof, and alterations as needed defined by the CEO based on the object under test.

8.4.1 In the event that any non-uniformities or artifacts (other than bad pixels) appear in an image between recommended intervals of gain and offset calibration, the detector is to be recalibrated for gain and offset correction so that these anomalies are removed prior to continuing production imaging. If these anomalies could be found to either mask a relevant discontinuity or be interpreted as a relevant discontinuity, then

the effected product shall be re-imaged. When non- uniformities and artifacts occur outside of the area of interest within an image, re-imaging is not required as they do not interfere with interpretation.

8.4.2 In the event that any detector-related non-uniformities or artifacts remain in the area of interpretation in a flat x-ray field image (no object) after recalibration, then the detector shall be tested in accordance with Practice E2737 for requalification and long term stability testing, where a determination will be made if the detector needs to be removed from service. If the detector is removed from service, then the part or parts under question will be re-examined with a fully qualified detector, and this new detector will be used for future examinations. If the detector is returned to service following testing with recommended changes to methodology, these changes shall be approved by the CEO and implemented prior to the detector being placed back into service.

8.5 If any new relevant clusters are identified, any parts evaluated since the establishment of the previous bad pixel map shall be assessed to determine if the newly identified relevant cluster had any impact on the proper disposition of the affected product, and whether re-examination of the product is required. When deemed necessary by the CEO, the detector shall be tested in accordance with Practice E2737 for requalification and for long term stability testing. A determination will then be made by the CEO if the detector needs to be removed from service. If the detector is removed from service, then the part(s) under question will be re-examined with a fully qualified detector, and this detector will be used for future examinations. If the detector is returned to service following testing with recommended changes to methodology, these changes shall be approved by the CEO and implemented prior to the detector being placed back into service.

9. Procedural Requirements

9.1 Digital detector array systems shall be qualified by the CEO prior to the examination of production hardware. The DDA system shall be tested to establish baseline performance as required in Practice E2737, as well as its suitability for its intended application. In addition to the Practice E2737 tests, the following minimum tests shall be conducted:

a) Required radiographic quality levels shall be demonstrated.
b) Applicable software tools shall be tested and validated.
c) Applicable image processing parameters used to obtain the required image quality shall be tested and verified.
d) Image display monitor(s) shall be tested to ensure the requirements of 7.5 are met.
e) When systems are intended to be used outside of specified environmental conditions, such as portable systems, system qualification tests shall be performed in the expected conditions for temperature and humidity.

9.1.1 The system qualification results shall be documented and the report shall provide traceability to system components and software. The report shall include radiographic techniques for all tests. The report shall include the results of all Practice E2737 baseline performance tests, all qualification test results, results of all image display monitor tests, and background ambient light measurements. For systems that are DICONDE compliant, the report shall also include the system manufacturer's DICONDE conformance statement.

9.2 It shall be the responsibility of the user NDT facility to develop written procedures and examination techniques that are capable of consistently producing the desired results and radiographic quality level. All written procedures shall be approved by an individual qualified and certified as a Level 3 in Radiographic Testing in accordance with 5.1.1. When required by contract or purchase order, the procedure and/or techniques shall be submitted to the CEO for approval. The following items shall be addressed in the written documentation:

a) Name and address of the NDT facility, the date, and revision of the procedure.
b) Radiographic Image Identification scheme used to correlate the image to the part. If the examination procedures are similar for many components, a master written procedure shall be used that covers the details common to a variety of components.
c) The thickness and type of material.
d) A drawing, sketch, or photograph of the general exposure setup showing the object's location and the IQI, with respect to the radiation source for each view. The angle of the radiation beam in relation to the object, the source to DDA distance, source to object distance, and any blocking or masking, if used shall be documented. For robotic or similar systems with hard fixturing and controlled scan plans, a drawing, sketch or photograph is not required.
e) For X-ray tube exposures; the model and manufacturer of the x-ray tube and the focal spot size.
e.1) The nominal exposure: voltage, current, exposure time, frame rate, frames averaged, beam and/or detector collimation, beam filters used including their locations (tube, part, detector, and so forth)
f.) For radioisotope source exposures: the isotope type and source size.
f.1) The nominal exposure: source strength, exposure time, frame rate, frames averaged, beam and/or detector collimation, beam filters used including their locations (tube, part, detector, and so forth).
g.) The make, model, and manufacturer of the DDA used in the examination. The detectors $iSR_b^{detector}$ shall be addressed on the procedure, technique, or other related documentation along with the detector mode (full resolution, pixel binned, and so forth) and the detector's gain setting (as available).
h.) The geometric magnification factor used, including source to object and object to detector distances and the measured or calculated total image unsharpness.
i.) The IQI size and type, the required radiographic quality level and a minimum quality level to achieve in the region of interest. If alternate IQIs are used, include details of the design or reference to documents where such information is found.
j.) Thickness and type of material for shims or blocks, or both if used.
k.) The window width and level used to visualize the image as well as any digital image zoom.
l.) Any image processing parameters used to obtain the required image quality or improve fine detail detection. This would include noise reduction methods, contrast enhancement, or other filtering procedures.
m.) The acceptance limits shall be documented and if applicable, the zones or sections of the part or assembly to which they apply. If permitted, the acceptance criteria may be separate from the procedure but documented and available to the image interpreters.
n.) A system of measurement verification shall be documented. If a physical standard is used to verify the accuracy of a measurement, the standard shall be certified annually using standards traceable to NIST (or other recognized standardizing body). The user and the CEO shall agree to the tolerance of this standard.

