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Standard Practice for Radiographic Examination[1]

This standard is issued under the fixed designation E1742/E1742M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This practice[2] establishes the minimum requirements for radiographic examination for metallic and nonmetallic materials.

1.2 *Applicability*—The criteria for the radiographic examination in this practice are applicable to all types of metallic and nonmetallic materials. The requirements expressed in this practice are intended to control the quality of the radiographic images and are not intended to establish acceptance criteria for parts and materials.

1.3 *Basis of Application*—There are areas in this practice that may require agreement between the cognizant engineering organization and the supplier, or specific direction from the cognizant engineering organization. These items should be addressed in the purchase order or the contract.

1.3.1 DoD contracts.
1.3.2 Personnel qualification, 5.1.1.
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1.4 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

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

2. Referenced Documents

2.1 The following documents form a part of this practice to the extent specified herein:

2.2 *ASTM Standards:*[3]

E94 Guide for Radiographic Examination
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
E801 Practice for Controlling Quality of Radiological Examination of Electronic Devices
E999 Guide for Controlling the Quality of Industrial Radiographic Film Processing
E1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology
E1030 Test Method for Radiographic Examination of Metallic Castings
E1032 Test Method for Radiographic Examination of Weldments
E1079 Practice for Calibration of Transmission Densitometers

[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] This practice replaced MIL-STD-453.

[3] 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.

***A Summary of Changes section appears at the end of this standard**

E1165 Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging
E1254 Guide for Storage of Radiographs and Unexposed Industrial Radiographic Films
E1255 Practice for Radioscopy
E1316 Terminology for Nondestructive Examinations
E1390 Specification for Illuminators Used for Viewing Industrial Radiographs
E1411 Practice for Qualification of Radioscopic Systems
E1416 Test Method for Radioscopic Examination of Weldments
E1815 Test Method for Classification of Film Systems for Industrial Radiography
E2033 Practice for Computed Radiology (Photostimulable Luminescence Method)
E2698 Practice for Radiological Examination Using Digital Detector Arrays

2.3 *AWS Document:*
AWS A2.4 Standard Symbols for Welding, Brazing, and Nondestructive Examination[4]

2.4 *Aerospace Industries Association Document:*
NAS 410 Certification & Qualification of Nondestructive Test Personnel[5]

2.5 *ASNT Documents:*[6]
SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing
ANSI/ASNT-CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel

2.6 *NCRP Documents:*[7]
NCRP 116 Limitation of Exposure to Ionizing Radiation
NCRP 144 Radiation Protection for Particle Accelerator Facilities
NCRP 147 Structural Shielding Design for Medical X-ray Imaging Facilities

2.7 *CEN Standards:*[8]
EN 444 Non-Destructive Testing- General Principles for Radiographic Examination of Metallic Materials by X-and Gamma-Rays

2.8 *ANSI/ISO Standards:*[9]
ANSI/NCSL Z540-3 Requirements for the Calibration of Measuring and Test Equipment
ISO 10012 Measurement Management Systems—Requirements for Measurement Processes and Measuring Equipment
ISO 5579 Non-Destructive Testing-Radiographic Examination of Metallic Materials by X-and Gamma-Rays-Basic Rules

2.9 *Military Standard:*
MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification (Eddy Current, Liquid Penetrant, Magnetic Particle, Radiographic and Ultrasonic)[10]

NOTE 1—*DoD Contracts:* Unless otherwise specified, the issues of the documents that are DoD adopted are those listed in the issue of the DoDISS (Department of Defense Index of Specifications and Standards) cited in the solicitation.

NOTE 2—*Order of Precedence:* In the event of conflict between the text of this practice and the references cited herein, the text of this practice takes precedence. Nothing in this practice, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. Terminology

3.1 *Definitions*—Definitions relating to 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 *cognizant engineering organization*—the company, government agency, or other authority responsible for the design, or end use, of the system or component for which radiographic examination is required. This, in addition to design personnel, may include personnel from engineering, material and process engineering, stress analysis, NDT, or quality groups and others, as appropriate.

