



Standard Test Method for Radiographic Examination of Weldments¹

This standard is issued under the fixed designation E 1032; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method provides a uniform procedure for radiographic examination of weldments using industrial radiographic film. Requirements expressed in this method are intended to control the quality of the radiographic images and are not intended for controlling acceptability or quality of welds.

1.2 The radiographic extent, the quality level, and the acceptance criteria to be applied shall be specified in the contract, purchase order, product specification, or drawings.

1.3 The radiographic techniques stated herein provide adequate assurance for defect detectability; however, it is recognized that, for special applications, specific techniques using more or less stringent requirements may be required than those specified. In these cases, the use of alternative radiographic techniques shall be as agreed upon between purchaser and supplier (also see Section 4).

1.4 The values stated in inch-pound units are to be regarded as standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (For more specific safety precautionary information, see Section 7.)

2. Referenced Documents

2.1 ASTM Standards:²

- E 94 Guide for Radiographic Examination
- E 242 Reference Radiographs for Appearances of Radiographic Images as Certain Parameters Are Changed
- E 390 Reference Radiographs for Steel Fusion Welds
- 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

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 1079 Practice for Calibration of Transmission Densitometers

E 1254 Guide for Storage of Radiographs and Unexposed Industrial Radiographic Films

E 1316 Terminology for Nondestructive Examinations

E 1815 Test Method for Classification of Film Systems for Industrial Radiography

2.2 ASNT Standards:³

Recommended Practice No. SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

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

2.3 Other Standards:

NAS 410 National Aerospace Standard Certification and Qualification of Nondestructive Test Personnel⁴

EN 444 Nondestructive Testing—General Principles for Radiographic Examination of Metallic Materials by X and Gamma Rays—Basic Rules⁵

ISO 5579 Nondestructive Testing—Radiographic Examination of Metallic Materials by X and Gamma Rays—Basic Rules⁵

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, see Terminology E 1316.

4. Basis of Application

4.1 *Personnel Qualification*—Nondestructive testing (NDT) personnel shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, NAS 410 or a

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

Current edition approved July 1, 2006. Published July 2006. Originally approved in 1985. Last previous edition approved in 2001 as E 1032 - 01.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from American Society for Nondestructive Testing (ANST), 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH 43228-0518.

⁴ Available from Aerospace Industries Association of America, Inc. (AIA), 1250 Eye St., NW, Washington, DC 20005.

⁵ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

similar document. The practice or standard used and its applicable revision shall be specified in the contractual agreement between the using parties.

4.2 Qualification of Nondestructive Agencies—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated in accordance with Practice E 543. The applicable edition of Practice E 543 shall be specified in the contractual agreement.

4.3 Time of Examination—The time of examination shall be in accordance with 8.1 unless otherwise specified.

4.4 Procedures—The procedures to be utilized shall be as described in 7.1.

4.5 Extent of Examination—The extent of the examination shall be in accordance with 7.2.

4.6 Reporting Criteria/Acceptance Criteria—Reporting criteria of the examination results shall be in accordance with Section 11.

4.7 Reexamination of Repaired or Reworked Items—Reexamination of repaired or reworked items is not addressed in this test method and if required shall be specified in the contractual agreement.

4.8 Radiographic Quality Level—The radiographic quality level shall be in accordance with 7.4.

5. Materials

5.1 Film Systems—Only film systems having cognizant engineering organization (CEO) approval or meeting the requirements of test method E 1815 shall be used to meet the requirements of this standard.

6. Apparatus

6.1 Radiation Source (X-Ray or Gamma-Ray)—Selection of the appropriate source is dependent upon variables regarding the weld being examined (material composition and thickness). The suitability of the source shall be demonstrated by attainment of the required IQI sensitivity and compliance with all other requirements stipulated herein (film density and area of interest density tolerances, etc.).

6.2 Film Holders and Cassettes—Film holders and cassettes shall be light tight and shall be handled properly to reduce the likelihood that they may be damaged. They may be flexible vinyl, plastic, or other durable material, or they may be made from metallic materials. 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 encroach on the radiographic area of interest. If the film holder exhibits

light leaks, it shall be repaired before reuse or discarded. Film holders and cassettes should be routinely examined to minimize the likelihood of light leaks.

6.3 Intensifying Screens:

6.3.1 Lead-Foil Screens:

6.3.1.1 Intensifying screens of the lead-foil type are generally used for production radiography. Lead-foil screens shall be of the same approximate dimensions as the film being used and shall be in direct contact with the film during exposure.

