METHOD 2012.7

RADIOGRAPHY

1. Purpose. The purpose of this examination is to nondestructively detect defects within the sealed case, especially those resulting from the sealing process and internal defects such as foreign objects, improper interconnecting wires, and voids in the die attach material or in the glass when glass seals are used. It establishes methods, criteria, and standards for radiographic examination of semiconductor and hybrid devices.

NOTE: For certain device types, opacity of the construction materials (packages or internal attachment) may effectively prevent radiographic identification of certain types of defects from some or all possible viewing angles. This factor should be considered in relation to the design of each device when application of this test method is specified.

2. Apparatus. The apparatus and material for this test shall include:

a. Radiographic equipment with a sufficient voltage range to penetrate the device. The focal distance shall be adequate to maintain a sharply defined image of an object with a major dimension of 0.0254 mm (0.001 inch).

b. Radiographic film: Very fine grain industrial X-ray film grade, either single or double emulsion.

c. Radiographic viewer: Capable of 0.0254 mm (0.001 inch) resolution in major dimension.

d. Holding fixtures: Capable of holding devices in the required positions without interfering with the accuracy or ease of image interpretation.

e. Radiographic quality standards: Capable of verifying the ability to detect all specified defects.

f. Film holder: A 1.6 mm (0.0625 inch) minimum lead-topped table or lead-backed film holders to prevent back scatter of radiation.

3. Procedure. The X-ray exposure factors, voltage, milliampere and time settings shall be selected or adjusted as necessary to obtain satisfactory exposures and achieve maximum image details within the sensitivity requirements for the device or defect features the radiographic test is directed toward. The X-ray voltage shall be the lowest consistent with these requirements and shall not exceed 200 kV.

3.1 Mounting and views. The devices shall be mounted in the holding fixture so that the devices are not damaged or contaminated and are in the proper plane as specified. The devices may be mounted in any type of fixture and masking with lead diaphragms or barium clay may be employed to isolate multiple specimens provided the fixtures or masking material do not block the view from X-ray source to the film of any portion of the body of the device.

3.1.1 Views.

3.1.1.1 Flat packages, dual-in-line packages, hybrid packages, and single ended cylindrical devices. Flat packages, dual-in-line packages, hybrid packages, and single ended cylindrical devices, unless otherwise specified, shall have one view taken with the X-rays penetrating in the Y direction as defined on figures 1 and 2 of MIL-STD-883, GENERAL REQUIREMENTS. 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 and X direction respectively (either Z or X for flat packages). The die/cavity interface shall be positioned as close as possible to the film to avoid distortion.

3.1.1.2 Stud-mounted and cylindrical axial lead devices. Stud-mounted and cylindrical axial lead devices, unless otherwise specified, shall have one view taken with the X-rays penetrating in the X direction as defined on figures 1 and 2 of MIL-STD-883, GENERAL REQUIREMENTS. 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° between the X and Z direction. The die/cavity interface shall be positioned as close as possible to the film to avoid distortion.

3.2 Radiographic quality standard. Each radiograph shall have at least two quality standards exposed with each view, located (and properly identified) in opposite corners of the film. These penetrameters shall be of a radiographic density nearest the density of the devices being inspected. The radiographic quality standard shall consist of a suitable ASTM penetrameter as described in the DOD adopted standard ASTM E 801 Standard Practice for Controlling Quality of Radiographic Testing of Electronic Devices, or equivalent.

3.3 Film and marking. The radiographic film shall be in a film holder backed with a minimum of 1/16 inch lead or the holder shall be placed on the lead topped table. The film shall be identified using techniques that print the following information, photographically, on the radiograph:

a. Device manufacturer's name or code identification number.

b. Device type or Part or Identifying Number.

c. Production lot number or date code or inspection lot number.

d. Radiographic film view number and date.

e. Device serial or cross reference numbers, when applicable.

