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An American National Standard

Standard Practice for Radiographic Examination¹

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¹ This practice is under the jurisdiction of ASTM Committee E7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on Radiology (X and Gamma) Method.

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1. Scope

1.1 This practice² establishes the minimum requirements for radiographic examination for metallic and nonmetallic materials.
~~NOTE 1—When coordinated through the Department of Defense (DoD), this practice is intended as a direct replacement of MIL-STD-453.~~

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 areas are identified as follows: items should be addressed in the purchase order or the contract.~~

- 1.3.1 DoD contracts, ~~2.9.~~
- 1.3.2 Personnel qualification, 5.1.1.
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- 1.3.19 Reproduction of radiographs, 6.27.10~~†~~ and 6.27.10~~2~~1.
- 1.3.20 Acceptable parts, 6.28.1.

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.*

2. Referenced Documents

- 2.1 The following documents form a part of this practice to the extent specified herein:
- 2.2 *ASTM Standards*:

~~Annual Book of ASTM Standards, Vol 03.03.~~

² This practice replaced MIL-STD-453.

- E 543 Practice for ~~Evaluating Agencies that Perform~~ Performing Nondestructive Testing³
- E 747 Practice for Design, Manufacture, and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology³
- E 801 Practice for Controlling Quality of Radiological Examination of Electronic Devices³
- E 999 Guide for Controlling the Quality of Industrial Radiographic Film Processing³
- E 1025 Practice for Design, Manufacturer, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology³
- E 1030 Test Method for Radiographic Examination of Metallic Castings³
- E 1032 Test Method for Radiographic Examination of Weldments³
- E 1079 Practice for Calibration of Transmission Densitometers³
- E 1165 Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging³
- E 1254 Guide for Storage of Radiographs and Unexposed Industrial Radiographic Film³
- E 1255 Practice for Radioscopy³
- E 1316 Terminology for Nondestructive Examinations³
- E 1390 Guide for Illuminators Used for Viewing Industrial Radiographs³
- E 1411 Practice for Qualification of Radioscopic Systems³
- E 1416 Test Method for Radioscopic Examination of Weldments³
- E 1815 Test Method for Classification of Film Systems, for Industrial Radiography³

2.3 ~~AWS Document:~~

AWS A2.4 Symbols for Welding and Nondestructive Testing⁴

2.4 ~~Aerospace Industries Association Document:~~

NAS 410 Certification & Qualification of Nondestructive Test Personnel⁵

2.5 ~~ASNT Documents:~~

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing⁶

ANSI/ASNT-CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel⁶

2.56 ~~NCRP Documents:~~

NCRP 51 Radiation Protection Design Guidelines for 0.1–100 MeV Particle Accelerator Facilities⁷

NCRP 91 Recommendations on Limits for Exposures to Ionizing Radiation⁷

2.67 ~~ANSI Standards:~~

ANSI IT 9.1 Imaging Media (Film)—Silver-Gelatin Type Specifications for Stability⁸

ANSI PH 4.8 Photography (Chemicals)—Residual Thiosulphate and Other Chemicals in Films, Plates, and Papers—Determination and Measurement⁸

2.78 ~~Government Standard:~~

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification (Eddy Current, Liquid Penetrant, Magnetic Particle, Radiographic and Ultrasonic)⁹

2.89 ~~Other Government Documents:~~

NIST Handbook 114 General Safety Standard for Installations Using Non-Medical X-Ray and Sealed Gamma Ray Sources, Energies up to 10 MeV

2.9 ~~DoD Contracts—Unless¹⁰~~

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~~.

2.10 ~~Order 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 Available from American Welding Society (AWS), P.O. Box 351040, Miami, FL 33135.

³ Annual Book of ASTM Standards, Vol 03.03.

⁴ Available from American Welding Society for Nondestructive Testing, 1711 Arlingate Plaza, (AWS), P.O. Box 28518, Columbus, OH 43228-0518; 351040, Miami, FL 33135.

⁵ Available from National Council on Radiation Protection and Measurements, NCRP Publications, 7910 Woodmount Ave., Suite 800, Bethesda, MD 20814; Aerospace Industries Association, 1050 Eye St. N.W., Washington, DC 20005.

⁶ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036; Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

⁷ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS; National Council on Radiation Protection and Measurements, NCRP Publications, 7910 Woodmount Ave., Suite 800, Bethesda, MD 20814.

⁸ Available from American National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899; Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

⁹ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

¹⁰ Available from National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899.

3. Terminology

3.1 *Definitions*—Definitions relating to radiographic examination, which appear in Terminology E 1316, 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 engineering organization 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 (kV), 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 E 1025.

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

3.2.7 *prime contractor*—~~a contractor having overall responsibility for design, control, and delivery of a system or piece of equipment.~~

~~3.2.8—radiographic quality level—The ability of a radiographic procedure to demonstrate a certain IQI sensitivity.~~

3.2.9 *subcontractor*—subcontractor (supplier) shall mean that organization responsible to the prime contractor for a portion of the system:

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 Methods E 1030, E 1032, and E 1416 contain information to help develop detailed technique/procedure requirements.

5. General Practice

5.1 *Qualification:*

5.1.1 *Personnel Qualification*—~~Personnel processing parts in radiography, or making accept/reject decisions based on the results of radiographic performing examinations performed in accordance with this practice; shall be qualified and certified in accordance with MIL-STD-410. Qualification documents such as MIL-STD-410, NAS 410, ANSI/ASNT-CP-189, SNT-TC-1A, 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 Qualification*—~~The agency performing examinations to Evaluation—If specified in the requirements of this practice may contractual agreement, NDT agencies shall be qualified and evaluated in accordance with Practice E 543. The applicable revision of Practice E 543 if so shall be specified in the requesting document. 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 51, NCRP 91 and 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 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 6.27.64).

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 E 1815 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 ~~6.27.3. Annex A4.~~ Guide E 999

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 kV, 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 provided the specified radiographic quality level, density, and contrast are obtained.

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

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 6.27.46).

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 E 1390 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.

TABLE 1 Lead Screen Thickness

| KV Range | Lead Thickness ^A | |
|--------------------------|------------------------------------|-------------------------------|
| | Front Screen Maximum, in. | Back Screen Minimum, in. |
| 0 to 150 kV ^B | 0.000 | 0.005 (0.127 mm) ^C |
| 150 to 200 kV—Ir 192 | 0.005 (0.127 mm) | 0.005 (0.127 mm) |
| 200 kV to 2 MV—Co 60 | 0.005 to 0.010 (0.126 to 0.254 mm) | 0.010 (0.254 mm) |
| 2 to 4 MV | 0.010 (0.254 mm) | 0.010 (0.254 mm) |
| 4 to 10 MV | 0.010 to 0.030 (0.254 to 0.762 mm) | 0.010 (0.254 mm) |
| 10 to 25 MV | 0.010 to 0.050 (0.254 to 1.27 mm) | 0.010 (0.254 mm) |

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

^B Prepackaged film without lead screens may be used up to 150 kV. Prepackaged film with lead screens may be used from 80 to 150 kV. Both types of prepackaged film may be used at higher energy levels provided the contrast, density, radiographic quality level, and backscatter requirements are achieved.