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

3.2.3 *energy*—a property of radiation that determines its penetrating ability. In X-ray radiography, energy machine rating is determined by kilovolts (keV), million electronvolts (MeV). In gamma ray radiography, energy is a characteristic of the source used.

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

3.2.5 *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.

3.2.6 *NDT facility*—the NDT facility performing the radiographic examination.

3.2.7 *radiographic quality level*—The ability of a radiographic procedure to demonstrate a certain IQI sensitivity.

4. Significance and Use

4.1 This practice establishes the basic parameters for the application and control of the radiographic method. This practice is written so it can be specified on the engineering drawing, specification, or contract. It is not a detailed how-to procedure to be used by the NDT facility and, therefore, must be supplemented by a detailed procedure (see 6.1). Test

[4] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.
[5] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.
[6] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.
[7] Available from National Council on Radiation Protection and Measurements, NCRP Publications, 7910 Woodmount Ave., Suite 800, Bethesda, MD 20814.
[8] Available from CEN-European Committee for Standardization, Rue De Stassart 36, Bruxelles, Belgium B-1050, http://www.cen.eu
[9] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[10] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

Methods E1030, E1032, and E1416 contain information to help develop detailed technique/procedure requirements.

5. General Practice

5.1 *Qualification:*

5.1.1 *Personnel Qualification*—Personnel performing examinations in accordance with this practice shall be qualified in accordance with MIL-STD-410, NAS 410, ANSI/ASNT-CP-189, or SNT-TC-1A and certified by the employer or certifying agency as applicable. Other equivalent qualification documents may be used when specified in the contract or purchase order.

5.1.2 *Agency Evaluation*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated in accordance with Practice E543. The applicable revision of Practice E543 shall be specified in the contractual agreement.

5.2 *Laboratory Installations:*

5.2.1 *Safety*—The premises and equipment shall present no hazards to the safety of personnel or property. NCRP 147, NCRP 116, and NCRP 144 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 city, state, or national codes.

5.2.2 *Radiographic Exposure Areas*—Radiographic exposure areas shall be clean and equipped so that acceptable radiographs may be produced in accordance with the requirements of this practice.

5.2.3 *Darkroom*—Darkroom facilities, including equipment and materials, shall be capable of producing uniform radiographs free of blemishes or artifacts, which might interfere with interpretation in the area of interest.

5.2.4 *Film Viewing Area*—The film viewing room or enclosure shall be an area with subdued lighting to preclude objectionable reflective glare from the surface of the film under examination, (see 6.27.6).

5.3 *Materials:*

5.3.1 *Film*—Film selection for production radiographs should be based on radiation source energy level, part thickness/configuration, and image quality. Only film systems having cognizant engineering organization approval or meeting the class requirements of Test Method E1815 shall be used.

5.3.1.1 *Non-film Recording Media*—Other recording media, such as paper and analog tape, may be used when approved by the cognizant engineering organization.

5.3.2 *Film Processing Solutions*—Production radiographs shall be processed in solutions capable of consistently producing radiographs that meet the requirements of this practice. Solution control shall be in accordance with Annex A4. Guide E999 should be consulted for guidance on film processing.

5.4 *Equipment:*

5.4.1 *Radiation Sources.*

5.4.1.1 *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.

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

5.4.2 *Film Holders and Cassettes*—Film holders and cassettes shall be light tight, constructed of materials that do not interfere with the quality or sensitivity of radiographs, and shall be handled properly to reduce damage. In the event that light leaks into the film holder and produces images on the radiograph, the radiograph need not be rejected unless the images obscure, or interfere with, the area of interest. If the film holder exhibits light leaks it shall be further repaired before use, or discarded. Film holders and cassettes should be routinely examined for cracks or other defects to minimize the likelihood of light leaks.

