Designation: E1161 – 21

Standard Practice for Radiographic Examination of Semiconductors and Electronic Components[1]

This standard is issued under the fixed designation E1161; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

1. Scope

1.1 This practice provides the minimum requirements for nondestructive radiographic examination of semiconductor devices, microelectronic devices, electromagnetic devices, electronic and electrical devices, and the materials used for construction of these items.

1.2 This practice covers the radiographic examination of these items to detect possible defective conditions within the sealed case, especially those resulting from sealing the lid to the case, and internal defects such as extraneous material (foreign objects), improper interconnecting wires, voids in the die attach material or in the glass (when sealing glass is used), solder defects, or physical damage.

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, contract, or inspection technique. Specific applications may require adherence to this practice in part or in full. Deviations from this practice shall be enumerated in inspection plan and approved by both cognizant engineering organization and supplier.

1.4 *Units*—The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this practice.

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

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

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

2.2 *ASTM Standards:*[2]

E94/E94M Guide for Radiographic Examination Using Industrial Radiographic Film

E431 Guide to Interpretation of Radiographs of Semiconductors and Related Devices

E543 Specification for Agencies Performing Nondestructive Testing

E666 Practice for Calculating Absorbed Dose From Gamma or X Radiation

E801 Practice for Controlling Quality of Radiographic Examination of Electronic Devices

E999 Guide for Controlling the Quality of Industrial Radiographic Film Processing

E1000 Guide for Radioscopy

E1079 Practice for Calibration of Transmission Densitometers

E1255 Practice for Radioscopy

E1316 Terminology for Nondestructive Examinations

E1390 Specification for Illuminators Used for Viewing Industrial Radiographs

E1411 Practice for Qualification of Radioscopic Systems

E1453 Guide for Storage of Magnetic Tape Media that Contains Analog or Digital Radioscopic Data

E1475 Guide for Data Fields for Computerized Transfer of Digital Radiological Examination Data

E1742/E1742M Practice for Radiographic Examination

E1815 Test Method for Classification of Film Systems for Industrial Radiography

[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.

Current edition approved June 1, 2021. Published July 2021. Originally approved in 1987. Last previous edition approved in 2014 as E1161 – 09(2014). DOI: 10.1520/E1161-21.

[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.

E1817 Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)
E1936 Reference Radiograph for Evaluating the Performance of Radiographic Digitization Systems
E2002 Practice for Determining Total Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy
E2007 Guide for Computed Radiography
E2033 Practice for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method)
E2339 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)
E2445/E2445M Practice for Performance Evaluation and Long-Term Stability of Computed Radiography Systems
E2597/E2597M Practice for Manufacturing Characterization of Digital Detector Arrays
E2698 Practice for Radiographic Examination Using Digital Detector Arrays
E2736 Guide for Digital Detector Array Radiography
E2737 Practice for Digital Detector Array Performance Evaluation and Long-Term Stability

2.3 *ANSI Standards:*[3]

ANSI/ESD S20.20 ESD Association Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
ANSI/NCSL Z540-3 Requirements for the Calibration of Measuring and Test Equipment

2.4 *ASNT Standard:*[4]

ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel
SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

2.5 *AIA Document:*[5]

NAS-410 Certification and Qualification of Nondestructive Test Personnel

2.6 *Department of Defense (DOD) Documents:*[6]

MIL-PRF-28861 Performance Specification—General Specification for Filters and Capacitors, Radio Frequency/Electromagnetic Interference Suppression
MIL-STD-202 Test Method Standard Electronic and Electrical Component Parts
MIL-STD-202, Method 209 Radiographic Inspection
MIL-STD-750 Test Method Standard Test Methods for Semiconductor Devices
MIL-STD-750, Method 2076 Radiographic Inspection
MIL-STD-883 Test Method Standard Microcircuits
MIL-STD-883, Method 2012 Radiography
MIL-STD-981 Design, Manufacturing and Quality Standards for Custom Electromagnetic Devices for Space Applications

