Designation: E1161 – 09 (Reapproved 2014)

Standard Practice for Radiologic 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 radiologic 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 radiologic 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) or physical damage.

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

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 *ASTM Standards:*[2]

E94 Guide for Radiographic Examination

E431 Guide to Interpretation of Radiographs of Semiconductors and Related Devices

E543 Specification for Agencies Performing Nondestructive Testing

E801 Practice for Controlling Quality of Radiological Examination of Electronic Devices

E666 Practice for Calculating Absorbed Dose From Gamma or X Radiation

E999 Guide for Controlling the Quality of Industrial Radiographic Film Processing

E1000 Guide for Radioscopy

E1079 Practice for Calibration of Transmission Densitometers

E1254 Guide for Storage of Radiographs and Unexposed Industrial Radiographic Films

E1255 Practice for Radioscopy

E1316 Terminology for Nondestructive Examinations

E1390 Specification for Illuminators Used for Viewing Industrial Radiographs

E1411 Practice for Qualification of Radioscopic Systems

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 Practice for Radiographic Examination

E1815 Test Method for Classification of Film Systems for Industrial Radiography

E1817 Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)

E2339 Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)

E2597 Practice for Manufacturing Characterization of Digital Detector Arrays

2.2 *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)

[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, 2014. Published July 2014. Originally approved in 1987. Last previous edition approved in 2009 as E1161 – 09. DOI: 10.1520/E1161-09R14.

[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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

2.3 *ASNT Standard:*[4]
ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel
SNT-TC-1A Personnel Qualification and Certification
2.4 *AIA Documents:*[5]
NAS-410 Certification and Qualification of Nondestructive Test Personnel
2.5 *Department of Defense (DOD) Documents:*[6]
MIL-PRF-28861 Performance Specification—General Specification for Filters, 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 Radiography
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
2.6 *Federal Standard:*[6]
FED-STD-595 Color (Requirements for Individual Color Chits)
2.7 *NCRP Documents:*
NCRP 116 Limitation of Exposure to Ionizing Radiation
NCRP 144 Radiation Protection for Particle Accelerator Facilities

3. Terminology

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

3.2 *Abbreviations:*

3.2.1 *controlling documentation* —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)*—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 radiological examination process.

3.2.3 *micro-bubbles*—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).

3.2.4 *parallax error effect*—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 on double emulsion film.

3.2.5 *pick-off*—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*—Prior to capping or encapsulation.

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 radiological 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 *DDA*—Digital Detector Array. DDAs are described in Practice E2597.

3.3.4 *DPA*—Destructive Physical Analysis

3.3.5 *ESD*—Electrostatic Discharge

3.3.6 *ESDS*—Electrostatic Discharge Sensitive

3.3.7 *FDD*—Focal spot to Detector Distance

3.3.8 *FFD*—Focal spot to Film Distance

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

3.3.10 *PIND*—Particle Impact Noise Detection

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

3.3.12 *TLD*—Thermoluminescence Dosimetry

4. Significance and Use

4.1 This practice establishes the basic minimum parameters and controls for the application of radiological 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

[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.

detailed how-to procedure and must be supplemented by a detailed examination technique/procedure (see 9.1).

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 radiological 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 to 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, or 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 2.5), NAS-410 shall be the required standard.

5.2 *Qualification of Nondestructive Testing (NDT) Agencies*—When specified in the contractual agreement, Nondestructive Testing agencies shall be qualified and evaluated as described in Practice E543.

5.2.1 *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 radiological 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. Equipment

6.1 *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 radiological quality level and compliance with all other requirements stipulated in this practice.

6.1.1 *Focal Spot*—The focal spot size shall be such that the radiological quality level specified in 10.3 can be achieved.

6.2 *Non-Film Systems*—Radioscopy systems designed specifically for the examination of electronic devices are generally the alternative to film based radiography. However, DDA based systems may also be used.

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

6.2.2 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 operaating procedures and qualification procedures shall be agreed upon between the using parties.