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

3.3.1 Nonfilm techniques, when specified. The use of nonfilm techniques is permitted if permanent records are not required and the equipment is capable of producing results of equal quality when compared with film techniques, and all requirements of this method are complied with, except those pertaining to the actual film.

3.3.2 Serialized devices. When device serialization is required, each device shall be readily identified by a serial number. They shall be radiographed in consecutive, increasing serial order. When a device is missing, the blank space shall contain either the serial number or other X-ray opaque object 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 the multiple opaque objects.

3.3.3 Special device marking. When specified (see 4.c), the devices that have been X-rayed and found acceptable shall be identified with a blue dot on the external case. The blue dot shall be approximately 1.6 mm (0.0625 inch) 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.

3.4 Tests. The X-ray exposure factor shall be selected to achieve resolution of 0.0254 mm (0.001 inch) major dimension, less than 10 percent distortion and an "H" and "D" film density between 1 and 2.5 in the area of interest of the device image. Radiographs shall be made for each view required (see 4).

3.5 Processing. The radiographic film manufacturer's recommended procedure shall be used to develop the exposed film, and film shall be processed so that it is free of processing defects such as fingerprints, scratches, fogging, chemical spots, blemishes, etc.

3.6 Operating personnel. Personnel who will perform radiographic inspection shall have training in radiographic procedures and techniques so that defects revealed by this method can be validly interpreted and compared with applicable standards. The following minimum vision requirements shall apply for personnel inspecting film:

a. Distant vision shall equal at least 20/30 in both eyes, corrected or uncorrected.

b. Near vision shall be such that the operator can read Jaeger type No. 2 at a distance of 16 inches, corrected or uncorrected.

c. Vision tests shall be performed by an oculist, optometrist, or other professionally recognized personnel at least once a year. Personnel authorized to conduct radiographic tests shall be required to pass the vision test specified in 3.6 a and b.

3.7 Personnel safety precautions. The safety precautions described in National Institute of Standards and Technology (NIST) Handbook 76 - X-ray Protection; NIST Handbook 73 - Protection Against Radiations From Sealed Gamma Sources; Nuclear Regulatory Commission Book Title 10, Part 20 - Standard for Protection Against Radiation, Part 30 - Licensing of By-Product Material, Part 31 - Radiation Safety Requirements for Radiographic Operations, shall be complied with when applicable.

3.8 Interpretation of radiographs. Utilizing the equipment specified herein, radiographs shall be inspected to determine that each device conforms to this standard and defective devices shall be rejected. Interpretation of the radiograph shall be made under low light level conditions without glare on the radiographic viewing surface. The radiographs shall be examined on a suitable illuminator with variable intensity or on a viewer suitable for radiographic inspection on projection type viewing equipment. The radiograph shall be viewed at a magnification between 6X and 25X. Viewing masks may be used when necessary. Any radiograph not clearly illustrating the features in the radiographic quality standards is not acceptable and another radiograph of the devices shall be taken.

3.9 Reports of records.

3.9.1 Reports of inspection. For class S devices, or when specified for other device classes, the manufacturer shall furnish inspection reports with each shipment of devices. The report shall describe the results of the radiographic inspection, and list the purchase order number or equivalent identification, the PIN, the date code, the quantity inspected, the quantity rejected, and the date of test and which devices utilize the note in 3.10.2.1. For each rejected device, the PIN, the serial number, when applicable, and the cause for rejection shall be listed.

3.9.2 Radiograph submission. Photographic reproduction of complete radiographs may be submitted, but artistic renditions are not acceptable.

3.9.3 Radiograph and report retention. When specified, the manufacturer shall retain a set of the radiographs and a copy of the inspection report. These shall be retained for the period specified.

3.10 Examination and acceptance criteria for monolithic devices.

3.10.1 Device construction. Acceptable devices shall be of the specified design and construction with regard to the characteristics discernible through radiographic examination. Devices that deviate significantly from the specified construction shall be rejected.