^C No back screen is required provided the back scatter requirements of 6.22 are met.

Devices used for determining defect size shall be calibrated as scheduled in 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 (see 5.5.2), military, or practice, Practice E 1025, or the alternate design of Annex A1. or wire-type IQI's in accordance with Practice E 747, 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 E 747. For the radiography of electronic devices, Practice E 801 shall be used. This practice permits the use of either military or ASTM designs used.

5.5.2 Hole-Type IQIs (Military)—The IQI design shall be as follows:

5.5.2.1 Image Quality Indicator dimensions shall be in accordance with Fig. 1.

5.5.2.2 The IQIs shall be fabricated from the same material group (see 3.2.5) or radiographically similar materials (see 5.5.3) as the object to be radiographed. Material groups and their designations are listed in Fig. 1.

5.5.2.3 The IQIs shall be identified as to material group and thickness representing the thickness (see Fig. 1) of the specimen

TABLE 2 Quality Control Examination Checks

| IQI Designation | Radiographic Quality Level | Maxiragraph |
|----------------------------|----------------------------|--|
| Check | Frequency | Paragraph |
| Defect measuring device | A | Minimum Hole Diameter ^B 5.4.7 |
| Image equivalent IQI Sors: | | |
| Image quality indicators: | | |
| Certified | whens procured | 5.5.4 |
| Certified | when procured | 5.5.4 |
| Check (condition) | pri ty, % ^C | 5.5.4 |
| Check (condition) | prior to use ^C | 5.5.4 |
| Automatic processing | | |
| Processor performance: | daily | A4.2.1 |
| Base fog | 00 | 4-1TA4.2.5 |
| Developer temperature | daily | A4.2.5 |
| Replenishing flow rate | 4T | 0-7 |
| Transport speed | prior to use ^C | A4.2.3 |
| Manual Processing: | 0 | 1-2T.2 |
| Processing performance | 2T | A4.2.2 |
| Base fog | E | 1.02.4 |
| Developer temperature | prior to use ^F | A4.2.4 |
| Viewer intensity | -4 | 2-4T |
| Viewer intensity | daily | A4.3.1 |
| Thermometer calibration | 4T | 4-4 |
| Densitometer: | monthly | A4.2.5 |
| Verification check | -2 | 2-2T |
| Ambient visible light | 2 | 27.4 |
| Ambient visible light | 6 months ^B | 6.27.4 |
| Visible light meter | 6 months ^B | A4.2.03 |
| Visible light meter | 3 | A4.2.3 |
| Stepwedge calibration | H | 2-4T7.5 |
| | 2 | 6.27.5 |
| | 6 months | 4T6.27.6 |
| | annual ^B | 6.27.6 |
| | annual ^B | 6.2.86 |
| | annual ^B | 6.27.6 |
| | annual | 6.27.5 |

^A Expressed as a percentage of material thickness. Optical Devices— When procured; mechanical devices (see Footnote B).

^B Expressed as multiple thickness of IQI.

^C Documentation of this check not required.

^D Measured and recorded when solutions are changed during preventative maintenance or repair.

^E Measured and recorded during preventative maintenance or repair and recorded.

^F Temperatures shall be checked prior to each use. Daily documentation of this check is required.

^G When procured, when bulb type or wattage is changed or maintenance is performed.

^H 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.

to be radiographed. For example, a specimen thickness of $\frac{3}{4}$ in. requires a 75 IQI. Lead numbers and letters, or a material of similar radiographic opacity, shall be used for identification. For identification of materials not listed in Fig. 1, the chemical symbol of the predominant element shall be used.

~~5.5.2.4 The IQI thickness shall consist of a two-digit number that expresses the material thickness in one hundredths of an inch. When the material is a composite or does not have a predominant element, a controlled system for IQI identification shall be established and referenced in the written procedure (see 6.1).~~

~~5.5.2.5 Rectangular IQI identification shall be permanently attached to the IQI. Circular IQI identification shall be placed adjacent to the IQI to provide identification of the IQI on the radiograph. (See Fig. 1.)~~

~~5.5.3 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 IQI materials 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. The IQI's of a lower radiographic density may be used.~~

~~5.5.43 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 E 1025, 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. Included shall be the angle of the radiation beam in relation to the component, the source-to-film distance, and any blocking or masking, if used.

6.1.2 Part zone, if applicable, and acceptance criteria. This may be accomplished through drawings and tables or by reference to documents where such information is found.

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

6.1.4 Film designation, intensifying screens, or filters used and the desired film density range.

6.1.5 Thickness and type of material.

6.1.6 The IQI size and type, and the required radiographic quality level. If alternate IQI's are used (see 5.5.43), include details of the design or reference to documents where such information is found.

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

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

6.1.9 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 23—Information on reference radiographs can be obtained from the *ASTM 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 ~~6.19.1~~ 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 inspecting 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. 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 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 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, radiosopic examination shall be in accordance with Practice E 1255 and appropriate annex. Qualification of radiosopic systems shall be in accordance with Practice E 1411. Prior approval of the detailed examination, evaluation, and quality control procedures 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 2.3 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. or less in thickness shall be 0.005-in. minimum thickness.

6.10 *Film Density*—For single-film viewing, the density shall be in the range from 1.5 to 4.0 (inclusive) in the area of interest. Where superimposed film viewing is used, the density of the superimposed films shall be in the range from 2.0 to 4.0 (inclusive) in the area of interest, and each individual film shall not have a 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. For single-film viewing, densities less than 1.5 are permitted only when items not requiring an IQI (see 6.18) are inspected.

6.11 *Processing Radiographs*—Radiographs shall be free from blemishes that will mask discontinuities or which may interfere with film interpretation.

6.12 *IQI Selection*—The IQI thickness shall be based on a thickness not greater than the nominal thickness to be radiographed. For double-wall exposures and double-wall viewing techniques, the IQI shall be based on the double-wall thickness of the component. The IQI thicknesses that are in between, or smaller than, the thickness increments in Fig. 1 (for example, a hole-type IQI that is 0.0025 or 0.006 in. thick) may be used but are not mandatory. 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. For fabrication welds the IQI shall be selected as specified in 6.19.2. accordance with Annex A2. For explosive/propellants, rocket motors, and their components, IQI selection shall be as specified in 6.20. accordance with Annex A3.

TABLE 3 UnshQuarpnlity Levelss (Ug) (Ma of Exiamum)ination

| MatIQI Designat Thickness (in.) | URadiog {raphic Quality Level | Maximum IQI Thickness, % ^A | Minimum Hole Diameter ^B | Equivalent IQI Sensitivity, % ^C |
|--|-------------------------------------|--|---------------------------------------|---|
| 00 | 1–1T | 1 | 1T | 0.7 |
| Under | 0–02T | 4 | 2T | 4.0 |
| 2 | 1–2T | 1 | 2T | 1.0 |
| Under | 02–4T | 2 | 4T | 4.030 |
| 2 | 2–1T | 2 | 1T | 1.4 |
| through 4 | 02–2T | 2 | 2T | 2.0 |
| 2 | 2–2T | 2 | 2T | 2.0 |
| through 4 | 2–40T | 2 | 4T | 2.8 |
| Over | 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.