5.4.3 *Intensifying Screens:*

5.4.3.1 *Lead Foil Screens*—When using a source greater than 150 keV, intensifying screens of the lead foil type are recommended. Screens shall have the same area dimensions as the film being used and shall be in intimate contact with the film during exposure. Recommended screen thicknesses are listed in Table 1 for the applicable voltage range being used. Screens shall be free from any cracks, creases, scratches, or foreign material that could render undesirable nonrelevant images on the film.

5.4.3.2 *Fluorescent, Fluorometallic, or Other Metallic Screens*—Fluorescent, fluorometallic, or other metallic screens may be used. However, they must be capable of demonstrating the required penetrameter (IQI) sensitivity. Fluorescent or fluorometallic screens may cause limitations in image quality (see Guide E94, Appendix X1).

5.4.4 *Film Viewers*—Viewers used for final interpretation shall meet the following requirements:

TABLE 1 Lead Screen Thickness[A]

Energy Range/ Isotopes	Front Screen	Back Screen Minimum	Front and Back Screens[B]
	in.	in.	mm
0 – 150 keV[C]	0.000 to 0.001	0.005[D]	0-0.15
151 – 200 keV	0.000 to 0.005	0.005[D]	0.02-0.15
201 – 320 keV	0.001 to 0.010	0.005	0.02-0.2
Se-75	0.001 to 0.010	0.005	0.1-0.2
321 – 450 keV	0.005 to 0.015	0.01	0.1-0.2
Ir-192	0.005 to 0.015	0.01	0.02-0.2
451 keV – 2 MeV	0.005 to 0.020	0.01	0.1-0.5
Co-60	0.005 to 0.020	0.01	0.1-0.5
2 – 4 MeV	0.010 to 0.020	0.01	0.1-0.5
4 – 10 MeV	0.010 to 0.030	0.01	0.5-1.0
10 – 25 MeV	0.010 to 0.050	0.01	1.0-2.0

[A] The lead screen thickness listed for the various energy ranges are recommended thicknesses and not required thicknesses. Other thicknesses and materials may be used provided the required radiographic quality level, contrast, and density are achieved.

[B] Lead screen thicknesses in accordance with EN 444 and ISO 5579 in SI units. For energy ranges of Co-60 and 451 keV to 4 MeV, steel or copper screens of 0.1 to 0.5 mm may be used. For energy ranges above 4 MeV to 10 MeV, 0.5-1.0 mm steel or copper or up to 0.5 mm tantalum screens are recommended. Additional back scatter shielding may be achieved by additional lead screens behind the cassettes.

[C] Prepackaged film with lead screens may be used from 80 to 150 keV. No lead screens are recommended below 80 keV. Prepackaged film may be used at higher energy levels provided the contrast, density, radiographic quality level, and backscatter requirements are achieved. Additional intermediate lead screens may be used for reduction of scattered radiation at higher energies.

[D] No back screen is required provided the backscatter requirements of 6.22 are met.

5.4.4.1 The viewer shall contain a variable control to allow the selection of optimum intensities for film with varying densities.

5.4.4.2 The light source shall have sufficient intensity to enable viewing of film densities in the area of interest (see 6.27.4).

5.4.4.3 The light enclosure shall be designed to provide a uniform brightness level over the entire viewing screen.

5.4.4.4 The viewer shall be equipped with a suitable fan, blower, or other means to provide stable temperature at the viewing port to avoid damaging the radiographic film while viewing.

5.4.4.5 The viewer shall be equipped with a translucent material front in each viewing port, except for localized high-intensity viewing of high-density film areas through separate viewing ports, apertures, or other suitable openings.

5.4.4.6 A set of opaque masks, an iris-type aperture, or any other method to reduce the viewing area to suit the size of the area of interest shall be provided.