6.2.3 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 6.13) to establish best practices between radiological quality levels and total dose during examination. All exposure information shall be tracked and recorded in the examination record (see 11.1).

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

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

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

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

6.3.4 All film viewers shall be tested for and posted with the maximum readable density in accordance with Practice E1742, Figure 2 and subsection 6.27.4.

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

6.4 *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.

6.5 *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 with out 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.

6.6 *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 radiological quality level and compliance with all other requirements stipulated in this practice.

6.7 *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.

6.8 *Image Quality Indicators (IQIs)*—IQIs shall be in accordance with Practice E801. RQIs may be used in place of IQIs and shall comply with 6.9.

6.8.1 *Shims*—Shims shall be used with IQI's in order to achieve the density requirements in 10.1 and 10.4. Shims shall be made of stainless steel or radiographically similar material.

6.9 *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 radiological images shall be documented and these records shall be kept on file and available.

6.10 *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 10.4 or any higher film densities determined suitable for use by the CEO. Densitometers shall be operated and calibrated in accordance with Practice E1079.

6.11 *Magnifiers*—Magnifiers shall be available to provide magnification between 6× to 25× to aid in interpretation and determine indication size, as applicable.

6.12 *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.

6.13 *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 and/or CEO. 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 9.1).

7. Materials

7.1 *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 radiological examination process and comply with all ESD handling and storage requirements.

7.2 *Film*—Only film systems meeting the Class I (or better) requirements of ASTM 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.

7.2.1 *Non-Film Recording Media*—The use of recording medium such as CD-ROMs and DVDs are allowed, provided the proper image clarity and definition can be demonstrated. Media storage and handling, when in accordance with Guides E1453 and E1475, is acceptable for use.

7.3 *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.

8. Precautions

8.1 *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.

8.1.1 When performing examinations on a lead topped table, the table top 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 6.6.

8.1.2 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.

8.1.3 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.

8.2 *Radiation Dose Control*—Unless otherwise specified, all silicon based devices shall be considered radiation sensitive, precautions shall be taken to minimize radiation dose during radiological 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 devise=microcircuit, passive device=transformer). When in doubt, always treat devices as radiation sensitive. Devices are exempt from this Section's requirements only when noted on the controlling documentations.

8.2.1 *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 film radiography. 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.

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

8.2.3 *Exposure Time and Distance:*

8.2.3.1 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.

8.2.3.2 For non-film applications where geometric enlargement is necessary, limit the geometric magnification to the minimum required to achieve an acceptable examination (see 10.11.1). By keeping the distance of the device as far as possible from the focal spot, total radiation dose can be reduced.

8.2.4 *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 6.2.3.

8.2.5 X-ray voltage shall 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.

8.3 *Handling:*

8.3.1 *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).

8.3.2 *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).

8.4 *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.

8.5 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.

9. Procedure

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

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

9.1.2 Device manufacturer's name or code identification number.

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

9.1.4 Required views and describe any holding fixtures or apparatus (see 6.4) required to obtain those views.

9.1.5 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. Included shall be the angle of the radiation beam in relation to the device(s) and the film (or detector).

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

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

9.1.8 Film type and screens (when used), and film holder type (for example, vacuum vinyl cassette, ready pack, etc.).

9.1.9 IQIs and shims (when used) or RQIs when used in lieu of IQIs. List the required radiological quality level (see 10.3) and if that cannot be achieved due to device package type, state the achieved sensitivity and the feature that hinders sensitivity (for example, Only ASTM 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.

9.1.10 Any special handling requirements (for example, ESD sensitive, Radiation sensitive, wear ESD approved finger cots when handling devices, etc.).

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

9.1.12 Acceptance criteria and revision number.

10. Requirements

10.1 *Image Quality Indicators (IQIs)*—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 6.8.1).

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

10.1.1 *IQIs for Non-Film Imaging*—IQIs shall be used in a similar fashion, as described in 10.1, when the device(s) are placed on a tray, as is the case for many radioscopy 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 12.1.