2.7 *Federal Standard:*[6]

FED-STD-595 Color (Requirements for Individual Color Chits)

2.8 *NCRP Documents:*[7]

NCRP 116 Limitation of Exposure to Ionizing Radiation
NCRP 144 Radiation Protection for Particle Accelerator Facilities

2.9 *ISO Standard:*[8]

ISO 9712 Non-destructive Testing – Qualification and Certification of NDT Personnel

2.10 *SMPTE Document:*[9]

SMPTE RP 133 Specifications for Medical Diagnostic Imaging Test Pattern for Television Monitors and Hard-Copy Recording Cameras

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *controlling documentation, n*—the document or standard that is specified by contractual agreement and lists such items as the examination requirements, number of views, and acceptance criteria. Controlling documentation may be in the form of a purchase order, engineering drawing, Military Standard, etc., or a combination thereof.

3.2.2 *device(s), n—for the purpose of this practice*, the term "device" and "devices" shall be used to describe microcircuits, semiconductors, electromagnetic devices, electronic and electrical component parts. Microcircuits include such items as, monolithic, multichip and hybrid microcircuits, microcircuit arrays, and the elements from which these circuits are made. Semiconductors include such items as diodes, transistors, voltage regulators, rectifiers, tunnel diodes, and other related parts. Electromagnetic devices include such items as transformers, inductors, and coils. Electronic and electrical components include such items as capacitors, resistors, switches, and relays. This is not an all-inclusive list, therefore, the term "device" or "devices" will be used throughout this practice to refer to the items which are the subject of the radiographic examination process.

3.2.3 *micro-bubbles, n*—a film defect where tiny bubbles in the film's emulsion create white dots on the processed radiograph. Micro-bubbles are unacceptable when they show up in the area of interest of a device because they can be interpreted as extraneous matter (foreign material).

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[4] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.
[5] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.
[6] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.
[7] Available from National Council on Radiation Protection and Measurements (NCRP), 7910 Woodmont Avenue, Suite 400, Bethesda, MD 20814-3095, https://ncrponline.org/.
[8] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.
[9] Available from SMPTE, White Plains Plaza 445 Hamilton Ave STE 601 White Plains NY 10601-1827, https://www.smpte.org.

3.2.4 *parallax error effect, n—for the purpose of this practice*, the term "parallax error effect" will refer to a double image on the radiograph of the device's internal features such as wires or ball bonds. This is caused by the device being too far from the central X-ray beam where the angle of the X-rays creates a double image.

3.2.5 *pick-off, n*—an automatic film processing artifact where tiny spots of emulsion are "picked off" of the radiograph as it is moving through the dryer. Pick-off artifacts are unacceptable when they show up in the area of interest of a device because they can be interpreted as extraneous matter (foreign material).

3.2.6 *pre-cap, n*—prior to capping or encapsulation.

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

3.3 *Abbreviations:*

3.3.1 *AWG*—American Wire Gauge

3.3.2 *CEO*—Cognizant Engineering Organization. The company, government agency, or other authority responsible for the design, or end use, of the device(s) for which radiographic examination is required. This, in addition to design personnel, may include personnel from electrical engineering, material and process engineering, nondestructive testing (usually the certified Radiographic Level 3), or quality groups, as appropriate.

3.3.3 *CNR*—Contrast-to-Noise Ratio, as described in Guide E2007 and Practice E2698.

3.3.4 *CR*—Computed Radiography

3.3.5 *DDA*—Digital Detector Array. DDAs are described in Practice E2597/E2597M.