6.13 *Placement of IQI's*—An IQI shall be placed on each part radiographed; for the duration of exposure, unless a number of identical parts are simultaneously exposed on a single film. 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 of the exposure setup (that is, farthest from the radiation beam centerline). For examination of irregular objects, the IQI shall be placed on the area of the part farthest from the film. The IQI's 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 practicable to place the IQI on the part, the separate block technique in 6.13.1, or the film-side technique in 6.13.2, may be used as applicable.

6.13.1 *Shim, Separate Block, or Like-Section IQI Technique* —Where it is impractical to place the IQI upon the part radiographed, the IQI may be placed on the source side of a separate shim, block, or like section, from the same material group (or material that is radiographically similar, see 5.5.32). The shim, block, or like section and IQI shall be placed on 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 on the radiograph. 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 film than the source side of the part, or area of interest being evaluated.

6.13.2 *Film-Side IQI Placement*—When examining double-walled parts such as tubing or hollow castings, and it is not practical to place an IQI on the source side of the part, IQI's may be placed on the film side of the part as specified in 6.13.2.1 and 6.13.2.2. A letter “F” shall be placed adjacent to the IQI.

6.13.2.1 *Film-Side IQI's (Double Wall-Double Image)*—When performing double-wall radiography in which both walls are viewed for acceptance, the film-side radiographic technique shall be demonstrated on an exposure of a like section in which the required IQI shall be placed on the source side, and sets of wire IQI's, (or a series of hole-type IQI's) ranging in thickness from that of the required IQI to one fourth that thickness shall be placed on the film side. If the required IQI on the source side indicates the specified radiographic quality level, then the image of either the smallest IQI hole in the thinnest IQI, or the image of the smallest wire, visible on the film side, shall be used to determine the proper film-side IQI to be used for production radiographs.

6.13.2.2 *Film-Side IQI's (Double Wall-Single Image)*—When performing double-wall radiography in which only the wall portion next to the film is viewed for acceptance, the film-side radiographic technique shall be demonstrated on an exposure of a like section in which the required IQI is placed on the inside of the part and a set of IQI's, as specified in 6.13.2.1, are placed on the film side. If the IQI on the inside indicates the required radiographic quality level, then the image of either the smallest IQI hole in the thinnest IQI, or the image of the smallest wire, visible on the film side, shall be used to determine the proper film-side IQI to be used for production radiographs.

6.13.3 *IQI Qualification Exposure*—When included in the written procedure and approved by the Level III radiographer of the cognizant engineering organization, a single exposure with the applicable IQI may be made to qualify the examination process.

6.13.3.1 *Qualification Exposure*—When it is impractical to continually place IQIs on a part requiring more than one exposure, a single exposure of the IQI may be made to qualify the examination process. As long as the radiographic technique is not changed, subsequent exposures may be performed without an IQI. A new qualification exposure with an IQI shall be made daily, or whenever any of the following parameters are changed:

- (1) Energy level (kilovolts or Megavolts),
- (2) Exposure (milliamperere × time),
- (3) Source to film distance,
- (4) Screens, collimation, masking, or filters,
- (5) Film type, or
- (6) Film processing parameters.

6.13.3.2 *Subsequent Exposures*—Subsequent exposures shall be positively tied to the qualification exposure by serialization or other methods. A copy of the qualification shall be provided to all parties with review authority.

6.13.4 *Re-radiography*—Whenever there is a reasonable doubt as to the interpretation or clarity of the radiograph because of film artifacts or improper technique, re-radiography is required.

6.14 *Masking*—Shot, masking solutions, sheet lead and foils, polytetrafluoroethylene (PTFE), plastic, or other low-density, nonmetallic absorbers may be used as masking to minimize the effects of scattered radiation or undercutting. The shot may be a mixture of many diameters to provide a uniform density. Heavy chemical solutions used for masking may be toxic; the proper health and safety precautions and markings shall be used.

6.15 *Filters*—Filters may be used whenever the contrast reductions caused by low-energy scattered radiation occurring on production radiographs are of significant magnitude to cause difficulty in meeting the radiographic quality level or radiographic coverage requirements as specified in the contract, purchase order, or drawing.

6.16 *Multiple-Film-Cassette Exposure*— Where more than one film cassette is used to cover the area of interest in a single exposure, an IQI image shall appear on at least one radiograph at the edge of the film most distant from the center of the radiation beam. When the source is placed on the axis of the object, and the complete circumference is radiographed with a single exposure, at least three equally spaced IQI's are to be used if possible.

6.17 *Applicable IQI Area of Interest*— When placed directly on the component, one IQI shall represent an area within which radiographic densities do not vary more than +30 to −15 % from the density measured through the body of the IQI. At least one

IQI per radiograph shall be used, except as specified in 6.17.1 and 6.18. Accept/reject decisions shall not be made directly beneath the IQI shim-combination when placed directly over the weld-combination.

6.17.1 *Radiograph Qualification Using Two IQI's*—When the film density varies by more than is specified in 6.17, two IQI's used in the following manner are acceptable. If one IQI shows an acceptable sensitivity in the most dense portion of the radiograph, and the second IQI shows an acceptable sensitivity in the least dense portion of the radiograph, the two IQI's shall serve to qualify the radiograph within these density limits. Additional pairs of IQI's may be used, as necessary in subsequent exposures, 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 two IQI's is not possible, the use of one IQI is acceptable. The IQI thickness shall be based on the thinnest wall being radiographed and shall be placed on the thickest wall section. The required +30 to -15 % density tolerance (see 6.17), need not be met; however, the density in the areas of interest shall be between 1.5 and 4.0 and the required radiographic quality level shall be obtained.

6.18 *Non-Requirement of IQI's*—The IQIs are not required when:

6.18.1 Examining assemblies for debris,

6.18.2 Conducting radiography for defect removal provided final examination of the area includes an IQI,

6.18.3 Examining to show material details or contrast between two or more dissimilar materials in component parts or assemblies including honeycomb areas for the detection of fabrication irregularities or the presence or absence of material, or

6.18.4 When surfaces are inaccessible an alternate method of qualification shall be used subject to the approval of the cognizant engineering organization.

6.19 *Fabrication Welds:*

6.19.1 *Accessible surfaces of Fabrication welds to be radiographed shall be prepared as necessary processed* in accordance with the welding process specification if applicable, and the valleys between beads, weld ripples, or other surface irregularities are blended to a degree such that the resulting radiographic contrast due to surface condition cannot mask or be confused with that of any defect.

6.19.2 *IQI Selection for Welds*—For butt joints on simple structures such as pipe or plate, the thickness on which the IQI is based shall be the single-wall thickness plus any reinforcement allowed. For T-joints, lap joints, corner joints, fillet welds, weld surfacing, or for joints in complex assemblies where both sides of the joint are not accessible, the thickness on which the IQI is based shall be the total thickness through which the X-ray beam will pass. If different size sections are joined, the IQI shall be based on the thinner wall section. Backing strips or rings are not considered as a part of the weld, base material, or reinforcement (bead) thickness upon which the IQI is based. If subsequent machining reduces the thickness of the weld area of interest and follow-up NDT (ultrasonic, liquid penetrant, or radiography) is not required, IQI size selection shall be based on final product thickness. If the required sensitivity cannot be obtained, radiographic examination shall be required after final machining.