6.3.1.2 Unless otherwise specified in the purchaser-supplier agreement, the lead-foil screens shown in Table 1 shall be used, except as provided within the tabular notes below it.

6.3.2 Fluorescent, Fluorometallic, or Other Metallic Screens—Such screens may be used with CEO approval as described under 5.1; however, they must be capable of demonstrating the required IQI sensitivity. Fluorescent or fluorometallic screens may cause limitations in image quality (see Guide E 94, Appendix X1).

6.3.3 Screen Care:

6.3.3.1 All screens should be handled carefully to avoid dents, scratches, grease, or dirt on active surfaces. Screens that render nonrelevant indications on radiographs shall be visually examined and discarded if physical damage is observed.

6.3.3.2 Screens, with or without backing, shall be free of dust, dirt, oxidation, or any other foreign material that render undesirable nonrelevant images on the film.

6.3.3.3 **Other Screens**—European Standard CEN EN 444 contains similar provisions for intensifying screens as in this test method. International users of these type screens who prefer the use of CEN EN 444 or ISO 5579 for their particular applications should specify such alternative provisions within separate contractual arrangements from this test method.

6.4 Filters—Filters shall be used whenever the contrast reductions caused by low energy, scattered radiation, or the extent of undercut (edge burn-off) occurring on production radiographs is of significant magnitude to cause difficulty in meeting the quality level or radiographic coverage requirements stipulated by the job order or contract (see Guide E 94).

6.5 Masking—Masking material may improve radiographic quality (see Guide E 94).

6.6 IQI's (Penetrameters)—Unless otherwise specified by the applicable job order or contract, only those IQI's that comply with the design and identification requirements specified in Practice E 1025 or Practice E 747 shall be used.

TABLE 1 Lead-Foil Screens

KeV Range	Front Screen ^A	Back Screen Minimum
0 to 150 KeV ^B	0.000 to 0.001 in. [0 to 0.025 mm]	0.005 in. [0.127 mm] ^C
150 to 200 KeV; Ir 192; Se 75	0.000 to 0.005 in. [0 to 0.127 mm]	0.005 in. [0.127 mm]
200 KeV to 2 MeV; Co 60	0.005 to 0.010 in. [0.126 to 0.254 mm]	0.010 in. [0.254 mm]
2 to 4 MeV	0.010 to 0.020 in. [0.254 to 0.508 mm]	0.010 in. [0.254 mm]
4 to 10 MeV	0.010 to 0.030 in. [0.254 to 0.762 mm]	0.010 in. [0.254 mm]
10 to 25 MeV	0.010 to 0.050 in. [0.254 to 1.27 mm]	0.010 in. [0.254 mm]

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

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

^CNo back screen is required provided the backscatter requirements of 8.5 are met.

6.7 *Shims, Separate Blocks, or Like Sections*—Shims, separate blocks, or like sections made of the same or radiographically similar materials (as defined in Practice E 1025) may be used to facilitate IQI positioning. There is no restriction on shim or separate block maximum thickness, provided the IQI and area-of-interest density variation requirements of 8.8.2 are met. The like section should be geometrically similar to the object being radiographed.

6.8 *Radiographic Location and Identification Markers*—Lead numbers and letters are used to designate the part number and location number. The size and thickness of the markers shall depend on the ability of the radiographic technique to discern the markers on the radiograph. As a general rule, markers 1/16 in. thick will suffice for most low energy (less than 1 MeV) X ray and Iridium 192 radiography; for higher energy radiography it may be necessary to use markers that are thicker (1/8 in. thick or more).

6.9 *Radiographic Density Measurement Apparatus*—Either a transmission densitometer or a step-wedge comparison film shall be used for judging film-density requirements. Step-wedge comparison films or densitometers calibration, or both, shall be verified by comparison with a calibrated step-wedge film traceable to the National Institute of Standards and Technology. Where applicable, a film digitization and analysis system may be substituted for a transmission densitometer provided the film digitization and analysis system has been calibrated and verified by comparison with a calibrated step-wedge film traceable to the National Institute of Standards and Technology. Densitometers shall be calibrated in accordance with Practice E 1079.

7. Requirements

7.1 *Procedure Requirement*—Unless otherwise specified by the applicable job order or contract, radiographic examination shall be performed in accordance with a written procedure. Specific requirements regarding the preparation and approval of the written procedures shall be dictated by purchaser and supplier agreement. The production procedure shall address all applicable portions of this document and shall be available for review during interpretation of the radiographs.