10.2 *Representative Quality Indicators (RQIs)*—RQIs may be used in lieu of the requirements of 10.1 and shall conform to 6.9 or Practice E1817 as applicable. RQIs shall be positioned in the same orientation as the device for each view.

10.3 *Radiological Quality Level*—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.

10.3.1 When the required Radiological 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 Radiological Quality Level shall be recorded on the radiographic technique (see 9.1) and examination report (see 11.1). 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 Radiological Quality Level, views X and Z shall be added to examination for increased coverage).

10.4 *Radiographic Film Density*—Unless otherwise specified, radiographic film density in the area of interest of the device and the IQI or RQI shall be between 1.0 and 2.5. IQI film densities shall bracket that of the device – see 10.1. Film 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 film density levels.

10.4.1 *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).

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

10.5.1 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.

10.5.2 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 taken with the X-rays penetrating in the Z direction and at 45 degrees between the X and Z directions. When applicable, the die/cavity interface shall be positioned as close as possible to the film to avoid distortion.

10.5.3 All JANS (Joint Army Navy Quality Level "S" Devices) devices shall have two views minimum. The views should be specified by the manufacturer or the requesting agency to show all internal components, including bond wires. Extra views shall be specified when necessary to show bond wires along their length (X1, X2, and Z axis) and the Y axis. Stud mounted and axial lead device views shall be taken with X-rays penetrating in the X and Z directions.

10.5.4 All electromagnetic devices (transformers, inductors and coils) shall have three views taken in the X, Y, and Z axis as shown in Fig. 7. When inadequate coverage is provided, additional views shall be taken as deemed necessary to satisfy the acceptance criteria as stated in the controlling documentation.

10.5.5 Radio frequency coils shall have two views taken normal to the major axis of the device. One view shall be taken 90 degrees from the other.