6.19.2.1 *IQI Placement for Welds*—The IQIs shall be placed on the source side parallel with, and at least 1/8 in., and not more than 1 1/4 in. from the weld being radiographed. When the weld is not radiographically similar or where part geometry precludes placement, the IQI wire or hole of the required sensitivity, as applicable, may be placed over the weld, but outside of the area of interest. When weld-reinforcement (weld bead), backing rings or strips are not removed, a shim of the same material group or radiographically similar material (see 5.5.3) shall be placed between the IQI and base material to provide approximately the same thickness of material under the IQI as the average thickness of the weld reinforcement plus the wall thickness and backing strip or ring.

6.19.2.2 *Examination Coverage for Welds*—Unless otherwise specified on the engineering drawing or other contractual documents, welded parts requiring radiography shall be radiographed for 100 % of the length of the weld zone, including the weld heat affected zone.

6.19.3 *Longitudinal Circumferential Weld Junctures*—Where portions of longitudinal welds adjoining a circumferential weld are being examined simultaneously with the circumferential weld, additional IQI's shall be placed on the longitudinal weld at the outer edge of the cone of radiation used to radiograph the circumferential weld.

6.19.4 *Longitudinal Welds*—For longitudinal welds, an IQI shall be placed at the extreme end of the area to be interpreted. The long axis of the IQI shall be parallel with and at least 1/8 in., but not more than 1 1/4 in., from the weld edge.

6.19.5 *Circumferential Welds*—Except as provided in 6.19.5.1 and 6.19.5.2, radiography shall be performed in which the radiation passes through only one wall. When double-wall techniques are used, either superimposed or elliptical (offset) projections may be used.

6.19.5.1 *Double-Wall Exposure, Double-Wall Image*—Welds in pipe and tubes 3 1/2 in. and less in nominal size (diameter) may be radiographed using the double-wall method where the radiation passes through both walls and both walls are viewed together for acceptance. An IQI, based on the double-wall thickness plus twice the weld reinforcement, as applicable, shall be placed on the source side wall, on top of a shim approximately equal to twice the weld reinforcement. As an alternate, the same IQI and shim may be placed on the source side of a like section that is placed adjacent to the weld being radiographed. When impractical to do the above, the IQI may be placed on top of a block that is approximately equal to twice the wall thickness plus twice the weld reinforcement, as applicable. The IQI and block shall be placed on a low-density material (such as polystyrene plastic or its equivalent), adjacent to the weld being examined, so that the top of the block is level with the upper surface of the tube or pipe.

6.19.5.2 *Double-Wall Exposure, Single-Wall Image*—For welds in pipe and tubes greater than 3 1/2 in. in nominal size (diameter),

only the weld closest to the film shall be viewed for acceptance. An IQI, corresponding to the single-wall thickness plus any single-wall weld reinforcement, shall be placed adjacent to the weld on the inner wall on top of a shim equal to the weld reinforcement. When this is not possible, the same IQI and shim may be placed on the bottom of the inner wall of a like section of a tube or pipe placed adjacent to the weld being radiographed. When a like section of the tube or pipe is unavailable, the IQI may be placed on a block adjacent to the weld being radiographed. The block thickness shall be equivalent to twice the wall thickness plus any single-wall weld reinforcement. The top of the block shall not be any lower than the bottom of the inner wall of the tube or pipe.

6.19.6 *Electron Beam (EB) Welds*—The central beam of radiation shall be directed parallel with the fusion lines. Cognizant engineering organization approval is required when the beam to weld groove angle exceeds 5°. Annex A2.

6.20 *IQI Selection for Explosives/Propellants, Rocket Motors, and Their Components*—These devices shall be radiographed in accordance with Annex A3.

6.20.1 *Installed Explosives/Propellants*—For the radiography of explosives/propellants contained within a vessel, the IQI shall be based on a chord length thickness of the explosive/propellant that is traversed by the X-ray beam. When it is not possible to obtain the required radiographic quality level using an IQI that is based only on the explosive/propellant thickness, the chord lengths through the vessel wall material layers may be used in determining the total equivalent thickness of explosive/propellant upon which the IQI thickness is to be determined. The equivalencies shall be determined in the following manner:

$$ET = AC/B \tag{1}$$

where:

- A = physical density of the vessel section;
- B = physical density of propellant/explosive;
- C = thickness of vessel section traversed by the center of the X-ray beam, and
- ET = equivalent thickness of propellant/explosive for each vessel wall material traversed by the center of the X-ray beam.

NOTE 3—This relationship was derived experimentally and has been determined adequate for the evaluation of vessels containing explosives/propellants.

The IQI's may be fabricated from inert materials that have approximately the same physical density as the propellant/explosive to be radiographed. As an alternate, the IQI may be fabricated from, and based on, a more dense material with a thickness that has been equated to the total equivalent propellant/explosive thickness as determined by the method previously shown.

6.20.2 *Single-Wire IQI's*—Single-wire IQI's of a denser (metallic) material may be used provided the thickness of metal upon which the IQI is based has been equated to the equivalent explosive/propellant thickness by the method shown in 6.20.1. Wire thickness shall be equated to hole-type radiographic quality levels (as specified in Table 2) 3) by the following method:

$$\text{Wire IQI diameter} = TPY/XF \tag{1}$$

where:

- T = total equivalent thickness, or thickness of explosive/propellant material,
- P = required sensitivity as a percentage of material thickness (that is, equivalent IQI sensitivity),
- Y = density of explosive/propellant,
- X = density of IQI material, and
- F = form factor for round wire (0.7854).

6.21 *Contrast*—The contrast of the radiograph shall be determined by measuring the difference in density of the film through the IQI and the adjacent material. The minimum density difference shown in Fig. 2 1 shall be achieved between the IQI and the

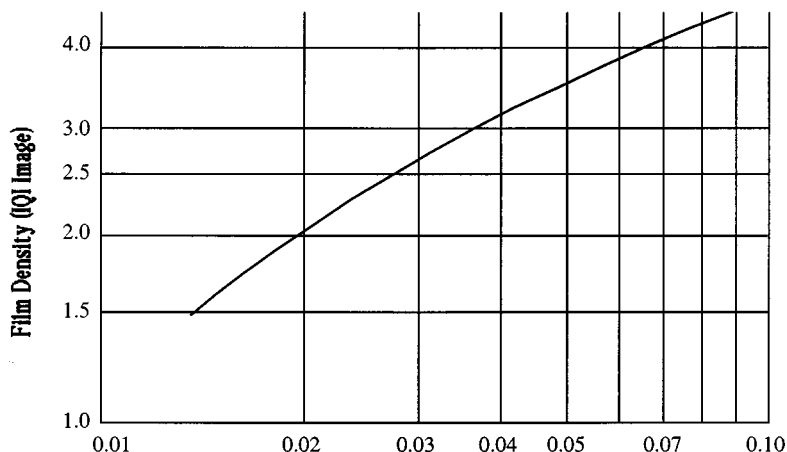


FIG. 1 Minimum Film Density Difference Between IQI and Adjacent Base Metal Material Images

base metals for Radiographic Quality Levels 1 and 2.