3.3.6 *DPA*—Destructive Physical Analysis

3.3.7 *DR*—Digital Radiography

3.3.8 *ESD*—Electrostatic Discharge

3.3.9 *ESDS*—Electrostatic Discharge Sensitive

3.3.10 *FDD*—Focal spot to Detector Distance

3.3.11 *FFD*—Focal spot to Film Distance

3.3.12 *FOD*—Focal spot to Object Distance (always measured to the "source side" of the object)

3.3.13 *PIND*—Particle Impact Noise Detection

3.3.14 *RAD*—Radiation Absorbed Dose, the dose causing 100 ergs of energy to be absorbed by one gram of matter.

3.3.15 *SNR*—Signal-to-Noise Ratio, as described in Guides E2007 and E2736 or Practice E2737.

3.3.16 *TLD*—Thermoluminescence Dosimetry

4. Significance and Use

4.1 This practice establishes the basic minimum parameters and controls for the application of radiographic examination of electronic devices. Factors such as device handling, equipment, ESDS, materials, personnel qualification, procedure and quality requirements, reporting, records and radiation sensitivity are addressed. This practice is written so it can be specified on the engineering drawing, specification, or contract. It is not a detailed how-to procedure and must be supplemented by a detailed examination technique/procedure (see 10.1).

4.2 This practice does not set limits on radiation dose but does list requirements to limit and document radiation dose to devices. When radiation dose limits are an issue, the requestor of radiographic examinations must be cognizant of this issue and state any maximum radiation dose limitations that are required in the contractual agreement between the using parties.

5. Qualification

5.1 *Personnel Qualification*—If specified in the contractual agreement, personnel performing examinations in accordance with this practice shall be qualified in accordance with a nationally or internationally recognized NDT personnel qualification practice or standard such as ANSI/ANST CP-189, SNT-TC-1A, NAS-410, ISO 9712, or a similar document and certified by the employer or certifying agency, as applicable. The practice or standard used, and its applicable revision, shall be identified in the contractual agreement between the using parties. When examining devices to DOD requirements (see 2.6), NAS-410 shall be the required standard.

5.2 *Agency Evaluation*—If specified in the contractual agreement, Nondestructive Testing agencies shall be qualified and evaluated as described in accordance with Specification E543. The applicable revision of Specification E543 shall be specified in the contractual agreement.

6. Environment and Safety

6.1 *Safety*—The NDT facility shall present no hazards to the safety of personnel and property. NCRP 144, NCRP 116 may be used as guides to ensure that radiographic procedures are performed so that personnel shall not receive a radiation dose exceeding the maximum safe limits as permitted by city, state, or national codes.

6.2 *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.

6.3 *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.

6.4 *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.

6.5 *Digital Image Viewing Stations*—Image viewing stations shall be arranged in accordance with Practice E2698 to exclude any objectionable illuminance that could cause a reflective glare from the display monitor and shall have light controls to achieve ambient (background) lighting levels of no greater than 30 lux. Ambient light shall be measured at the viewing surface with the display monitor off. Luminance/illuminance light meters are procured and calibrated in accordance with Practice E1742/E1742M, Table 2.

7. Equipment

7.1 Different examination system configurations are possible. It is important that the user understands the advantages and limitations of each. All radiographic methods shall be conducted according to Practice E1742/E1742M.

7.2 *Radiation Source*—Only X-ray generating equipment shall be used. Such factors as focal spot size, inherent filtration, accelerating voltage, and tube current shall be considered when choosing the proper X-ray source. The X-ray source and exposure parameters shall not cause damage to the device(s) under examination. The suitability of these exposure parameters shall be demonstrated by attainment of the required radiographic quality level and compliance with all other requirements stipulated in this practice.

7.2.1 *Focal Spot*—The focal spot size shall be such that the radiographic quality level specified in 11.3 can be achieved.

7.2.2 X-ray systems shall be characterized for their radiation dose rate using a calibrated dosimeter. The dose rate shall be identified at distances to be used during examination so safe limits can be established to ensure devices under examination are not subject to excessive levels of radiation. Dose rate characterization shall be performed with and without filters (see 7.9) to establish best practices between radiographic quality levels and total dose during examination. All exposure information shall be tracked and recorded in the examination record (see 12.1).