7.2 *Radiographic Coverage*—Unless otherwise specified by purchaser and supplier agreement, the extent of radiographic coverage shall include 100 % of the volume of the weld.

7.3 *Radiographic Film Quality*—All radiographs shall be free of mechanical, chemical, handling-related, or other blemishes which could mask or be confused with the image of any discontinuity in the area of interest on the radiograph. If any doubt exists as to the true nature of an indication exhibited by the film, the radiograph shall be rejected and the view retaken.

NOTE 1—Digital image enhancement techniques applied to scanned radiographic images have, in some cases, shown the ability to resolve

doubts regarding the true nature of indications shown in the original radiograph. Where applicable, these techniques may be used in an effort to resolve questions regarding the nature of the indication.

7.4 *Radiographic Quality Level*—Radiographic quality level shall be determined upon agreement between the purchaser and supplier and shall be specified in the applicable job order or contract.

7.5 *Acceptance Level*—Accept and reject levels shall be stipulated by the applicable contract, job order, drawing, or other purchaser and supplier agreement.

7.6 *Radiographic Density Limitations*—The density through the body of the IQI and area of interest shall be 1.5 to 4.0 for single film viewing and 2.0 to 4.0 for composite viewing.

7.7 Film Handling:

7.7.1 *Darkroom Facilities*—Darkroom facilities should be kept clean and as dust-free as practical. Safe-lights should be those recommended by film manufacturers for the radiographic materials used and should be positioned in accordance with the manufacturer's recommendations. All darkroom equipment and materials should be capable of producing radiographs that are suitable for interpretation.

7.7.2 *Film Processing*—Radiographic film processing should be controlled in accordance with Guide E 999.

7.7.3 *Film-Viewing Facilities*—Viewing facilities shall provide subdued background lighting of an intensity that will not cause troublesome reflection, shadows, or glare on the radiograph. The viewing light shall be of sufficient intensity to view densities up to 4.0 and be appropriately controlled so that the optimum intensity for single or superimposed viewing of radiographs may be selected.

7.7.4 *Storage of Radiographs*—When storage is required by the applicable job order or contract, the radiographs should be stored in an area with sufficient environmental control to preclude image deterioration or other damage. The radiograph storage duration and location shall be as agreed upon between purchaser and supplier. (See Guide E 1254 for storage information.)

8. Procedure

8.1 *Time of Examination*—Unless otherwise specified by the applicable job order or contract, radiography may be performed prior to heat treatment.

8.2 *Surface Preparation*—Unless otherwise agreed upon, remove the weld ripples or weld-surface irregularities on both the inside (where accessible) and outside by any suitable process so that the image of the irregularities cannot mask, or be confused with, the image of any discontinuity. Interpretation can be optimized if surface irregularities are removed such that the image of the irregularities is not discernible on the radiograph.

8.3 *Source to Film Distance*—Unless otherwise specified in the applicable job order or contract, geometric unsharpness (Ug) shall not exceed the following:

Material Thickness	Ug Maximum
Under 1 in. [25.4 mm]	0.010 in. [0.254 mm]
1 through 2 in. [25.4 through 50.8 mm]	0.020 in. [0.508 mm]
Over 2 through 3 in. [Over 50.8 through 76.2 mm]	0.030 in. [0.762 mm]
Over 3 through 4 in. [Over 76.2 through 101.6 mm]	0.040 in. [1.016 mm]
Greater than 4 in. [Greater than 101.6 mm]	0.070 in. [1.778 mm]

Geometric unsharpness values shall be determined (calculated) as specified by the formula in Guide E 94.

8.4 *Direction of the Radiation*—Direct the central beam of radiation perpendicularly toward the center of the effective area of the film or to a plane tangent to the center of the film, to the maximum extent possible, except for double-wall exposure—double-wall viewing elliptical-projection techniques, as described in 8.14.2.

8.5 *Back-Scattered Radiation Protection:*

8.5.1 Back-scattered radiation (radiation reflected from surfaces behind the film, (that is, walls, floors, etc.) serves to reduce radiographic contrast and may produce undesirable effects on radiographic quality. A 1/8-in. lead sheet, placed behind the film, generally furnishes adequate protection against back-scattered radiation.

8.5.2 To detect back-scattered radiation, position a lead letter *B* (approximately 1/8 in. thick by 1/2 in. high) on the rear side of the film holder. If a light image of the lead letter *B* appears on the radiograph, it indicates that more back-scatter protection is necessary. The appearance of a dark image of the lead letter *B* should be disregarded, unless the dark image could mask or be confused with rejectable weld defects.