10. Examination Details

10.1 Components shall be examined without surface preparation or conditioning except as required to remove surface conditions that may interfere with proper interpretation of the image.

10.1.1 Castings, forgings, and weldments shall be examined in the as cast, as forged, or as welded condition provided the surface condition does not interfere with interpretation.

10.2 Each image shall carry the identification or serial number of the component and view number, when multiple

views are taken. Each image shall also carry the identification of the NDT facility examining the component and date of the examination. Digital labeling shall never permanently alter the nature of the image or hinder interpretation of an area within the image. Images of a repair/rework area shall be identified such that it can be uniquely related to the repair/rework that was attempted. For explosives and propellants, the conditioning temperature shall be identified on the image if the ordnance has been conditioned to a temperature other than facility ambient for purposes of examination. Other methods of identifying repairs may be used with prior approval of the CEO.

10.3 The radiographic exposure coverage of each part and sampling if used shall be as specified by drawing, exposure techniques, radiographic manuals, handbooks for aircraft technical orders, or other specifications as applicable. Examination areas shall be identified on the drawing by using the symbols in accordance with ANSI/AWS A2.4 or other systems of designations that are easily identified on the drawing. If the number of parts to be examined and coverage is not specified, all parts shall be examined and 100 % coverage will be necessary.

10.4 The sequence for radiographic examination in the production operation shall be specified in the manufacturing or assembly process, specification, and contract or purchase order. If not specified, radiographic examination shall be performed at a stage in the process of manufacturing or assembly at which discontinuities can be detected. Radiographic examination may be performed prior to heat treatment providing liquid penetrant or magnetic particle examinations are performed after heat treatment.

10.5 The five quality levels listed in Table 1 shall be assigned on the basis of IQI thickness and the perceptibility of one, two, or three holes in the Hole-Type IQI image on the image. If the quality level is not specified on the drawing or other applicable documents, it shall be 2-2T. Unless otherwise specified by the CEO, Hole-Type IQIs used for examination of material 6.35 mm (0.25 in.) or less in thickness shall be a minimum of 0.13 mm (0.005 in.) thick.

10.6 When placed directly on the component, one IQI shall represent an area with a pixel value equal to or less than the least radiographically dense area of the represented area of the image.

10.6.1 Additional IQIs may be used, as necessary to cover the entire thickness range of the object. For components such as castings and forgings, where there are changes in wall thickness and wall alignment and the use of multiple IQIs is not possible, the use of one IQI is acceptable providing the required sensitivity level is achieved. The single IQI thickness shall be based on the thinnest wall being radiographed and shall be placed on the thickest wall section.

10.7 IQI selection shall be based on a thickness not greater than the nominal thickness to be radiographed. For double-wall exposure and double-wall viewing techniques, the IQI shall be based on the double-wall thickness of the component. For double-wall exposures and single-wall viewing techniques, the IQI shall be based on the single-wall thickness of the component. In no case shall the IQI thickness be based on a thickness greater than the thickness to be radiographed.

10.8 The IQI shall be placed on each part radiographed for the duration of the exposure, unless a number of identical parts are simultaneously exposed in a single image. In such a case, a single IQI shall be placed upon the source side of a part at the outer edge of the cone of radiation or farthest extremity from the central beam of radiation. For examination of irregular objects, the IQI shall be placed on the area of the part farthest from the detector. The IQI shall be placed adjacent to the area of interest since accept/reject decisions cannot be made in the area directly beneath the IQI. Where it is not practical to place the IQI on the part, the separate block technique or detector side technique may be used as applicable as described in 10.9.

10.9 Where it is impractical to place the IQI on the part, the IQI shall be placed on the source side of a separate shim, block, or like section, from the same material group. The shim, block, or like section and IQI shall be placed onto the outer edge of the cone of radiation. The shim, block, or like section shall exceed the IQI dimensions so that at least three sides of the IQI shall be visible in the image. If required, the shim shall be placed on a low absorptive material (such as polystyrene plastic or its equivalent) to ensure that the IQI shall not be any closer to the detector than the source side of the part, or area of interest being evaluated.

10.10 When examining double-walled parts such as tubing or hollow castings, where it is not practical to place an IQI on the source side of the part, IQIs may be placed on the detector side of the part and a letter F or D (Film/Detector) shall be placed adjacent to the IQI. The letter shall be made of a material and thickness that allows for it to be easily viewable within the image. Alternatively, the resulting image may be

TABLE 1 Quality Levels of Examination

IQI Designation	Radiographic Quality Level	Maximum IQI Thickness, % (a)	Minimum Hole Diameter (b)	Equivalent IQI Sensitivity, % (c)
00	1-1T	1	1T	0.7
0	1-2T	1	2T	1.0
1	2-1T	2	1T	1.4
2	2-2T	2	2T	2.0
3	2-4T	2	4T	2.8

(a) Expressed as a percentage of material thickness.
(b) Expressed as multiple thickness of IQI.
(c) Equivalent IQI sensitivity is that thickness of the IQI expressed as a percentage of the specimen thickness in which a 2T hole would be visible under the same radiographic conditions.