7.3 *Non-Film Systems*—DDA-based systems and radioscopy systems designed specifically for the examination of electronic devices are generally the alternative to film-based radiography. Examinations using non-film techniques shall be in accordance with Practices E1255, E2033, or E2698 or a non-film specification approved by the CEO as required. Prior approval shall be obtained from the Radiographic Testing Level III of the CEO.

7.3.1 The suitability of any film or non-film radiography system shall be demonstrated by attainment of the required radiographic quality level and compliance with all other applicable requirements stipulated in this practice.

7.3.2 When specified in the controlling documentation, non-film radioscopy systems shall be operated in accordance with Practice E1255 and qualified in accordance with Practice E1411. Other types of non-film systems operating procedures and qualification procedures shall be agreed upon between the using parties.

7.3.3 For all non-film methods, system suitability shall be determined such that basic spatial resolution is acceptable for minimum requirements as defined in Practice E2002. CR systems shall be proven suitable as defined by Practice E2445/E2445M and DDA systems shall be proven suitable as defined by Practices E2698 and E2737.

7.4 *Film Radiography Systems:*

7.4.1 *Viewers*—Viewers used for film interpretations shall meet the following minimum requirements:

7.4.1.1 The light source shall have sufficient intensity to enable viewing of film densities in the area of interest.

7.4.1.2 Film viewers procured to or meeting the requirements of Guide E1390 are acceptable for use.

7.4.1.3 Low intensity film viewers such as fluorescent 14 by 17-in. illuminators, shall be equipped with daylight fluorescent bulbs.

7.4.1.4 All film viewers shall be tested for and posted with the maximum readable density in accordance with Practice E1742/E1742M, Figure 2 and subsection 7.27.4.

7.4.1.5 Film viewers shall be kept clean and viewing surfaces shall be free of scratches or other defects that will interfere with proper film interpretation.

7.4.1.6 *Magnifiers*—Magnifiers shall be available to provide magnification between 6× to 25× 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 E1742/E1742M.

7.4.2 *Lead-Topped Tables*—When performing film radiography, a lead-topped table with at least 0.062 in. of lead shall be used. The lead shall be smooth, and without any gouges or scratches that will cause undesirable image artifacts. Lead vinyl or lead rubber may be used in lieu of lead. Tape or other low-density materials used to cover the lead topped table shall not be allowed unless directly related to ESD protection.

7.4.3 *Film Holders*—Film holders and cassettes shall be light tight. They may be flexible vinyl, plastic, or other durable material. Vacuum cassettes are preferred in order to keep the device(s) as close to the film as possible. The suitability of any film holder shall be such as to comply with any special handling requirements including ESD precautions and their suitability shall be demonstrated by attainment of the required radiographic quality level and compliance with all other requirements stipulated in this practice. Film holders and cassettes should be routinely examined for cracks or other defects to minimize the likelihood of light leaks.

7.4.4 *Lead Foil Screens*—When ESD mats are used on top of the lead topped exposure table, the film holder shall be equipped with a lead foil back screen of adequate thickness to protect the film from backscatter. Lead foil backing screens shall be 0.010 in. minimum thickness. Lead foil screens shall be free of blemishes such as cracks, creases, scratches, or foreign material that will cause undesirable non-relevant image artifacts on the radiograph.

7.4.5 *Densitometer*—Where film radiography is performed, a densitometer shall be available to check film densities. The densitometer shall be capable of measuring the light transmitted through a radiograph with a film density up to the maximum allowed by 11.4 or any higher film densities determined suitable for use by the CEO. Densitometers shall be operated and calibrated in accordance with Practice E1079.