3.10.2 Individual device defects. The individual device examination shall include, but not be limited to, inspection for foreign particles, solder or weld "splash", build-up of bonding material, proper shape and placement of lead wires or whiskers, bond of lead or whisker to semiconductor element and lead or whisker to terminal post, semiconductor metallization pattern, and mounting of semiconductor element. Any device for which the radiograph reveals any of the following defects shall be rejected:

3.10.2.1 Presence of extraneous matter. Extraneous matter (foreign particles) shall include, but not be limited to:

a. Any foreign particle, loose or attached, greater than 0.025 mm (0.001 inch) (see figure 2012-1), or of any lesser size which is sufficient to bridge nonconnected conducting elements of the semiconductor device.

b. Any wire tail extending beyond its normal end by more than two wire diameters at the semiconductor die pad or by more than four wire diameters at the semiconductor package post (see figure 2012-1).

c. Any burr on a post (header lead) greater than 0.08 mm (0.003 inch) in its major dimension or of such configuration that it may break away.

d. Excessive semiconductor element bonding material build-up.

(1) A semiconductor element shall be mounted and bonded so that it is not tilted more than 10° from the normal mounting surface. The bonding agent that accumulates around the perimeter of the semiconductor element whether or not it touches the side of the semiconductor element shall not accumulate to a thickness greater than the height of the semiconductor element (see figures 2012-2 and 2012-3), or any lead or post, or be separated from the main bonding material area (see 2012-7).

(2) There shall be no visible extraneous material 0.025 mm (0.001 inch) or larger in the major dimension inside the semiconductor device. Loose bonding material will be considered extraneous material. Excessive (but not loose) bonding material will not be considered extraneous unless it fails to meet the requirements of 3.10.2.1.d.(1) or unless the accumulation of bonding material is such that the height of the accumulation is greater than the width of its base or that the accumulation necks down at any point (see figures 2012-2 and 2012-3).

NOTE: Devices with suspect foreign particles or extraneous material (in accordance with 3.10.2.1a and 3.10.2.1.d(2) may be verified as acceptable provided the following conditions are met:

(a) A visual inspection of the die attach area at 30X to 60X shall have been conducted prior to die attach sufficient to assure there are no anomalies in the die attach area which could interfere with effective die attach.

(b) The precap inspection shall have been conducted 100 percent to condition A of method 2010 of MIL-STD-883 and the devices shall have been inspected and prepared for sealing in a class 100 environment.

(c) All devices with X-ray defects to other criteria of 3.10 shall have been removed from the lot.

(d) Serialized devices with less than 5 suspect foreign particles and extraneous material shall be vibrated and shocked in accordance with PIND method 2020, condition A with the detector off.

(e) A second X-ray examination of the failed view of the serialized devices after the PIND vibration/shock shall be conducted and each individual device shall be compared to its previous X-ray record.

(f) Any evidence of the suspect particle(s) having moved or having disappeared from their original location shall cause the device to be rejected. If the particle(s) exhibit no evidence of movement, the device may be accepted.

(g) The manufacturer doing the reinspection for suspect foreign particles or extraneous material shall implement a process monitor visual inspection of the cavity of the reinspected devices to assure that accepted devices do not have actual rejectable foreign particles or extraneous material (see 3.2.3.1a, 3.2.3.1d, and 3.2.3.1e, 3.2.3.2a, 3.2.3.2c, 3.2.3.2f, 3.2.3.2g, 3.2.3.2h, and 3.2.5 of method 2010). If any reinspected device fails the process monitor visual inspection, then all reinspected devices in the lot that have been inspected are subject to disposition. Corrective action, when appropriate, must be instituted. A procedure is required for the traceability, recovery, and disposition of all reinspected units accepted since the last successful monitor. The records for this monitor shall include identification of all lots which are reinspected to this note, identification of those lots which are monitored by this visual inspection, sample size, frequency of sampling, results of the visual inspections, and the package types reinspected.