5.4.4.7 Illuminators procured to, or meeting the requirements of, Guide E1390 are acceptable for use.

5.4.5 *Digitizing Techniques*—The use of film digitizing techniques is acceptable when approved by the cognizant engineering organization.

5.4.6 *Densitometers*—The densitometer shall be capable of measuring the light transmitted through a radiograph with a film density up to 4.0 with a density unit resolution of 0.02. When film densities greater than 4.0 are permitted, a densitometer capable of measuring densities up to the maximum density permitted is required.

5.4.7 *Film Viewing Aids*—Magnifiers shall be available to provide magnification between 3× and 10× to aid in interpretation and determine indication size, as applicable. The specific magnifier used should be determined by the interpretation requirements. Devices used for determining defect size shall be calibrated as scheduled in Table 2.

5.4.8 Luminance/illuminance light meters are procured and calibrated in accordance with Table 2.

5.5 *Image Quality Indicators (IQI's):*

5.5.1 *Image Quality Indicators (IQI's)*—The IQI's shall be in accordance with contract requirements. Hole-type IQI's in accordance with this practice, Practice E1025, or the alternate design of Annex A1, or wire-type IQI's in accordance with Practice E747, shall be used when IQI's are required. If wire IQI's are used, they shall be correlated to hole-type radiographic quality levels in accordance with Practice E747. For the radiography of electronic devices, Practice E801 shall be used.

5.5.2 *Radiographically Similar IQI Material*—Materials shall be considered radiographically similar if the following requirements are satisfied. Two blocks of equal thickness, one of the material to be radiographed and one of the material of which the IQI's are made, shall be exposed together on the same film at the lowest energy level to be used for production radiographs. If the film density of the IQI material to be radiographed is within the range from 0 to +15 % of the material to be radiographed, it shall be considered radiographically similar. The film density readings shall be between 2.0 and 4.0 for both materials. An IQI with a lower radiation attenuation may be used.

TABLE 2 Process Control Checks

Check	Frequency	Paragraph
Discontinuity Image Measuring Device	[A,B]	5.4.7
Image Quality Indicators:		
Certified	When procured	5.5.4
Check (Condition)	prior to use[C]	5.5.4
Automatic Processing:		
Processor Performance	Daily[D]	A4.2.1
Base Fog	Daily[D]	A4.2.5
Developer Temperature	Prior to use[C]	A4.2.3
Replenishment Rate	[E]	A4.2.2
Transport Speed	[F]	A4.2.4
Manual Processing:		
Processing Performance	Daily	A4.3.1
Base plus Fog	Monthly	A4.2.5
Developer Temperature	Prior to use[G]	A4.3.2
Densitometer:		
Verification Check	Each shift[H]	6.27.5
Calibration Check	90 days[I]	6.27.5
Light Meters	Annual	6.27.4/6.27.6
Viewer Light Intensity		6.27.4
Thermometer Calibration	6 months[B]	A4.2.3
Ambient Visible Light	6 months[J]	6.27.6
Stepwedge Calibration	Annual	6.27.5

[A] *Optical Devices*— When procured; mechanical devices (see Footnote *B*).
[B] Calibrated and recorded in accordance with ANSI Z540-3, or ISO 10012, as applicable.
[C] Documentation of this check not required.
[D] May be extended to weekly when substantiated by actual technical/reliability data and approved by the cognizant engineering organization.
[E] Measured and recorded when solutions are changed during preventative maintenance or repair.
[F] Measured and recorded during preventative maintenance or repair.
[G] Temperatures shall be checked prior to each use. Daily documentation of this check is required.
[H] Each shift or when maintenance is performed (bulb or aperture changed).
[I] Every 90 days or whenever the densitometer verification check is not within tolerance.
[J] Fixed viewing locations with acceptable and controlled ambient lighting conditions need not be re-verified as long as those conditions are maintained.