7.4.6 *Holding Fixtures*—Holding fixtures shall be capable of holding specimens in the required positions without interfering with the accuracy or ease of image interpretation. Holding fixtures shall not be made of materials that will create undesirable secondary radiation that will reduce image clarity. Holding fixtures shall be clean of debris that can interfere with image interpretation by appearing on the radiograph or radiological image and be confused with that of any defect. Holding

fixtures shall not cause damage to the devices under examination and shall be compliant with any special handling requirements including ESD precautions.

7.4.7 *Digitizing Techniques*—The use of film digitizing techniques is acceptable when approved by the CEO as per Reference Radiograph E1936. The digital image shall retain the IQI sensitivity of the original film.

7.5 *Image Quality Indicators (IQIs)*—IQIs shall be in accordance with Practice E801. RQIs may be used in place of IQIs and shall comply with 7.7.

7.6 *Shims*—Shims shall be used with IQI's in order to achieve the density requirements in 11.1 and 11.4. Shims shall be made of stainless steel or radiographically similar material. Definition of radiographically similar IQI material is provided in Practice E1742/E1742M.

7.7 *Representative Quality Indicators (RQIs)*—When RQIs are used in place of IQIs, they shall be similar in construction to the device being examined. RQIs may have natural or artificial defects similar to those that are expected to occur in the device being examined or may be of acceptable construction with an AWG number 48 (0.001 in.) tungsten wire mounted across the body. RQIs that conform to Practice E1817 are acceptable for use. Details of the design of RQIs and all features that must be demonstrated on the radiographic images shall be documented, and these records shall be kept on file and available.

7.8 *ESD Equipment*—ESD equipment such as ESD monitoring systems, wrist straps and grounding cords, lab coats, and ESD work surfaces shall be available to comply with all ESD precautions and requirements.

7.9 *Filters*—Filter material used for X-ray beam hardening shall have an atomic number (Z) in the range from 29 to 35. Pure copper (Z=29) or pure Zinc (Z=30) are preferred. Other materials may be used when approved by the Radiographic Level 3 or CEO, or both. Layering of these materials may be used as well; however, the order in which the materials are layered shall be documented in the radiological examination technique procedure (see 10.1).

7.10 *Digital Display*—When applicable, image display monitors used for interpretation shall meet the requirements as defined in Practices E2033 or E2698. An image display test pattern, in accordance with the requirements of SMPTE RP 133, shall be configured for the system display resolution and aspect ratio. Alternate test patterns may be used, provided they include the features described in SMPTE RP 133.

8. Materials

8.1 *ESD Materials*—ESD materials such as electrically conductive bags, ESD compliant tape, and other ESD approved materials shall be available as required to aid in the radiographic examination process and comply with all ESD handling and storage requirements.

8.2 *Film:*

8.2.1 Only film systems meeting the Class I (or better) requirements of Test Method E1815 shall be used. Radiographic film may be single or double emulsion; however, single emulsion film is preferred and required when parallax error effects cause double images of very small features (for example, interconnecting wires). Radiographic film shall be free of inherent defects, such as micro-bubbles, that will interfere with film interpretation or could be confused as defects in the device under examination.

8.2.2 *Film Processing Solutions*—Radiographs shall be processed in solutions specifically formulated for industrial radiographic film systems and shall be capable of consistently producing radiographs that meet the requirements of this practice. The time and temperature for film immersion shall be within the manufacturer's recommended range. Film processing method shall be validated by CEO as per Guide E999.

8.3 *Non-Film Recording Media*—The use of recording medium such as CD-ROMs, DVDs, USB drives, and hard disks are allowed, provided the proper image quality can be demonstrated and sufficient data backup strategy used. Media storage and handling, when in accordance with Guides E1453 and E1475, is acceptable for use.

9. Precautions

9.1 *Electrostatic Discharge*—Unless otherwise specified, all devices (except those identified for DPA testing) shall be treated as ESDS. The NDT Agency shall have an ESD program that complies with ANSI/ESD S20.20. ESD protocol shall be used when performing radiological examinations to this practice. A procedure shall be established and recorded that will protect the device(s) from ESD damage during radiological examination. The ESD radiological procedure shall be approved by the ESD CEO.