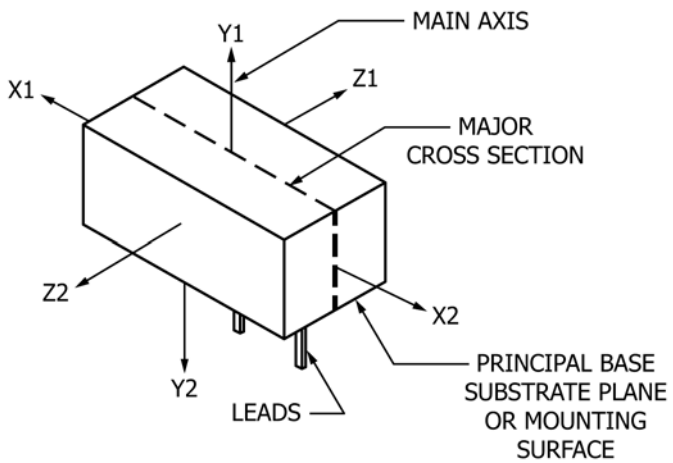


FIG. 1 Orientation of Microelectronic Device to Direction of Applied Force

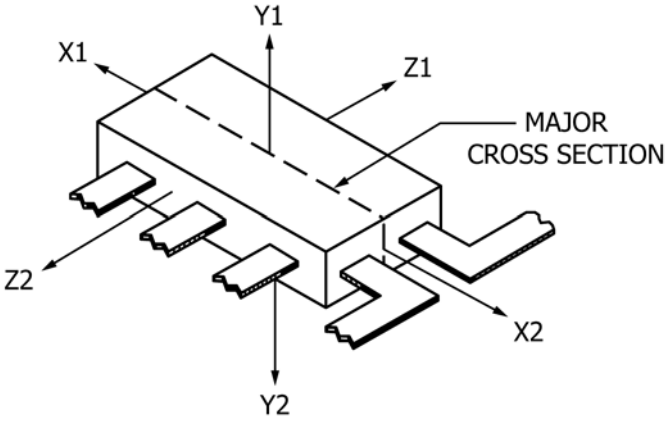


FIG. 2 Radial Lead Flat Packages

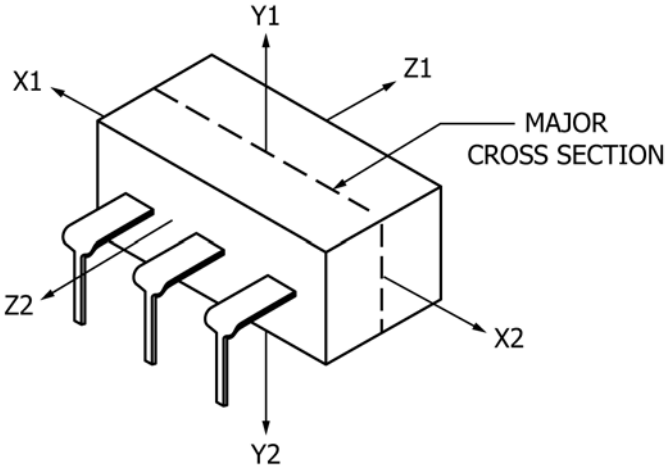


FIG. 3 Dual In-Line Package

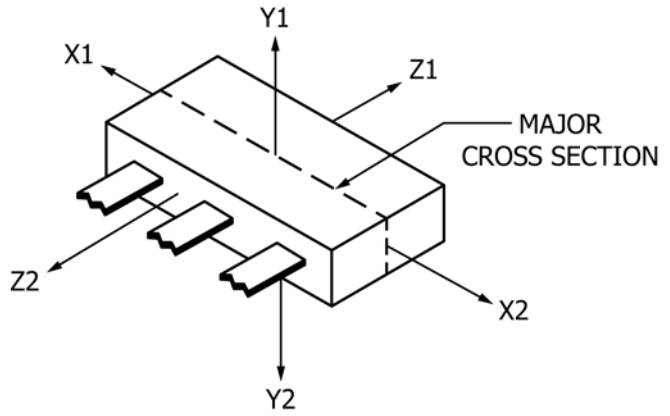
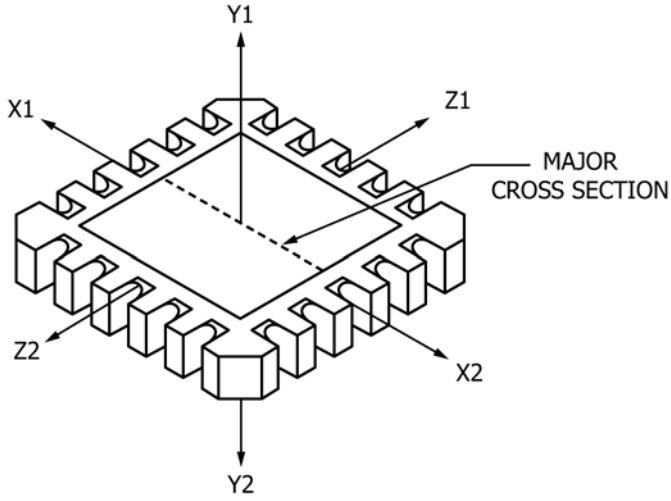
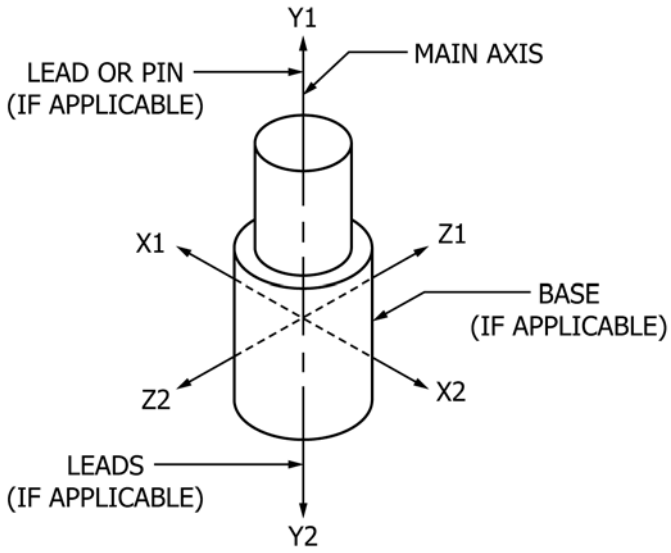