8.6 *IQI Selection*—The thickness on which the IQI is based is the single-wall thickness plus actual reinforcement thickness up to the maximum allowed. Backing strips or rings are not considered as part of the weld or reinforcement thickness in IQI selection. For any thickness, a thinner IQI may be used, provided all other requirements for radiography are met.

8.7 *IQI Placement:*

8.7.1 Place the IQIs on the source side adjacent to the weld being radiographed. Where the weld metal is not radiographically similar to the base material or where geometry precludes placement, the IQI may be placed over the weld.

8.7.2 *Film Side IQI*—In those cases where the physical placement of the IQI on the source side is not possible, the IQI may be placed on the film side. The applicable job order or contract shall specify the applicable film-side quality level. Place a lead letter *F* adjacent to the IQI for identification.

8.8 *Separate Block*—When configuration or size prevents placing the IQI on the object being radiographed, a shim or separate block or like section conforming to the requirements of 6.7 may be used, provided the following conditions are met:

8.8.1 The IQI shall be no closer to the film than the source side of the object being radiographed (unless otherwise specified).

8.8.2 The radiographic density measured through the body of the IQI on the shim, separate block, or like section shall not exceed the density measured in the area of interest by more than 15 %. The penetrameter density may be lighter than the area of interest density, provided the specified quality level is obtained and the density requirements of 7.6 are met.

8.8.3 The shim, separate block, or like section shall be placed as close as possible to the object being radiographed.

8.8.4 The shim, separate block, or like section dimensions shall exceed the IQI dimensions such that the outline of at least three sides of the IQI image shall be visible on the radiograph.

8.9 *Number of IQIs:*

8.9.1 One IQI shall represent an area within which radiographic densities are not less than 15 % from the density measured through the body of the IQI. At least one IQI per radiograph, exposed simultaneously with the specimen, shall be used except as noted in 8.9.2 and 8.9.3.

8.9.2 When film density, in the area of interest, is lower by more than 15 % of that measured through the body of the IQI, two IQIs used in the following manner will be satisfactory: (1) if one IQI shows an acceptable sensitivity at the most dense portion of the radiograph and (2) the second IQI shows an acceptable sensitivity at the least dense portion of the radiograph. These two IQIs will then serve to qualify the radiograph technique.

8.9.3 For cylindrical vessels or flat components where one or more film holders and cassettes are used for an exposure, at least one IQI image shall appear on each radiograph, except where the source is placed on the axis of the object and a complete circumference or portion of the circumference radiographed with a single exposure. In which case, at least three IQIs shall be placed approximately equidistant apart. When the source is placed on the axis of the circumference and a portion of that circumference (four or more continuous film locations) is radiographed during a single exposure, at least three IQIs placed approximately equidistant apart shall be used. Otherwise, at least one IQI image shall appear on each radiograph. Where portions of longitudinal welds adjoining the circumferential weld are being examined simultaneously with the circumferential weld, additional IQIs shall be placed on the longitudinal welds at the ends of the sections most remote from the position of the source used to radiograph the circumferential weld.

8.9.4 Qualifying radiographs, on which one or more IQIs were imaged during exposure, shall always be retained as part of record to validate required IQI sensitivity and placement.

NOTE 2—For parts of irregular geometry or widely varying thickness, it may be necessary to radiograph the first unit of a given design to determine proper placement of IQI for subsequent radiography.

8.10 *Shim Utilization*—When a weld reinforcement or backing ring and strip is not removed, place a shim of material which is radiographically similar to the backing ring and strip under the IQI 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 ring and strip. There is no restriction on shim thickness, provided the IQI and area-of-interest density variation requirements are met.

8.10.1 *Shim Dimensions and Location*—The shim dimension and location shall exceed the IQI dimensions by at least 1/8 in. on at least three sides. At least three sides of the IQI shall be discernible in accordance with 8.8.4 except that only the two ends of the IQI need to be discernible when located on piping less than 1-in. nominal pipe size. The shim shall be placed so as not to overlap the weld image including the backing strip or ring.

8.10.2 *Shim Image Film Density*—The film density of the shim image shall not be greater than 15 % more than the lightest film density of the area of interest. It may be less dense than the lightest film density of the area of interest.

8.11 *Location Markers*—Location markers shall be placed outside the weld area. The radiographic image of the location markers for the coordination of the part with the film shall appear on the film without interfering with the interpretation and with such an arrangement that it is evident that complete coverage was obtained.