9.1.1 When performing examinations on a lead topped table, the tabletop shall meet the requirements for an ESD work surface. An approved ESD mat may be used on the lead topped table; however, the film holder shall contain sufficient back screens to protect the film from backscatter as required in accordance with 7.4.3.

9.1.2 When performing film-based examinations, when the film holder is not an approved ESD material, the film holder may be placed in an approved ESD bag such that the device(s) are never placed on non-conductive material. Other methodologies are allowed when approved by the ESD CEO.

9.1.3 When performing non-film-based radiology, the system shall be designed such that the device(s) is never placed on a non-conductive surface that would violate ESD protocol.

9.2 *Radiation Dose Control*—Unless otherwise specified, all silicon-based devices shall be considered radiation sensitive, precautions shall be taken to minimize radiation dose during radiographic examinations to reduce the possibility of radiation damage. A general rule is that "active" devices are radiation sensitive and "passive" devices are not radiation sensitive (for example, active device = microcircuit, passive device = transformer). When in doubt, always treat devices as radiation sensitive. Note that different "active" components have different thresholds for damage. Devices are exempt from this Section's requirements only when noted on the controlling documentations.

9.2.1 *Filters*—Filters shall be used to harden the X-ray beam to reduce total radiation dose to the device(s). As a minimum,

a thickness of 0.005 in. pure copper or pure zinc filter shall be placed at the X-ray tube window to harden the X-ray beam. When performing geometric enlargement techniques with the device very close to the focal spot (for example, micro-focus X-ray tube/DDA), secondary radiation from the filter may increase the dose to the device; in such cases, proper filtering shall be determined prior to the actual examination by the Radiographic Level 3 or CEO. Other materials and thicknesses may be used when it is demonstrated that improvement in the radiological quality level is attained or further reduction in radiation dose is an overriding factor.

9.2.2 *Shielding*—When inspecting a large assembly with many installed devices, such as a printed circuit board, areas that are not under examination may be masked with lead shielding if not doing so violates dose limitations. Prop lead shielding up on blocks or other means such that the weight of the lead shielding does not damage the assembly.

9.2.3 *Exposure Time and Distance:*

9.2.3.1 Minimize the exposure time where practical:

(1) When developing the examination technique, use only one device for technique experimentation when there is more than one device in the lot to be examined.

(2) Limit re-radiography, that is, do not re-expose the entire lot when only one device needs re-radiography.

(3) Do not leave any devices in the exposure area that are not currently being examined.

(4) When performing non-film radiology, and when practical, minimize the dose by capturing a static image of the device rather than performing image interpretation with the radiation source continuously irradiating the device.

9.2.3.2 For non-film applications where geometric enlargement is necessary, limit the geometric magnification to the minimum required to achieve an acceptable examination (see 11.14.1). By keeping the distance of the device as far as possible from the focal spot, total radiation dose can be reduced.

9.2.4 *Calculating Radiation Dose*—When specified in the controlling documentation, radiation dose shall be monitored by using TLD in accordance with Practice E666, or when allowed, the dose may be estimated when using non-film systems that have had their radiation output characterized and documented as required in 7.3.3.

9.2.5 X-ray voltage should not exceed 160 kV. Although higher voltages may be necessary to penetrate certain packages, these levels may be damaging to some device technologies. Higher voltages shall only be used when approved by the manufacturer or CEO.

9.3 *Handling:*

9.3.1 *Pre-Cap Examination*—When performing examination at the pre-cap level, special precautions shall be taken to prevent damage of internal components. Care shall be taken to not touch the inside area of the device. When practical, leave the device in its protective carrier unless it will interfere with complete coverage or reduce the radiological quality level (Pre-cap protective carriers often have a plastic lid in place to protect the interior of the device).