6.22 *Back Scatter Radiation*—During each exposure the film shall be monitored for back scatter. Each film holder shall have a lead letter “B” a minimum of ½ in. high and a minimum of 1/16 in. thick positioned behind the film and within the general area of the film to be viewed. Should the image of the lead letter “B” appear on the film as a light image, the film should be considered unacceptable and screens, lead backing, or other appropriate measures shall be implemented on subsequent exposures to reduce back scatter. The appearance of a dark image (higher density “B” image) should be disregarded unless the dark image could be confused with, or interfere with, interpretation in the area of interest. When identical parts, or segments of parts, are to be examined by the same technique, the letter “B” may be used to qualify the initial exposure only and may be omitted for subsequent exposures as long as the proximity and nature of backscattering objects and similar conditions are maintained constant. A new qualification exposure shall be made whenever any of the following parameters are changed:

- 6.22.1 X-ray machine energy (kilovolts, Megavolts, or gamma source type),
- 6.22.2 Exposure time (milliampere-time),
- 6.22.3 Source-to-film distance,
- 6.22.4 Screens, collimation, masking, or filters,
- 6.22.5 Film type,
- 6.22.6 Film processing parameters,
- 6.22.7 Type or amount of backing material, or
- 6.22.8 Radiation source change or relocation.

6.23 *Source-to-Film Distance*—The minimum allowable source-to-film distance shall be calculated by the following equation, using the material thicknesses and unsharpness values in Table 4 as a minimum, unless otherwise specified by the cognizant engineering organization.

$$SFD = (Ft/Ug) + t \quad (2)$$

where:

- SFD* = source-to-film distance,
- Ug* = geometric unsharpness,
- F* = size of radiation source, using the manufacturer’s nominal size or the effective focal spot size in accordance with Test Method E 1165, and
- t* = distance from the source side of the object to the film (regardless of whether or not the object is in contact with the film).

NOTE 4—Unit of measurement for *SFD*, *Ug*, *F*, and *t* may be in either English or SI units as long as they are consistent (not mixed).

6.24 *Identification*—Marking of the radiographic film and component shall be provided so that the radiograph may be traced to the component being inspected (see 6.28.6).

6.25 *Location Markers*—The images of location markers for coordination of the part with the film(s) shall appear on the film without interfering with interpretation and with such an arrangement that it is evident that complete coverage was obtained. The location marker positions shall be established on the part, and the position of the markers shall be maintained on the part during radiography. If the entire part can be radiographed with one film for each view, and the orientation of the part with respect to the film is obvious, then location markers are not required.

6.25.1 As an alternative to markers, view numbers (see 6.4), may be used provided orientation of the radiographs to the part can demonstrate the required radiographic coverage and the location of defects can be accomplished.

6.26 *Crack Detection*—When parts are radiographed to detect in-service cracks in aircraft assemblies and the parts being examined are covered by aircraft skin, only the area of the film that falls within a 10° cone of radiation (10° total solid angle, apex at the radiation source, central axis of cone equal to central axis of radiation beam) shall be considered valid for interpretation.

6.27 *Quality Assurance Provisions* :

6.27.1 *Responsibility for Examination*— The NDT facility is responsible for furnishing all supplies in conformance to contract or purchase order requirements and, unless otherwise specified in the contract or purchase order, the performance of all examination requirements contained herein. The examination provisions contained herein shall become a part of the NDT facility overall examination system or quality program.

6.27.2 *Examination Report*—The results of all radiographic examinations shall be recorded and kept on file in accordance with the contract or purchase order. The examination reports shall reference this practice, or the applicable specification and provide for traceability to the specific part or lot examined and shall include the examiner’s identification, the date of the examination, the disposition of the component (accept or reject), and the reason for rejection of any items.

TABLE 4 Unsharpness (*Ug*) (Maximum)

| Material Thickness (in.) | <i>Ug</i> (in.) |
|--------------------------|-----------------|
| Under 2 | 0.020 |
| 2 through 4 | 0.030 |
| Over 4 | 0.040 |

6.27.3 *Solution/Film Processing Control*—For both automatic and hand processing, developer solutions shall be checked by—Film processing a sensitometric strip, a radiograph of a step wedge, or a standard test part in a freshly mixed or replenished developer, measuring the film density between 2.0 and 4.0 H&D in three chosen areas of interest (high, medium, and low densities) and recording the values. For monitoring purposes, a sensitometric strip, the step wedge, or the test part, shall be radiographed controlled and the film developed weekly. Densities shall be measured in the same areas as the control film and recorded. The film density in the areas of interest being monitored shall be within $\pm 15\%$ of the original control film density. If the film density is outside this range, appropriate measures shall be taken to make the developer solution capable of meeting the control film density range prior to processing any additional film. If the test film density is out of the specified range, the test shall be run daily until it is ensured that control has been reestablished. Test strips for the past four weeks shall be maintained for auditing purposes. Any film processing from the last successful check need not be discarded provided the radiographic quality level and density requirements of 6.9 and 6.10 are achieved. When using the step wedge or standard test part methods, all radiographs used for monitoring purposes shall be exposed using a standard technique.

6.27.3.1 In hand-processing installations a log shall be maintained to show the number and size of film processed and replenishing dates, in accordance with Annex A4.

6.27.4 *Viewers*—Film viewers shall meet the intensity requirements of Fig. 3 2 or Guide E 1390. For example, in Fig. 3, in order to view a film with a 4.0 film density, at least 20 fc (200 lx) (measured at the screen). The maximum readable density shall be determined by measuring the transmitted light through a 2.0-density film at each viewing port. The maximum readable density shall be posted on each viewer.

6.27.5 *Densitometer Verification Check*—Densitometers—Accuracy verification shall be calibrated in accordance with Practice E 1079 performed at the beginning of each shift or equipment change, such as, replacement of bulb or change of aperture. The check shall be conducted using a calibrated transmission density strip traceable to NIST, stepwedge film with at least 3 steps. Verification checks using readings shall be taken at high, low, intermediate, and intermediate densities low densities. Readings shall be ± 0.05 of the values on the stepwedge film; if not, calibration is required in accordance with Practice E 1079 at the beginning E 1079. Calibration of each shift or when a malfunction is suspected; the density readings stepwedge film shall be verified by comparison to a NIST serialized step tablet. Verification frequency shall be in accordance with Table 2.

6.27.6 *Ambient Light*—Subdued lighting, rather than total darkness, is preferable— Subdued lighting in the viewing room. The brightness of the surroundings should be about the same as the area of interest in the radiograph. Room room is preferred rather than total darkness. Background illumination must lighting shall be so arranged such that there are no light reflections from the surface do not interfere with review of radiographs. Background ambient light levels shall not exceed 3 fc (30 lx), light levels shall be measured at the film under examination, viewer surface, with the viewer off, and recorded in accordance with Table 2.

6.27.7 *Dark Adaptation*—The interpreter should wait sufficient time, after entering the viewing area, before interpreting radiographs that the features of the IQI are visible (hole and IQI outline). If the eyes are momentarily subjected to the full brightness of the illuminator, at least 30-s readaptation should be allowed.