FIG. 4 Flat Package with Radial Leads from One Side Only



NOTE 1—The Y1 force is such that it will tend to lift the die off the substrate or wires off the die. The reference to applied force actually refers to the force which operates on the device itself and may be the result of the primary forces applied in a different manner or direction to achieve the desired stress at the device (for example, constant acceleration)

FIG. 5 Leadless Chip Carrier (Top View)



NOTE 1—The Y1 force is such that it will tend to lift the die off the substrate or wires off the die. The reference to applied force actually refers to the force which operates on the device itself and may be the result of the primary forces applied in a different manner or direction to achieve the desired stress at the device (for example, constant acceleration)

FIG. 6 Orientation of Noncylindrical Semiconductor Device to Direction of Accelerating Force

10.5.6 Due to device construction and configuration, additional exposures (lighter and or darker) of any view shall be taken as deemed necessary in order to achieve full coverage of the device and to meet radiographic film density or pixel value requirements of 10.4.

10.6 *Radiographic Film Identification*—All radiographs shall be identified with the following minimum information:

10.6.1 Date of the examination.

10.6.2 Device manufacturer's name or code identification number.

10.6.3 X-ray laboratory identification, if other than device manufacturer.

10.6.4 Device type or part number.

10.6.5 Device serial or cross-reference numbers, when applicable.

10.6.6 Production lot number, date code and examination report number, as applicable.

10.6.7 Device axis view number.

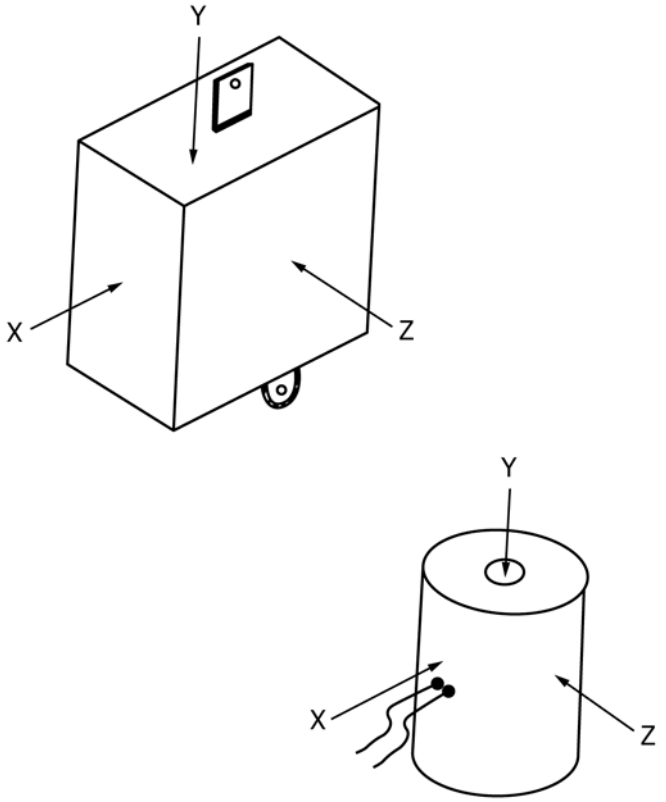


FIG. 7 Orientation of Cylindrical Semiconductor Device to Direction of Accelerating Force

10.7 *Digital Image Identification*—Image files shall be named in such a way as to provide traceability to the device(s), the view number and the examination report (for example, Report Number-Part Number-Serial Number-View Number). The examination report shall contain all the required information from 10.6.

10.8 *Serialized Devices*—When device serialization is required, identify each device readily by a serial number. Radiograph in consecutive, increasing serial order. When a device is missing, the blank space shall contain either the serial number or other X-ray objects to readily identify and correlate X-ray data. When large skips occur within serialized devices, the serial number of the last device before the skip and the first device after the skip may be used in place of multiple opaque objects.