9.3.2 *Final Examination*—When practical, leave the device in its protective carrier unless it will interfere with complete coverage or reduce the radiological quality level (Sealed devices may be installed in protective carriers to prevent damage to external leads).

9.4 *Exposure Areas*—Exposure areas shall be kept clean and free of debris that can interfere with the examination process. Exposure areas shall not be located where particulate contamination can be introduced into the interior of the device (when performing pre-cap examinations) or on the exterior of the device where it would show up as extraneous matter on the resulting radiological image.

9.5 Whenever practical, prior to radiological examination, examine the exterior of the device with magnification between 6× and 25× to verify no debris is present on the exterior of the case.

10. Written Procedure

10.1 *Examinations*—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 CEO for approval. X-ray exposure factors shall be selected to obtain satisfactory radiographic images and achieve maximum image details that consistently meet the requirements of this practice and shall be documented in the form of a written radiographic examination technique/procedure. For certain device types, the radiopacity of the construction materials (packages or internal attachment) may effectively prevent radiographic imaging of certain types of defects from some or all possible viewing angles and should be considered when developing the examination technique. Guide E94/E94M may be consulted for guidance for technique development and Guide E1000 may be consulted for guidance with radioscopy. Guide E2736 may be consulted for guidance with DDAs. As a minimum, the procedure shall include the following:

10.1.1 The name and address of the NDT facility and the date or revision of the procedure.

10.1.2 Device manufacturer's name or code identification number.

10.1.3 Device type, part number, and package type (for example, single ended cylindrical device, flat package, etc.).

10.1.4 Required views and describe any holding fixtures or apparatus (see 7.4.2) required to obtain those views.

10.1.5 A drawing, sketch, or photograph of the device(s) showing the film or detector and IQI/RQI with respect to the radiation source for each view.

10.1.6 The angle of the radiation beam in relation to the device(s) and the film or detector.

10.1.7 X-ray machine, system identification, or type.

10.1.8 X-ray exposure factors: kV, mA (or μA), focal spot size, exposure time, FFD or FDD, FOD, and filter material with thickness (when used).

10.1.9 Film type and screens (when used), and film holder type (for example, vacuum vinyl cassette, ready pack, etc.). When using digital radiography, detector type and settings (for example, gain, integration time, averaging number).

10.1.10 IQIs and shims (when used) or RQIs when used in lieu of IQIs. List the required radiographic quality level (see 11.3) and if that cannot be achieved due to device package type, state the achieved sensitivity and the feature that hinders sensitivity (for example, only Practice E801 #6 0.002-in. wire visible due to integral heat sink base thickness of 0.125 in.). When RQIs are used, include details of the design or reference to documentations where such information is found.

10.1.11 Any special handling requirements (for example, ESD sensitive, radiation sensitive; wear ESD approved finger cots when handling devices, etc.).

10.1.12 All radiographic examination procedures shall be approved by an individual qualified and certified as a Level 3 in Radiographic Testing in accordance with 5.1.

10.1.13 *Acceptance Criteria*—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.

11. Requirements

11.1 *Image Quality Indicators (IQIs):*

11.1.1 Each radiograph shall have at least two IQIs exposed with each view located (and properly identified) in opposite corners of the film or opposite corners of the device. IQIs shall be used in accordance with Practice E801 and their resulting radiographic film density shall bracket that of the device being examined. Shimming may be necessary (see 7.6).

NOTE 1—When the radiographic quality level requirement is 0.001 in., the #7 and #8 E801 IQIs are not allowed since their smallest wire is 0.002 in.

11.1.2 *IQIs for Non-Film Imaging*—IQIs shall be used in a similar fashion, as described in 11.1, when the device(s) are placed on a tray, as is the case for many radiography systems that use vertical X-ray-to-detector geometry. The alternative is to image one IQI at the beginning of the examination of a lot of devices, and image the other IQI at the end of the examination. IQIs and RQIs shall be imaged and verified with the full range of exposure settings (for example, when kV is changed during an examination to view multiple features, IQIs and RQIs shall be subject to those same settings). Permanent records of IQIs/RQIs are required as described in 12.2.