6.27.8 *Retention of Radiographs*—Retention and delivery of radiographs and other records (see 6.1, written procedure; and 6.27.2, examination report) shall be in accordance with the provisions specified in the contract. For DoD contracts they shall be in accordance with the contract data requirements list (see 7.1). If no specific requirements are specified for retention or delivery

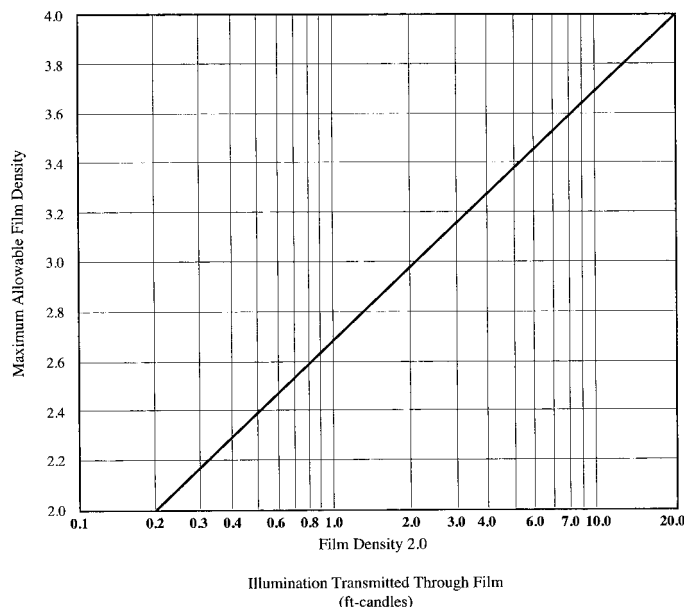


FIG. 3 2 Maximum Allowable Film Density Usable with Film Viewer

of radiographs, they shall become the property of the purchaser of the component.

6.27.9 *Storage of Radiographs*—Radiographs shall be stored in accordance with Guide E 1254.

6.27.10 *Reproduction of Radiographs*—~~When radiographs may be reproduced by digitization for the cognizant engineering organization, the quality assurance program shall include a procedure for controlling and monitoring the accuracy of radiographic images, microfilming, or other recording media provided the following requirements are met:~~ process, so that the radiograph, when reproduced to its original size, will provide the IQI image and required holes as on the original radiograph.

6.27.10.1 The reproduction process shall be subject to the approval of the cognizant engineering organization.

~~6.27.10.2 When radiographs are reproduced~~

~~6.27.10.2 Procedures for the cognizant engineering organization, the quality assurance program shall include a system for controlling and monitoring the accuracy of the process so that the radiograph, when reproduced to its original size, will provide the IQI image and required holes as on the original radiograph.~~

~~6.27.10.3 Procedures for microfilming shall contain applicable requirements pertaining to exposure, scanning, focusing, contrast, resolution, and distinguishing film artifacts that might appear as material discontinuities in the reproduced image.~~

6.27.10.4₃ The reproduction process for radiographs may use an image projection system when the process provides the IQI image and required holes as the original photograph when the image is projected to its original size.

6.27.10.4 When the reproduction process consists of an Image Projection System the projected image must be projected to the radiograph's original size; the IQI image and required hole(s) must be the same as the original photograph.

6.28 *Marking:*

6.28.1 *Acceptable Parts*—Parts that conform satisfactorily to applicable radiographic examination requirements shall be marked in accordance with the applicable drawing, purchase order, contract, or as specified herein. Markings shall be applied in such a manner and location harmless to the part. Identification shall not be smeared or obliterated by subsequent handling. When subsequent processing would remove identification, the applicable marking shall be affixed to the records accompanying the parts or assembly.

6.28.2 *Impression Stamping, Laser Marking, or Vibro Engraving*—Impression stamping, laser marking, or vibro engraving shall be used only where permitted by the applicable specifications or drawings. Unless otherwise specified, marking shall be located in areas adjacent to the part number.

6.28.3 *Etching*—When impression stamping, laser marking, or vibro engraving is prohibited, parts may be marked by etching. Suitable etchants and application methods shall be employed. Etching methods other than fluid etching may be used.

6.28.4 *Dyeing*—Where etching, impression stamping, laser marking, or vibro engraving are not appropriate, identification may be accomplished by dyeing or ink stamping.

6.28.5 *Other Identification*—Other means of identification, such as tagging, may be applied to parts for which construction, finish, or functional requirement preclude the use of etching, impression stamping, vibro engraving, laser marking, dyeing, or ink stamping.

6.28.6 *Symbols*—Each part that has successfully passed radiographic examination shall be marked as follows:

6.28.6.1 When impression stamping, laser marking, vibro engraving, etching, or ink stamping is applicable, symbols shall be used. The symbol shall contain an identification symbol of the facility.

(1) Except for specialized applications, use the symbol “X” enclosed in a circle to denote 100 % radiographic examination.

(2) *When Sampling is Used*—Parts actually radiographed shall be marked as specified in (1). All items in the lot accepted on a sampling basis (part of the lot but not actually radiographed) shall be marked using the symbol “X” enclosed in an ellipse.

6.28.6.2 When dyeing is applicable, blue dye shall be used to indicate 100 % radiographic examination. When sampling is used, orange dye shall be used to indicate parts accepted on a sampling basis (part of the lot not actually examined), while the parts of the lot actually examined shall receive blue dye.

7. Notes

7.1 *Government Contracts:*

7.1.1 *Data Requirements*—The following Data Item Descriptions (DID's) must be listed, as applicable on the Contract Data Requirement List (DD Form 1423) when this practice is applied on a contract, in order to obtain the data, except where DoD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

7.1.2 The current issue of DoD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DIDs are cited on the DD Form 1423 (see 6.1, 6.28.2, and section 6.28.8). Reference DID number DI-MISC-80653, Test Reports.

8. Keywords

8.1 image quality indicator; nondestructive testing; penetrating radiation; radiographic; radiographic examination; radiography; radioscopy; X-ray

ANNEXES

(Mandatory Information)

A1. ALTERNATE TYPE IQI DESIGN (MIL-STD-453)

A1.1 Alternate Hole-Type IQI's—The IQI design shall be as follows:

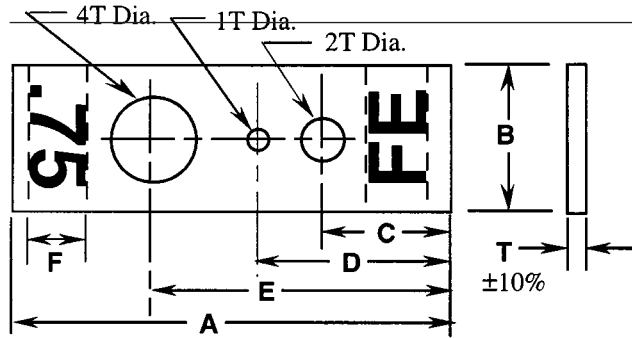
A1.1.1 Image quality indicator dimensions shall be in accordance with Fig. A1.1.

A1.1.2 The IQI's shall be fabricated from the same material group (see 3.2.5) or radiographically similar materials (see 5.5.2) as the object to be radiographed.