5.5.3 *Alternate IQI Types*—The use of other types of IQI's, or modifications to types specified in 5.5.1, is permitted upon approval of the cognizant engineering organization. Details of the design, materials designation, and thickness identification of the IQI's shall be in the written procedure, or documented on a drawing that shall be referenced in the written procedure (see 6.1).

5.5.4 *IQI Control*—The IQI's shall be procured or fabricated to the requirements of Practice of E1025, or the alternate design of Annex A1, as applicable, with a manufacturer's certification of compliance with respect to alloy and dimensions. Users shall visually inspect IQI's for damage and cleanliness in accordance with Table 2.

6. Detail Requirements

6.1 *Written Procedure*—It shall be the responsibility of the NDT facility to develop a workable examination technique recorded as a written procedure that is capable of consistently producing the desired results and radiographic quality level. When required by contract or purchase order, the procedure shall be submitted to the cognizant engineering organization

for approval. The written procedure shall contain, as a minimum, the following information:

6.1.1 A drawing, sketch, or photograph of the component showing the location of the film and IQI with respect to the radiation source for each exposure.

6.1.2 The angle of the radiation beam in relation to the component, the source-to-film distance, and any blocking or masking, if used.

6.1.3 Part zones, if applicable, should be included (see 6.2). This may be accomplished through drawings and tables or by reference to documents where such information is found.

6.1.4 The nominal exposure for X-ray machines, the voltage, milliamps, time (or rads as applicable), and effective focal spot size. For radioisotope sources, the isotope type, source strength (curies), exposure time, and source size.

6.1.5 Film designation (for example, brand, type, and processing parameters), intensifying screens (for example, type and thickness of screens), or filters (for example, filter material, thickness, and location) if used, film loading instructions (for example, when using multiple film exposure techniques), and the desired film density range.

6.1.6 Thickness and type of material.

6.1.7 The IQI size and type, and the required radiographic quality level. If alternate IQI's are used (see 5.5.3), include details of the design or reference to documents where such information is found.

6.1.8 Thickness and type of material for shims or blocks, or both, if used.

6.1.9 Name and address of the NDT facility and the date, or revision, of the procedure.

6.1.10 Radiographic identification scheme used to correlate part-to-film. If the examination procedures are similar for many components, a master written procedure may be used that covers the details common to a variety of components. All written procedures shall be approved by an individual qualified and certified as a Level III for radiography in accordance with 5.1.1.

6.2 *Acceptance Requirements*—When examination is performed in accordance with this practice, engineering drawings, specifications, or other applicable documents shall indicate the criteria by which the components are judged acceptable. Complex components may be divided into zones and separate criteria assigned to each zone in accordance with its design requirements. When used, direct references to ASTM reference radiographic standards shall include the grade level for each type of discontinuity permitted for each part or zone.

NOTE 3—Information on reference radiographs can be obtained from the *Annual Book of ASTM Standards*, Vol 03.03 or from ASTM Headquarters.

6.3 *Surface Preparation*—Components may be examined without surface preparation or conditioning except as required to remove surface conditions that may interfere with proper interpretation of radiographs.

6.3.1 Castings, forgings, and weldments may be radiographed in the as-cast, as-forged, or as-welded conditions provided the following requirements are met.

6.3.1.1 For castings and forgings, the surface condition shall not interfere with evaluation.

6.3.1.2 Accessible surfaces of welds shall be prepared in accordance with A2.1.

6.4 *Radiographic Identification*—Each radiograph shall carry the identification or serial number of the component and view number, when multiple views are taken. Each radiograph shall also carry the identification of the NDT facility examining the component and the date of the examination. Radiographs of a repair area shall be identified with *R1, R2, R3*, and so forth, indicating the number of times that repairs were attempted. Alternative schemes may be used for identification of repair radiographs so long as each film is clearly identified to relate to a particular repair area. For explosives and propellants, the conditioning temperature shall be identified on each X-ray film if the ordnance has been conditioned to a temperature other than facility ambient for purposes of examination.