11.2 *Representative Quality Indicators (RQIs)*—RQIs may be used in lieu of the requirements of 11.1 and shall conform to 7.7 or Practice E1817 as applicable. RQIs shall be positioned in the same orientation as the device for each view.

11.3 *Radiographic Quality Level:*

11.3.1 Unless otherwise specified, all device images (both film and non-film) shall demonstrate the 0.001-in. wire on the IQI or RQI. When RQIs without the AWG 48 tungsten wires are used, all features of the RQI shall be demonstrated.

11.3.2 When the required Radiographic Quality Level cannot be met due to device package design (for example, flat pack design with integral heat sink or spacer as base of package), the attained Radiographic Quality Level shall be recorded on the radiographic technique (see 10.1) and examination report (see 12.1).

11.3.3 When required Radiographic Quality Level cannot be met due to device design, additional views shall be taken to provide as much acceptable coverage of the device as possible (for example, only view Y is required but integral heat sink is too thick to attain required Radiographic Quality Level, views X and Z shall be added to examination for increased coverage).

11.4 *Radiographic Optical Density*—Unless otherwise specified, radiographic optical density in the area of interest of the device and the IQI or RQI shall be between 1.8 and 2.5. IQI optical densities shall bracket that of the device – see 11.1.

11.4.1 Optical density is usually measured in the background area of the more complex devices (that is, microcircuits) as it is not always practical or meaningful to expose the denser components (for example, tantalum capacitors) within the sealed case to reach these optical density levels.

11.5 *Non-Film Image Pixel Value*—Unless otherwise specified, the pixel value in the area of interest of the device and the IQI or RQI shall be between 15 % to 75 % of the pixel value range (for example, for a 16-bit image that has pixel value range from 0 to 65535, the pixel values shall fall between 9830 and 49152). In all cases, the required IQI sensitivity/radiographic quality shall be demonstrated.

11.6 *Views*—Unless otherwise specified, the following minimum views shall be taken:

11.6.1 All flat packages, dual in-line packages, hybrid packages, and single-ended cylindrical devices shall have one view taken with the X-rays penetrating in the Y direction as shown in Figs. 1-6. When more than one view is required, take the second and third views, as applicable, with the X-rays penetrating in the Z and X directions respectively. When applicable, the die/cavity interface shall be positioned as close as possible to the film (or detector) to avoid distortion.

11.6.2 All stud-mounted and cylindrical axial lead devices shall have one view taken with the X-rays penetrating in the X direction as defined in Figs. 1-6. When more than one view is required, the second and third views, as applicable, shall be

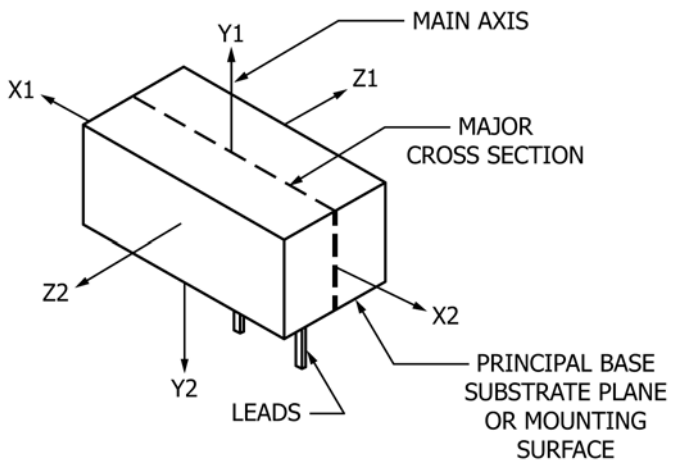

FIG. 1 Orientation of Microelectronic Device to Direction of Applied Force