10.8.1 *Unserialized Devices*—When the device(s) are not serialized, serial numbers shall be assigned during examination in order to separate rejectable devices from acceptable ones. Maintain serialization until image interpretation is complete and segregate rejectable devices from acceptable ones. Rejectable devices shall be clearly identified to prevent them from being used.

10.9 *Processing*—Film processing shall be controlled such that acceptable radiographs are created. Radiographs shall be free of processing blemishes or film defects that will interfere with image interpretation. Such blemishes may be (but not limited to) chemical spots, fingerprints, fogging, pick-off, micro-bubbles, scratches, etc. Guide E999 may be consulted for guidance with film processing. Film processing solution control shall be in accordance with Practice E1742, Annex A4.

10.10 *Qualification of Radiographs and Radiological Images*—All images (film and non-film) shall be qualified prior to interpretation. Radiological quality level, film density or pixel value, film identification or non-film file name, proper orientation and number of views shall be checked and verified to be correct prior to image interpretation.

10.10.1 *Image Distortion*—When examining more than one device at a time and when the device is not in the central ray, image distortion requirements of Practice E801 shall be verified and be no greater than 10 %.

10.11 *Interpretation of Radiographs*—Utilizing the equipment specified herein, examine the radiographs or radiological images to determine that each device conforms to the acceptance criteria as stated in the controlling documentations. The manufacturer shall also provide an image of the device, either a drawing or photograph, to show correct construction of the device and proper placement of components.

10.11.1 Radiographic film interpretation shall be accomplished at a magnification between 6× and 25×. Viewing masks may be used when necessary. Non-film images shall be viewed at the minimum geometric magnification required to demonstrate the required radiological quality level. Higher magnification may be required to aid and properly interpret discontinuities seen at the lower magnification levels.

10.11.2 Device images shall be reviewed for, but not limited to, such discontinuities as lid seal voids, extraneous matter, solder or weld splash, build up of bonding material, proper shape and placement of lead wires or whiskers, bond of lead wire or whisker to semiconductor element, bond of lead wire or whisker to terminal post, cracks in the substrate, semiconductor metallization pattern, mounting of semiconductor element, or physical damage.

10.11.3 Devices that are being examined to MIL-STD 750, Method 2076, or MIL-STD-883, Method 2012 acceptance criteria shall be rejected for any size of extraneous matter unless a minimum allowable size is stated in the controlling documentation. That is, extraneous matter is typically specified as “0.001 in. or of any lesser size which is sufficient to bridge non-connected conducting elements of the device.” Unless the controlling documentation states what that minimum size is, it shall be assumed any detectable extraneous matter be rejected.

10.11.4 Guide E431 provides many useful illustrations which may aid in this interpretation. Image interpretation shall be made under low light level conditions without glare on the viewing surface, whether a film viewer or computer monitor.

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

10.12.1 *Re-radiography to Rule Out a Defect*—When defects such as extraneous matter (foreign material) are seen, the exterior of the device shall be visually examined, using at least the same level of magnification as was used to review the image. When any debris is present on the exterior surface of the device, it shall be removed in such a manner as to not harm or

scratch the device (for example, use a wood or plastic dowel rather than a sharp blade or instrument) and the device shall be re-radiographed to verify acceptance or rejection.

10.12.2 *Re-radiography Following PIND Testing*—When allowed by the controlling documentation, extraneous matter may be verified as attached by subjecting the device to a vibration or shock using a PIND tester. When this is allowed, the radiological image taken after PIND shall be clearly identified as "Post-PIND" and shall be the same view(s) that was originally rejected. Post PIND images shall be compared to the original view(s) to determine if the extraneous matter has moved.

10.12.3 *Re-radiography for Parallax Error Effect*—When parallax error effect creates a double image of small features of the device(s) such as internal interconnecting wires, re-radiography shall be performed using single emulsion film (see 7.2).