8.11.1 *Double-Wall Technique*—When using a technique in which radiation passes through two walls and the welds in both walls are viewed for acceptance, and the entire image of the object being radiographed is shown on the radiograph, only one location marker is required in the radiograph.

8.11.2 *Series of Radiographs*—For welds that require a series of radiographs to cover the full length or circumference of the weld, the complete set of location markers must be applied at one time, wherever possible. A reference or zero position for each series must be identified on the component. A known feature on the object (for example, keyway, nozzle, and axis line) may also be used for establishment of a zero position; indicate this feature on the radiographic record.

8.11.3 *Similar Welds*—On similar type welds on a single component, the sequence and spacing of the location markers must conform to a uniform system that shall be positively identified in the radiographic procedure or interpretation records. In addition, reference points on the component will be shown on the sketch to indicate the direction of the numbering system.

8.12 *Radiograph Identification*—A system of positive identification of the film shall be provided. As a minimum, the following shall appear on the radiograph: the name or symbol of the company performing radiography, the date, and the weld identification number traceable to part and contract. Subsequent radiographs made by reasons of a repaired area shall be identified with the letter R.

8.13 *Multiple-Film Techniques*—Film techniques with two or more films of equal or different speeds in the same cassette are allowed, provided prescribed quality level and density requirements stipulated herein are met.

8.14 *Radiographic Techniques*:

8.14.1 *Single-Wall Technique*—Except as provided in 8.14.2 and 8.14.3, radiography shall be performed using a technique in which the radiation passes through only one wall.

8.14.2 *Double-Wall Technique for Circumferential Welds*—For circumferential welds 3½ in. (OD) outside diameter or less, a technique may be used in which the radiation passes through both walls and both walls are viewed for acceptance on

the same film. Unless otherwise specified, either elliptical or superimposed projections may be used.

8.14.2.1 For elliptical projections, where the weld is not superimposed, at least two views separated by 90° shall be required.

8.14.2.2 Where design or access restricts a practical technique from obtaining 90° separation of views, agreement between contracting parties must specify necessary weld coverage.

8.14.2.3 For superimposed projections a minimum of three views is required at approximately 0°, 60°, and 120°.

8.14.2.4 For circumferential welds greater than 3½ in. outside diameter (OD), a technique shall be used in which only single-wall viewing is performed. Sufficient exposures shall be taken to ensure complete coverage.

8.14.3 For radiographic techniques which prevent single-wall exposures due to restricted access, such as jacketed pipe or ship hull, technique should be agreed upon in advance between the purchaser and supplier. It should be recognized that IQI sensitivities based on single-wall thickness may not be obtainable under some conditions.

9. Safety

9.1 Radiographic procedures shall comply with applicable city, state, and federal regulations.

10. Radiograph Evaluation

10.1 *Film Quality*—Verify that the radiograph meets the quality requirements specified in 7.3, 7.4, 7.6, 8.5.2, 8.8, and 8.9.

10.2 *Film Evaluation*—Determine the acceptance or rejection of the weldment by comparing the radiographic image to the agreed upon acceptance criteria (see 7.5).

10.3 *Reference Radiographs*—Graded reference radiographs showing typical indications of various welding defects in graded levels of severity are useful tools for specifying and evaluating acceptance criteria for weld radiographs. Since severity levels are typically provided for each of a variety of flaw types, the acceptance criteria may specify different severity levels for the different conditions. For optimal utility the reference radiographs should be representative of the part to be radiographed in both material and section thickness. Reference radiographs for steel fusion welds are available in Reference Radiographs E 390. Additional reference radiographs which illustrate the effects of modifying certain radiographic parameters, particularly energy and screen combinations, are available in Reference Radiographs E 242.

11. Records

11.1 The following radiographic records shall be maintained as agreed upon between purchaser and supplier:

11.1.1 Radiographic Standard Shooting Sketch.

11.1.2 Weld Repair Documentation.

11.1.3 Film.

11.1.4 Film interpretation record shall contain as a minimum the following information:

11.1.4.1 Disposition of each radiograph (acceptable or rejectable).

11.1.4.2 If rejectable, cause for rejection (slag, crack, porosity, etc.).

11.1.4.3 Surface indication verified by visual examination (grinding marks, weld ripple, spatter, etc.).

11.1.4.4 Signature of the film interpreter, including certification level.

12. Keywords

12.1 gamma ray; nondestructive testing; radiographic examination; radiography; weldments; X-ray

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