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Standard Practice for Radiographic Examination¹

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

1. Scope

1.1 This practice² 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 *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

E 543 Specification for Agencies Performing Nondestructive Testing

E 747 Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology

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.

E 801 Practice for Controlling Quality of Radiological Examination of Electronic Devices
 E 999 Guide for Controlling the Quality of Industrial Radiographic Film Processing
 E 1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology
 E 1030 Test Method for Radiographic Examination of Metallic Castings
 E 1032 Test Method for Radiographic Examination of Weldments
 E 1079 Practice for Calibration of Transmission Densitometers
 E 1165 Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging
 E 1254 Guide for Storage of Radiographs and Unexposed Industrial Radiographic Films
 E 1255 Practice for Radioscopy
 E 1316 Terminology for Nondestructive Examinations
 E 1390 Specification for Illuminators Used for Viewing Industrial Radiographs
 E 1411 Practice for Qualification of Radioscopic Systems
 E 1416 Test Method for Radioscopic Examination of Weldments
 E 1815 Test Method for Classification of Film Systems for Industrial Radiography

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:*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 51 Radiation Protection Design Guidelines for 0.1–100 MeV Particle Accelerator Facilities
 NCRP 91 Recommendations on Limits for Exposures to Ionizing Radiation

2.7 *ANSI Standards:*

~~ANSI IT 9.1 Imaging Media (Film)—Silver-Gelatin Type Specifications for Stability~~
~~ANSI PH 4.8 Photography (Chemicals)—Residual Thiosulphate and Other Chemicals in Films, Plates, and Papers—~~
~~Determination and Measurement~~⁸

ANSI IT 9.1 Imaging Media (Film)—Silver-Gelatin Type Specifications for Stability
ANSI PH 4.8 Photography (Chemicals)—Residual Thiosulphate and Other Chemicals in Films, Plates, and Papers—
Determination and Measurement

ANSI/NCSL Z540-1 General Requirement for Calibration Laboratories and Measuring Test Equipment
ISO 10012-1 Measurement Management Systems—Requirements for Measurement Processes and Measuring Equipment

2.8 ~~Government Standard—Military Standard:~~

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

2.9 *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 MeV¹⁰

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 E 1316, shall apply to the terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

⁴ Available from The American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.
⁵ Available from Aerospace Industries Association of America, Inc. (AIA), 1250 Eye St., NW, Washington, DC 20005.
⁶ ~~E07 Available~~ Available from The 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 Woodmont Ave., Suite 800, Bethesda, MD 20814.
⁸ ~~E07 Available~~ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.
⁹ Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, ~~Attn: NPODS; 19111-5098,~~ <http://www.dodssp.daps.mil>.
¹⁰ Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 3460/1070, Gaithersburg, MD 20899-3460/20899-1070, <http://www.nist.gov>.

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 E 1025.

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 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 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 E 543. The applicable revision of Practice E 543 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 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 6.27.46.27.6).

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 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 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 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 provided the specified radiographic quality level, density, and contrast are obtained.~~ 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 Test Method E 94, Appendix X1).

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 6.27.66.27.4).

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 E 1390 are acceptable for use.

TABLE 1 Lead Screen Thickness^A

Front Screen Maximum, in.	Front Screen	Back Screen Minimum, in.
Energy Range	Front Screen	Back Screen Minimum
0 to 150 kV ^B	0.000	0.005
0 – 150 keV ^B	0.000 to 0.001 in. (0 to 0.025 mm)	{0.127 mm} ^C 0.005 in. (0.127 mm) ^C
150 to 200 kV—Ir 192	0.005	0.005
151 – 200 keV	{0.127 mm} 0.000 to 0.005 in. (0 to 0.127 mm)	{0.127 mm} 0.005 in. (0.127 mm) ^C
200 kV to 2 MV—Co-60	0.005 to 0.010 (0.126 to 0.254 mm)	0.010 {0.254 mm}
201 – 320 keV	0.001 to 0.010 in. (0.025 to 0.254 mm)	0.005 in. (0.254 mm)
2 to 4 MV	0.010 {0.254 mm}	0.010 {0.254 mm}
321 – 450 keV, Ir-192, Se-75	0.005 to 0.015 in. (0.127 to 0.381 mm)	0.010 in. (0.254 mm)
4 to 10 MV	0.010 to 0.030 (0.254 to 0.762 mm)	0.010 {0.254 mm}
451 keV – 2 MeV, Co-60	0.005 to 0.020 in. (0.127 to 0.508 mm)	0.010 in. (0.254 mm)
10 to 25 MV	0.010 to 0.050 {0.254 to 1.27 mm}	0.010 {0.254 mm}
2 – 4 MeV	0.010 to 0.020 in. (0.254 to 0.508 mm)	0.010 in. (0.254 mm)
4 – 10 MeV	0.010 to 0.030 in. (0.254 to 0.762 mm)	0.010 in. (0.254 mm)
10 – 25 MeV	0.010 to 0.050 in. (0.254 to 1.27 mm)	0.010 in. (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.

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 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.

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.

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	A4.2.1
Processor Performance	Daily ^D	A4.2.1
Base Fog	Daily	A4.2.5
Base Fog	Daily ^D	A4.2.5
Developer Temperature	Prior to use ^C	A4.2.3
Replenishing Flow Rate	^E	A4.2.2
Replenishment Rate	^E	A4.2.2
Transport Speed	^F	A4.2.4
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 ^F	
Developer Temperature	Prior to use ^G	
Densitometer:		
Verification Check	Each shift ^G	6.27.5
Verification Check	Each shift ^H	6.27.5
Calibration Check	90 days ^H	6.27.5
Calibration Check	90 days ^I	6.27.5
Light Meter	Semi-annual	6.27.6
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	6.27.6
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 MIL-STD-45662, ANSI Z-540, or ISO 10012, as applicable. , or ISO 10012-1, as applicable.

^C Documentation of this check not required.

^D ~~Measur~~ ~~bed a~~ ~~extend~~ ~~recor~~ ~~d to~~ ~~wedekly~~ ~~when~~ ~~selubstian~~ ~~started~~ ~~by~~ ~~achtu~~ ~~angl~~ ~~ted~~ ~~duchnical~~ ~~/reliability~~ ~~data~~ ~~and~~ ~~appreovend~~ ~~by~~ ~~tativhe~~ ~~ma~~ ~~cognizant~~ ~~enagineeeering~~ ~~or~~ ~~reppganization~~.

^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 Each shift or when maintenance is performed (bulb or aperture changed).

^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.

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. ~~The IQI's of an IQI with a lower radiographic density radiation attenuation may be used.~~

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 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~~

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.

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

~~6.1.3~~ 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.

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

6.1.56 Thickness and type of material.

~~6.1.6~~ 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.

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

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

6.1.910 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 ~~inspecting~~ 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. ~~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.~~, 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