6.5 *Examination and Coverage*—The number of parts examined, and the radiographic coverage of each part shall be as specified by drawings, radiographic techniques, radiographic manuals, handbooks for aircraft technical orders, or other specifications, as applicable. Areas to be examined shall be identified on the drawing by using the symbols in accordance with AWS A2.4 or other systems of designations that are easily identified on the drawing. If the number of parts to be examined and the amount of coverage of each part is not specified, all parts shall be examined and shall receive 100 % radiographic coverage.

6.6 *Examination Sequence*—The sequence for radiographic examination in the production operation should be specified in the manufacturing or assembly process specification, 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 before heat treatment, provided liquid penetrant or magnetic particle examinations are performed after heat treatment.

6.7 *Nonfilm Techniques*—When permitted by purchase order, contract, or specification, radioscopic/radiological examinations using nonfilm techniques shall be in accordance with Practices E1255, E2033 or E2698 or a nonfilm specification approved by the CEO as required. Prior approval shall be obtained from the Level III radiographer of the cognizant engineering organization (see 5.1.1).

6.8 *Multi-Film Techniques*—Film techniques with two or more films of the same or different speeds in the same film holder, to be used in either single or superimposed film viewing, shall be permitted provided that the applicable radiographic quality level, and film density requirements (see 6.9 and 6.10), are achieved for the area of interest.

6.9 *Radiographic Quality Levels*—The five quality levels listed in Table 3 may 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 radiograph. If the quality level is not specified on the drawing or other applicable documents, it shall be Level 2-2T. Unless otherwise specified by the cognizant engineering organization, hole-type IQIs used for examination of material 0.25 in. (6.35 mm) or less in thickness shall be 0.005-in. (0.127-mm) minimum thickness.