A1.1.3 The IQI's shall be identified as to material group (see Fig. A1.1) and thickness relative to the thickness of the component to be radiographed. Identification shall consist of lead letters and numbers, or a material of similar radiographic opacity.

A1.1.4 Material identification shall be the chemical symbol of the predominant element. For example, if iron is the predominant element, "FE" shall be used. Identification of some common materials are listed in Fig. A1.1. When the material is a composite or does not have a predominant element, a controlled system for IQI identification shall be established and referenced in the written procedure (see 6.1).

A1.1.5 The IQI thickness identification shall consist of a two-digit number that expresses the material thickness in one hundredths of an inch, .XX. For example, a specimen thickness of ¾ in. requires an IQI identified by the two-digit number .75.

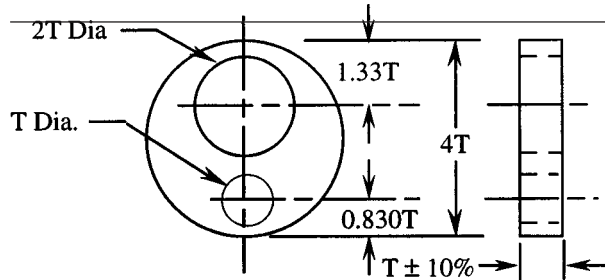


| T, in. (mm) | Increments, in. (mm) | A, in. (mm) | B, in. (mm) | C, in. (mm) | D, in. (mm) | E, in. (mm) | F, in. (mm) |
|--|----------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 0.005 - 0.020, incl (0.013 - 0.508) | 0.0025 (0.064) | 2.000 (50.8) | 0.500 (12.7) | 0.520 (13.2) | 0.800 (20.3) | 1.150 (29.2) | 0.250 (6.35) |
| 0.025 - 0.050, incl (0.636 - 1.27) | 0.005 (0.127) | 2.000 (50.8) | 0.500 (12.7) | 0.520 (13.3) | 0.800 (20.3) | 1.150 (29.2) | 0.250 (6.35) |
| 0.060 - 0.160, incl (1.52 - 4.06) | 0.010 (0.254) | 2.8 (72.4) | 1.000 (25.4) | 0.800 (20.3) | 1.250 (31.8) | 1.900 (48.3) | 0.375 (9.52) |

NOTE 1—

- Minimum IQI thickness = $0.005 \pm 10\%$.
- Minimum diameter for 1T hole = $0.010 \pm 10\%$. (Hole is not 1T for thicknesses less than 0.010 in.)
- Minimum diameter for 2T hole = $0.020 \pm 10\%$. (Hole is not 2T for thicknesses less than 0.010 in.)
- Minimum diameter for 4T hole = $0.040 \pm 10\%$. (Hole is not 4T for thicknesses less than 0.010 in.)

Design for IQI Thicknesses up to and Including 0.160



Design for IQI Thickness of 0.180 and Over made in 0.020 Increments

| Symbol | Material |
|--------|-----------------|
| SS | Stainless steel |
| AL | Aluminum |
| FE | Steel |
| MG | Magnesium |
| CU | Copper |
| TI | Titanium |

NOTE 2—All Dimensions in inches.

NOTE 3—Holes shall be true and normal to the surface of the IQI. Do not chamfer.

NOTE 4—Tolerances on IQI thickness and hole diameter shall be $\pm 10\%$ or $1/2$ of the thickness increment between IQI sizes, whichever is smaller.

NOTE 5—Steel IQI's (FE) and stainless steel IQI's (SS) shall be considered to be from the same material group.

FIG. A1.1 Alternate Hole Type IQI

A2. FABRICATION WELDS

A2.1 *Fabrication Welds*—Accessible surfaces of welds to be radiographed shall be prepared as necessary in accordance with the welding process specification if applicable, and the valleys between beads, weld ripples, or other surface irregularities are blended to a degree such that the resulting radiographic contrast due to surface condition cannot mask or be confused with that of any defect.

A2.2 IQI Selection for Welds—For butt joints on simple structures such as pipe or plate, the thickness on which the IQI is based shall be the single-wall thickness plus any reinforcement allowed. For T-joints, lap joints, corner joints, fillet welds, weld surfacing, or for joints in complex assemblies where both sides of the joint are not accessible, the IQI shall be based on the total thickness through which the X-ray beam will pass. If different size sections are joined, the IQI shall be based on the thinner wall section. Backing strips or rings are not considered as a part of the weld, base material, or reinforcement (bead) thickness upon which the IQI is based. If subsequent machining or mechanical preparation reduces the weld thickness, IQI shall be based on final product thickness. If the required sensitivity cannot be obtained, radiographic examination shall be required after final machining or mechanical preparation.

A2.2.1 IQI Placement for Welds—The IQI's shall be placed on the source side parallel with, and at least 1/8 in., and not more than 1/4 in. from the weld being radiographed. When the weld is not radiographically similar or where part geometry precludes placement, the IQI wire or hole of the required sensitivity, as applicable, may be placed over the weld but outside of the area of interest. When weld-reinforcement (weld bead), backing rings or strips are not removed, a shim of the same material group or radiographically similar material (see 5.5.2) shall be placed between the IQI and base material to provide approximately the same thickness of material under the IQI as the average thickness of the weld reinforcement plus the wall thickness and backing strip or ring.

A2.2.2 Examination Coverage for Welds —Unless otherwise specified on the engineering drawing or other contractual documents, welded parts requiring radiography shall be radiographed for 100 % of the length of the weld zone, including the weld heat affected zone.

A2.2.3 Longitudinal Circumferential Weld Junctures—Where portions of longitudinal welds adjoining a circumferential weld are being examined simultaneously with the circumferential weld, additional IQI's shall be placed on the longitudinal weld at the outer edge of the cone of radiation used to radiograph the circumferential weld.

A2.2.4 Longitudinal Welds—For longitudinal welds, an IQI shall be placed at the extreme end of the area to be interpreted. The long axis of the IQI shall be parallel with and at least 1/8 in., but not more than 1/4 in. from the weld edge.

A2.2.5 Circumferential Welds—Except as provided in A2.2.5.1 and A2.2.5.2, radiography shall be performed in which the radiation passes through only one wall. When double-wall techniques are used, either superimposed or elliptical (offset) projections may be used.

A2.2.5.1 Double-Wall Exposure, Double-Wall Image—Welds in pipe and tubes 3 1/2 in. and less in nominal size (diameter) may be radiographed using the double-wall method where the radiation passes through both walls and both walls are viewed together for acceptance. An IQI, based on the double-wall thickness plus twice the weld reinforcement, as applicable, shall be placed on the source side, on top of a shim approximately equal to twice the weld reinforcement. As an alternate, the same IQI and shim may be placed on the source side of a like section that is placed adjacent to the weld being radiographed. When impractical to do the preceding, the IQI may be placed on top of a block that is approximately equal to twice the wall thickness plus twice the weld reinforcement, as applicable. The IQI and block shall be placed on a low-density material (such as polystyrene plastic or its equivalent), adjacent to the weld being examined, so that the top of the block is level with the upper surface of the tube or pipe.