In the case of a failed monitor, the records must identify all lots affected, their final disposition and a rationale for their disposition. Additionally, for a failed monitor, the records must also contain a description of any instituted corrective action together with its rationale. Records of this type shall be made available to the qualifying activity upon request.

e. Gold flaking on the header or posts or anywhere inside the case.

f. Extraneous ball bonds anywhere inside case, except for attached bond residue when rebonding is allowed.

3.10.2.2 Unacceptable construction. In the examination of devices, the following aspects shall be considered unacceptable construction and devices that exhibit any of the following defects shall be rejected.

a. Voids: When radiographing devices, certain types of mounting do not give true representations of voids. When such devices are inspected, the mounting shall be noted on the inspection report (see figure 2012-1).

(1) Contact area voids in excess of one-half of the total contact area.

(2) A single void which traverses either the length or width of the semiconductor element and exceeds 10 percent of the total intended contact area.

b. Wires present, other than those connecting specific areas of the semiconductor element to the external leads. Device designs calling for the use of such wires including jumper wires necessary to trim load resistors are acceptable (see figure 2012-1).

c. Cracks, splits, or chips of the electrical elements.

d. Excessive undercutting of the electrical elements (X and Z plane only, see figure 2012-4).

e. Defective seal: Any device wherein the integral lid seal is not continuous or is reduced from its designed sealing width by more than 75 percent. Expulsion resulting from the final sealing operation is not considered extraneous material as long as it can be established that it is continuous, uniform and attached to the parent material and does not exhibit a ball, splash or tear-drop configuration (i.e., where the base support least dimension is smaller than the dimension it is supposed to support).

f. Inadequate clearance: Acceptable devices shall have adequate internal clearance to assure that the elements cannot contact one another or the case. No crossover shall be allowed except as permitted by 3.2.2e of method 2010 (condition A). Depending upon the case type, devices shall be rejected for the following conditions:

NOTE: Any of the following criteria for bond wires shall not apply, if the wires are not visible In the X-ray.

(1) Flat pack and dual-in-line (see figure 2012-5).

(a) Any lead wire that appears to touch or cross another lead wire or bond, (Y plane only).

(b) Any lead wire that deviates from a straight line from bond to external lead and appears to be within 0.05 mm (.002 inch) of another bond or lead wire (Y plane only).

(c) Lead wires that do not deviate from a straight line from bond to external lead and appear to touch another wire or bond, excluding common wires, (Y plane only).

(d) Any lead wire that touches or comes within 0.05 mm (0.002 inch) of the case or external lead to which it is not attached (X and Y plane).

(e) Any bond that is less than 0.025 mm (0.001 inch) (excluding bonds connected by a common conductor) from another bond (Y plane only).

(f) Any wire making a straight line run from die bonding pad to package post that has no arc.

(g) Lead wires that sag below an imaginary plane across the top of the die bond (X plane only) except by design.

(2) Round or "box" transistor type (see figure 2012-6).

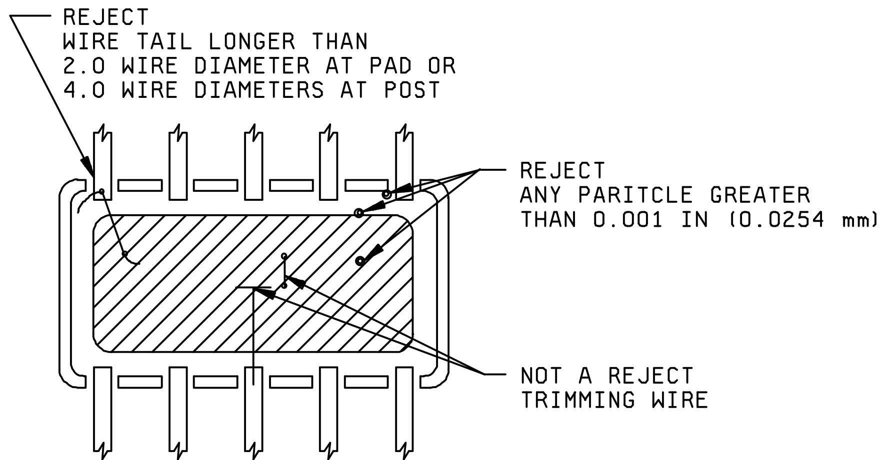
(a) Any lead wire that touches or comes within 0.05 mm (0.002 inch) of the case or external lead to which it is not attached (X and Y plane).