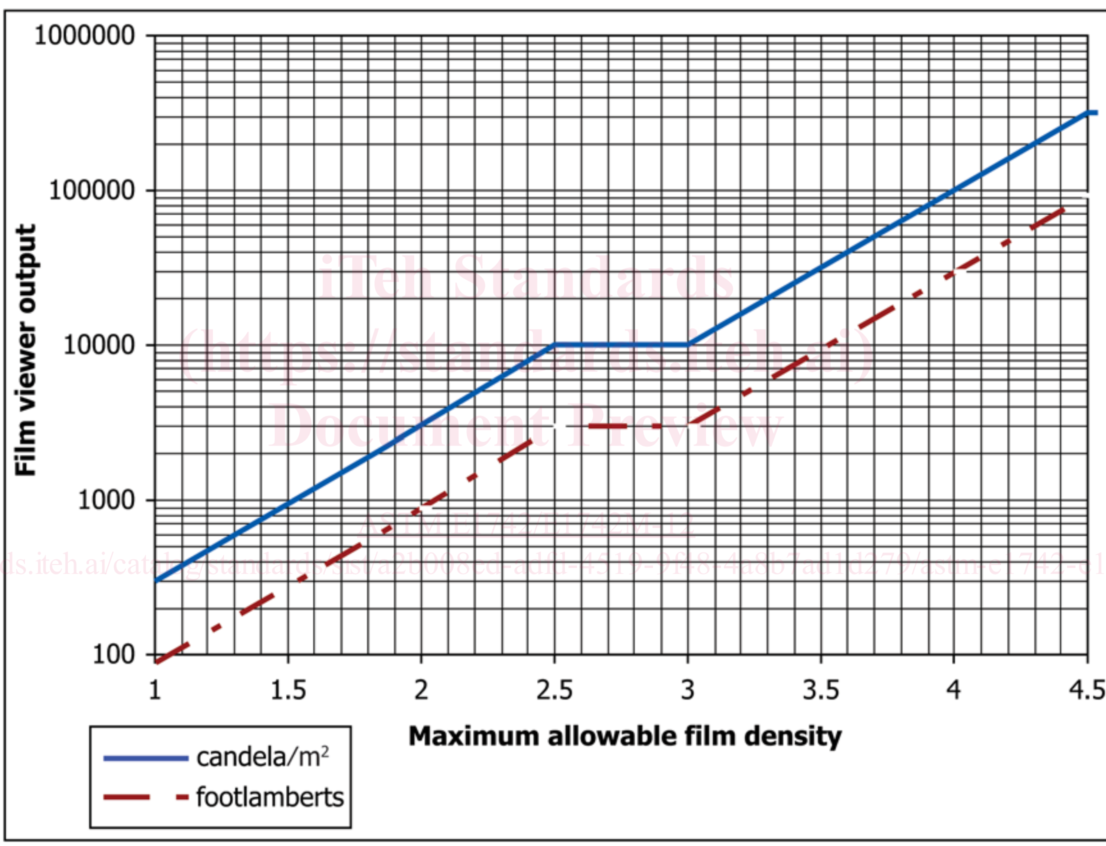
TABLE 3 Quality Levels of Examination

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 clearly visible under the same radiographic conditions.

6.10 *Film Density*—For single-film viewing, the film density shall be ≥1.5 in the area of interest. Where superimposed film viewing is used, the film density of the superimposed films shall be from 2.0 in the area of interest, and each individual film shall not have a film density below 1.0 in the area of interest. Film densities above 4.0 are permitted when agreed upon between the cognizant engineering organization and the NDT facility (see Note 1 of Fig. 1). In no case shall the maximum film density exceed 4.5. For single-film viewing, film densities less than 1.5 are permitted only when items not requiring an IQI (see 6.18) are examined. The maximum readable film density depends on the film viewer used and its maximum luminance (see 6.27.4). The maximum readable film density shall always be posted on the viewer.

6.11 *Processing Radiographs*—Radiographs shall be free from blemishes which may interfere with film interpretation.



NOTE 1—This figure is a depiction of the abscissa axis: Maximum Allowable Film Density versus ordinate axis: Candela/m^2 and footlamberts in graphical format from tabular data derived from Guide E1390 and ISO 5580 (also known as EN 25580). Conversion from tabular data to a graph accounts for the step in the line. For Film Viewer Output of 10 000 Candela/m^2 (2919 Footlamberts), the Maximum Allowable Film Density shall be 3.0. Regarding the ordinate axis: Candela/m^2, the minimum luminance level required for the average human eye to achieve photopic eye response (that is where maximum resolution and contrast discrimination occurs) is at 10 candela/m^2. At levels below this value the eye responds scotopically which means lower contrast discrimination and resolution. While photopic vision typically occurs at a threshold of 10 candela/m^2 for the average human eye, this curve takes advantage of the fact that at lower film densities most viewers can achieve an amount of light that guarantees that virtually all operators will be viewing film in the photopic vision mode, that is 30 candela/m^2 for densities <2.5. A theoretical advantage of this curve is that it compensates for the reduced contrast sensitivity of radiographic film at lower densities.

NOTE 2—NDT film systems, classified corresponding to E1815 system classes "Special, I and II", with or without lead screens, are suitable for the extended viewing range above a density of 4, due to their high gradient ($G_{D\text{-}D0 = 4}$ >6) at D = 4 above fog and base. These double sided NDT film systems have a high silver content and do not saturate as early as medical and classes III, W-A, W-B and W-C film systems. The basic advantage of increasing the density is the increase of contrast with density. Since the contrast/noise ratio also increases (with the square root of density), the perception of indications of small flaws improves with higher density significantly. The operator should mask all film areas of lower density to avoid blinding (dazzling). Blinding reduces the eye perception and requires longer eye adaptation time. High brightness viewing stations also heat up films depending on the density and viewing time. The operator shall prevent overheating to protect the film integrity.

FIG. 1 Maximum Allowable Film Density with Film Viewer Output