A2.2.5.2 Double-Wall Exposure, Single-Wall Image—For welds in pipe and tubes greater than 3 1/2 in. in nominal size (diameter), only the weld closest to the film shall be viewed for acceptance. An IQI, corresponding to the single-wall thickness plus any single-wall weld reinforcement, shall be placed adjacent to the weld on the inner wall on top of a shim equal to the weld reinforcement. When this is not possible, the same IQI and shim may be placed on the inner wall of a like section of a tube or pipe placed adjacent to the weld being radiographed. When a like section of the tube or pipe is unavailable, the IQI may be placed on a block adjacent to the weld being radiographed. The block thickness shall be equivalent to twice the wall thickness plus any single-wall weld reinforcement. The top of the block shall not be any lower than the inner surface of the inner wall of the tube or pipe.

A2.3 Electron Beam (EB) Welds—The central beam of radiation shall be in line with and parallel to the fusion interface. Cognizant Engineering Organization approval is required when the beam to weld angle exceeds 2°.

A3. PROPELLANTS/EXPLOSIVES

A3.1 Installed Explosives/Propellants—For the radiography of explosives/propellants contained within a vessel, the IQI shall be based on a chord length thickness of the explosive/propellant that is traversed by the X-ray beam. When it is not possible to obtain the required radiographic quality level using an IQI that is based only on the explosive/propellant thickness, the chord lengths through the vessel wall material layers may be used in determining the total equivalent thickness of explosive/propellant upon which the IQI thickness is to be determined. The equivalencies shall be determined in the following manner:

$$ET = AC/B \tag{A3.1}$$

For energy levels of 320 keV and less, the following equation shall be used:

$$ET = M_e AC / M_p B \tag{A3.2}$$

where:

- A = physical density of the vessel section,
- B = physical density of propellant/explosive,
- C = thickness of vessel section traversed by the center of the X-ray beam,
- ET = equivalent thickness of propellant/explosive for each vessel wall material traversed by the center of the X-ray beam,
- M_a = mass attenuation coefficient of the predominant element of the vessel section, and
- M_b = Mass attenuation coefficient of the predominant chemical element of the propellant/explosive.

NOTE A3.1—These relationships were derived experimentally and have been determined adequate for the evaluation of vessels containing explosives/propellants.

The IQI's may be fabricated from inert materials that have approximately the same physical density as the propellant/explosive to be radiographed. As an alternate, the IQI may be fabricated from, and based on, a more dense material with a thickness that has been equated to the total equivalent propellant/explosive thickness as determined by the method previously shown.

A3.2 Single-Wire IQI's—Single-wire IQI's of a denser (metallic) material may be used provided the thickness of metal upon which the IQI is based has been equated to the equivalent explosive/propellant thickness by the method shown in A3.1. Wire thickness shall be equated to hole-type radiographic quality levels (as specified in Table 3 by the following method:

$$\text{Wire IQI diameter} = TPY/XF \quad (\text{A3.3})$$

For energy levels of 320 keV and less, the following equation shall be used:

$$\text{Wire IQI diameter} = M_a TPY / M_b XF \quad (\text{A3.4})$$

where:

- T = total equivalent thickness, or thickness of explosive/propellant material,
- P = required sensitivity as a percentage of material thickness (that is equivalent IQI sensitivity),
- Y = density of explosive/propellant,
- X = density of IQI material,
- F = form factor for round wire (0.7854),
- M_a = mass attenuation coefficient of the predominant element of the vessel section, and
- M_b = mass attenuation coefficient of the predominant chemical element of the propellant/explosive.

A4. FILM PROCESSING SOLUTION CONTROL

A4.1 Processing Equipment and Solutions—For both automated and manual processing, the following shall be performed and recorded:

A4.2 Automated Processing:

A4.2.1 Processor Performance—Processor performance shall be determined by processing a control film, as scheduled in A4.2.1.1 and Table 2, and a monitor film as scheduled in A4.2.1.2 and Table 2, in freshly mixed seasoned developer.

A4.2.1.1 Control Film, shall be a sensitometric film strip, or pre-exposed film of a standard test piece (see Note A4.1). When using the standard Test Piece Method to produce the control film, establish a standardized technique and dedicate one batch of film to reduce variables. The control film shall have at least one area with a density of 2.0 to 2.5 H&D inclusive, and can include an unexposed area of the film for monitoring base fog. (Sufficient blocking should be used to ensure that the area for monitoring base fog receives no radiation exposure.) Control film densities shall be measured and recorded, establishing nominal control values.

NOTE A4.1—The test piece shall be a block of uniform thickness, or a stepwedge. Both the block and stepwedge shall be large enough to ensure that no radiation due to undercutting has affected the area of interest.

A4.2.1.2 Monitor Film— To monitor processor performance, a monitor film shall be processed to the standardized technique or a sensitometric film strip shall be used. The monitor film density shall be measured in the same areas as the control film and compared to the control film densities. The monitor film densities shall be within $\pm 10\%$ of the current control film. If the monitor film density is out of tolerance, necessary steps shall be taken to correct the problem, and another monitor film shall be processed to verify that the problem has been corrected. Monitor film for the past four weeks shall be maintained for auditing purposes. Any production film processed from the last successful check need not be discarded provided the radiographic quality level and density requirements of 6.9 and 6.10 are achieved. Density measurements shall be recorded as scheduled in Table 2.

Caution: Newly changed solutions should be seasoned in accordance with Guide E 999 prior to exposing the control standard test piece film.

A4.2.2 Replenishing Rates—The rate at which developer and fixer are replenished shall be maintained within the manufacturer's recommended range and checked when solutions are changed, during preventative maintenance, or maintenance associated with the replenishment system. Replenishment rates shall be checked in accordance with the manufacturer's instructions

(preventative maintenance does not include the daily cleaning of the cross-oversee, and so forth). Flow rates shall be recorded as scheduled in Table 2.

A4.2.3 Temperatures—The temperature of the developer shall be maintained within the manufacturer’s limits and checked on the processor prior to use. A calibrated thermometer shall be used to verify temperature during preventative maintenance.

A4.2.4 Transport Speed—The transport speed shall be set as prescribed by the manufacturer. It shall be measured and recorded as scheduled in Table 2.

A4.2.5 Base Fog—The base fog level shall be monitored and can be included with the test film as an unexposed portion of the film. The maximum base fog shall be 0.30 for Class I, II, or special film systems. It shall be measured and recorded as scheduled in Table 2.

A4.2.6 Wash—Maintain water flow to ensure proper washing to remove residual fixer from film which could cause subsequent damage (staining) and deterioration of the radiographic image. The effectiveness of washing may be checked by using the method prescribed in Guide E 999.

A4.3 Manual Processing :

A4.3.1 Processing Performance—Film processing shall be monitored by processing a sensitometric or a pre-exposed film of a standard test piece as prescribed in A4.2.1.2. The test shall be run daily or before use.

A4.3.2 Developer Temperature—A time-temperature system shall be maintained within the manufacturer’s recommendations. The developer solution shall be stirred and the temperature checked prior to development.

A4.3.3 Film Processing Log—A log shall be maintained to show the number, size, and date of film processed.

A4.3.4 Replenishing Rates—Replenishment shall be in accordance with the manufacturer’s recommendations. The replenishing dates and the mixing dates of new solution shall be recorded.

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