(b) Lead wires that sag below an imaginary plane across the top of the die bond (X plane only) except by design.

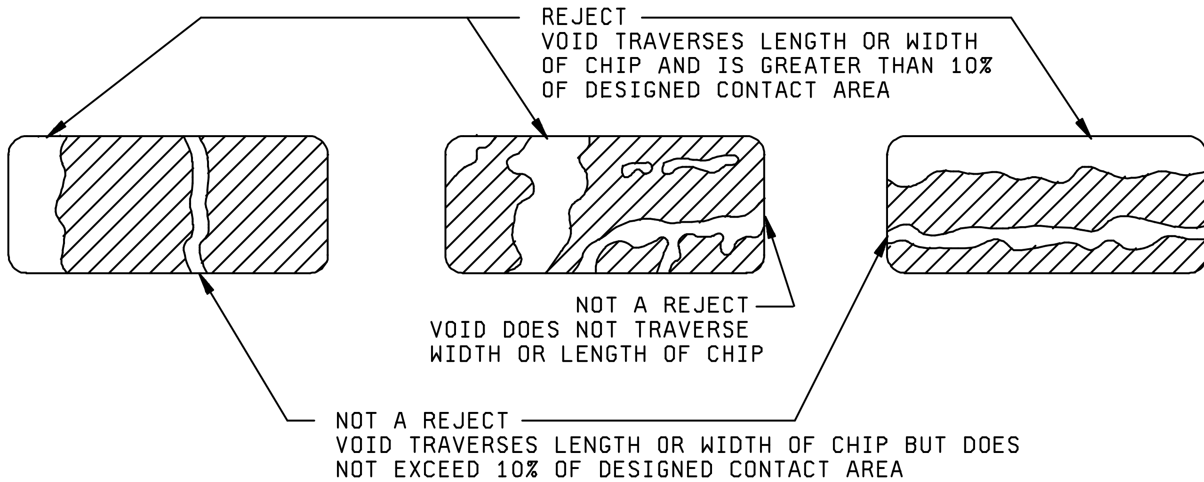
(c) Any lead wire that appears to touch or cross another lead wire or bond (Y plane only).

(d) Any lead wire that deviates from a straight line from bond to external lead and appears to touch or to be within 0.05 mm (0.002 inch) of another wire or bond (Y plane only).

(e) Any bond that is less than 0.025 mm (0.001 inch) (excluding bonds connected by a common conductor) from another bond (Y plane only).



(a) PARTICLE LOCATIONS, PIGTAILS, AND TRIMMING WIRES



(b) VOIDS

FIGURE 2012-1. Particle locations, pigtails, trimming wires, and voids.

(f) Any wire making a straight line run from die bonding pad to package post that has no arc, unless specifically designed in this manner (e.g., clips or rigid connecting leads).

(g) Any internal post that is bent more than 10° from the vertical (or intended design position) or is not uniform in length and construction or comes closer than one post diameter to another post.

(h) Where a low profile case (such as TO-46) is used, any post which comes closer to the top of the case than 20 percent of the total inside dimension between the header and the top of the case. In devices which have the semiconductor element vertical to the header, any device where the semiconductor element comes closer than 0.05 mm (0.002 inch) to the header or to any part of the case.

(i) Any case which does not have a header design incorporating a header edge or other feature (e.g., a "splash ring") to prevent solder or weld splash from entering the interior of the case.

(3) Cylindrical axial lead type (see figure 2012-8).

(a) Whisker to case distance less than one-half of the diameter of the external lead wire.