10.13 *Double Read*—Due to the complexity of design and the fact that very small indications (0.001 in. or smaller) must be interpreted and evaluated, a double read is recommended to ensure a high level of accuracy for the examination results. A double read consists of image interpretation and evaluation, by two separate radiographers qualified and certified in accordance with 5.1. When a double read is performed it shall be documented on the examination report in accordance with 11.1. When a double read is required it shall be specified in the contractual agreement.

10.14 *Special Device Marking*—When specified in the controlling documentation, devices that have been radiologically examined and found acceptable shall be identified with a blue or green dot on the external case. The dot shall be approximately 0.062 in. in diameter. The color selected from FED-STD-595 shall be any shade between 15102-15123 or 25102-25109. The dot shall be placed so that it is readily visible but shall not obliterate other device marking. Use blue dot for film radiography and green dot for non-film radiology.

11. Report

11.1 *Examination Reports*—The results of all radiological examinations shall be recorded and shall include the following minimum information:

11.1.1 The date of the examination.

11.1.2 The manufacturer of the device(s).

11.1.3 X-ray laboratory identification, if other than device manufacturer.

11.1.4 Reference to this practice, the approved ESD procedure (see 8.1) and the radiological examination technique/procedure (see 9.1) including revision numbers.

11.1.5 The acceptance criteria and revision number.

11.1.6 Provide traceability to the specific devices examined by listing part number, serial number, lot number and date code, as applicable.

11.1.7 The disposition of the device(s) (accept or reject) and the reason for rejection of any items. Rejections shall be correlated to the view(s) where the rejectable indication is seen.

11.1.8 Post PIND (see 10.12.2) results, when applicable.

11.1.9 The exposure levels for all devices, including any re-radiography (see 10.12) or technique development exposures in order to track total radiation dose to each device. Also, when required by the controlling documentation, the total dose in RADs, either as measured or estimated (see 8.2.4).

11.1.10 Record the attained radiological quality level and whether it meets the required radiological quality level (see 10.3.1).

11.1.11 In the event that parts of the device cannot be clearly seen due to opacity of construction materials (see 9.1) or case design (see 10.3.1), the interpreter shall so note on the examination report that the criteria has not been evaluated and cannot be confirmed. Be specific and note which view and reason. For example, view Y cannot be properly examined to the requirements of Mil-Std-XXX, Para. XXX due to the excessive thickness of the base of the case.

11.1.12 Names, signatures and level of certification (see 5.1) of the individuals performing the image interpretation and evaluation.

12. Records

12.1 Permanent records are required. Images not stored on radiographic film shall be archived using a reproducible electronic medium. Data file format and storage compliance with Practice E2339, Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) is preferred. Stored image files, whether in DICONDE or Tagged Image File Format (TIFF) shall maintain a bit depth and spatial resolution to demonstrate the required radiological quality level and compliance with all other applicable requirements stipulated in this practice. Regardless of file format, a raw unaltered image shall be preserved without altering the original spatial resolution and pixel intensity. Records shall also include images with any image processing that was required for interpretation and evaluation for acceptance. The use of recording medium such as CD-ROMs and DVDs are allowed, provided the proper image clarity and definition can be demonstrated. Media storage and handling, when in accordance with Guides E1453 and E1475, is acceptable for use.

12.2 Examination reports shall be kept on file in accordance with the requirements found in the controlling documentation. A copy of the examination report (see 11.1) and the radiological examination technique/procedure (see 9.1) shall be kept with the radiographs. For non-film applications where electronic images are provided, a copy of the examination report (see 11.1) and the radiological examination technique/procedure (see 9.1) shall be added to the approved storage media (see 12.1) along with the device(s) images.

12.3 Unless otherwise specified, one set of records specified by this Section shall accompany each shipment of devices. An additional set of records shall be kept by the NDT agency when specified in the controlling documentation.

13. Keywords

13.1 capacitor; diode; electronic device; hybrid; inductor; microcircuits; microcircuit array; monolithic; multichip; non-destructive testing; radiographic; radiologic; radiology; radioscopy; rectifier; relay; resistor; semiconductor; switches; transformer; transistor; tunnel diode; voltage regulator; x-ray