(b) Distance from case to semiconductor die or to any eutectic bonding material less than 0.05 mm (0.002 inch).

(c) Whisker tilted more than 5° in any direction from the device lead axis or deformed to the extent that it touches itself.

(d) C and S shaped whisker with air gap between any two points on it less than twice the diameter or thickness of the whisker wire. On diodes with whiskers metallurgically bonded to the post and to the die, the whisker may be deformed to the extent that it touches itself if the minimum whisker clearance zone specified in figure 2012-8 (a) is maintained.

(e) Whiskerless construction device with anode and cathode lead connections displaced more than 0.25 mm (0.01 inch) with respect to the central axis of the device.

(f) Semiconductor element mounting tilted more than 15° from normal to the main axis of the device.

(g) Die hanging over edge of header or pedestal more than 10 percent of the die area.

(h) Less than 75 percent of the semiconductor element base area is bonded to the mounting surface.

(i) Voids in the welds, from any edge, between the leads and the heat sink slugs greater than 15 percent of the lead wire diameter. Any voids whatever in the central part of the area that should be welded.

(j) Devices with package deformities such as, body glass cracks, incomplete seals (voids, position glass, etc), die chip outs and severe misalignment of S and C shaped whisker connections to die or post.

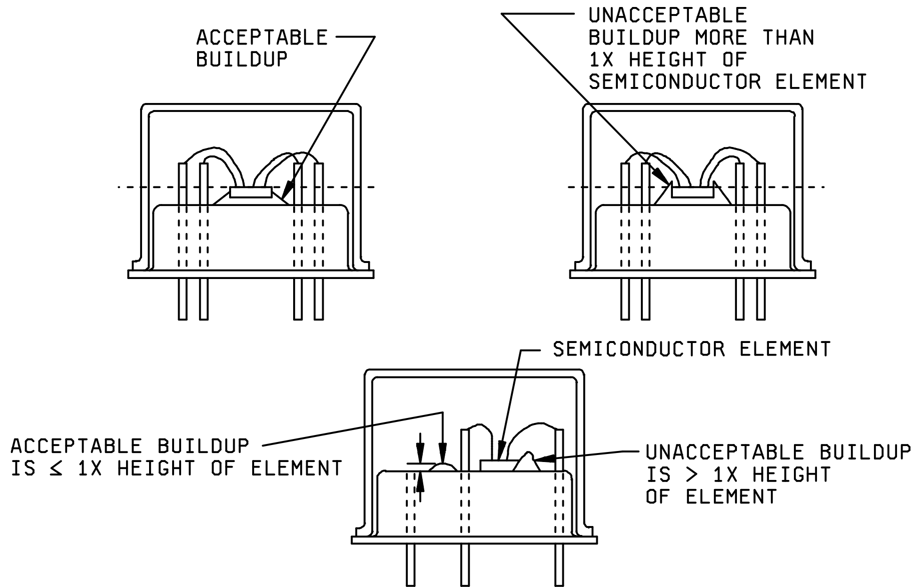


FIGURE 2012-2. Acceptable and unacceptable bonding material build-up.

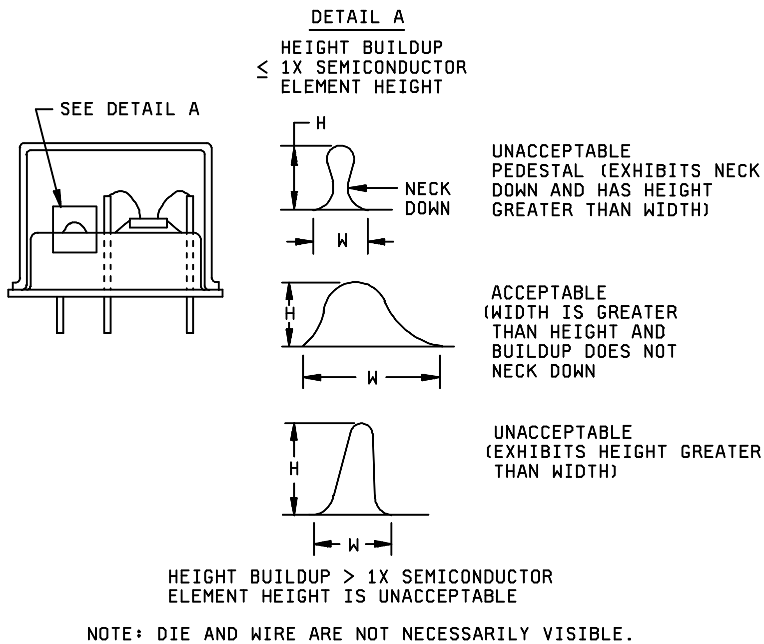


FIGURE 2012-3. Extraneous bonding material build-up.

3.11 Examination and acceptance criteria for hybrid devices.

3.11.1 Device construction. Acceptable devices shall be of the specified design and construction with regard to the characteristics discernible through radiographic examination. Devices that deviate significantly from the specified construction shall be rejected.

3.11.2 Individual device defects. The individual device examination shall include, but not be limited to, extraneous matter, location and orientation of elements, cracks in the substrate that exceed 0.127 mm (0.005 inch) in length or point toward active metallization, adhesive build-up, solder splashes, placement of wires, voids in the lid seal (this may not apply to power hybrid devices), and improper wetting between the substrate(s) and the package. Any device for which the radiograph reveals any of the following defects shall be rejected:

3.11.2.1 Presence of extraneous matter (foreign particles).

a. Unattached foreign material greater than 0.025 mm (0.001 inch), or of any lesser size which is sufficient to bridge metallization or nonconnected conducting elements, that appears to be on the surface of the die, component, substrate, or within the package.

b. Attached foreign material that bridges metallization paths, package leads, lead to package metallization, functional circuit elements, junctions, or any combination thereof.

NOTE: Attached or unattached material may be verified by comparing two identical views with a mild mechanical shock, such as PIND test, between the two views.

c. Wire tails or extra wires which make contact with any metallization not connected to the wire, or which exceed four wire diameters in length at the substrate pad or package post, or two wire diameters at the top of a die or component.

d. Any evidence of solder, alloy, or conductive adhesive that appears to bridge noncommon metallization (i.e., wire(s), bonding post, active metallization or any combination thereof) not intended by design.

e. Gold flaking on the bonding post or anywhere inside the case.

3.11.2.2 Unacceptable construction.

a. voids in substrate or component attachment medium.

(1) Contact area voids in excess of one-half of the total contact area.

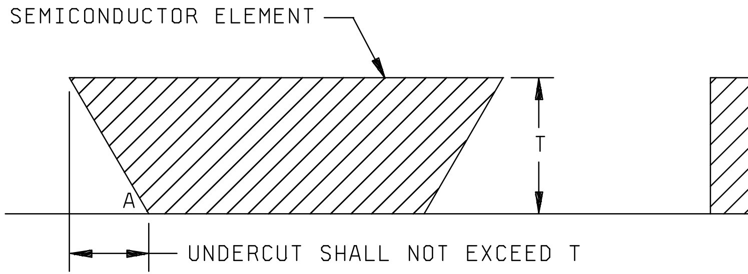
(2) A single void which traverses either the length or width of the substrate or semiconductor element and whose area exceeds 10 percent of the total intended contact area.

NOTE: To obtain, and/or verify substrate attachment the use of a thermal resistance analyzer, which measures the thermal characteristics (heat dissipation), is strongly recommended.

b. Wires present, other than those connecting specific areas as per the drawing, except wires designated as tuning devices on the bonding diagram, and except where bond-offs are allowed.

c. Improper component placement.

d. Cracks, splits, or chips in the component or substrate which enter the active circuit area.



NOTE: Angle A shall be greater than 45°.

FIGURE 2012-4 Undercutting.

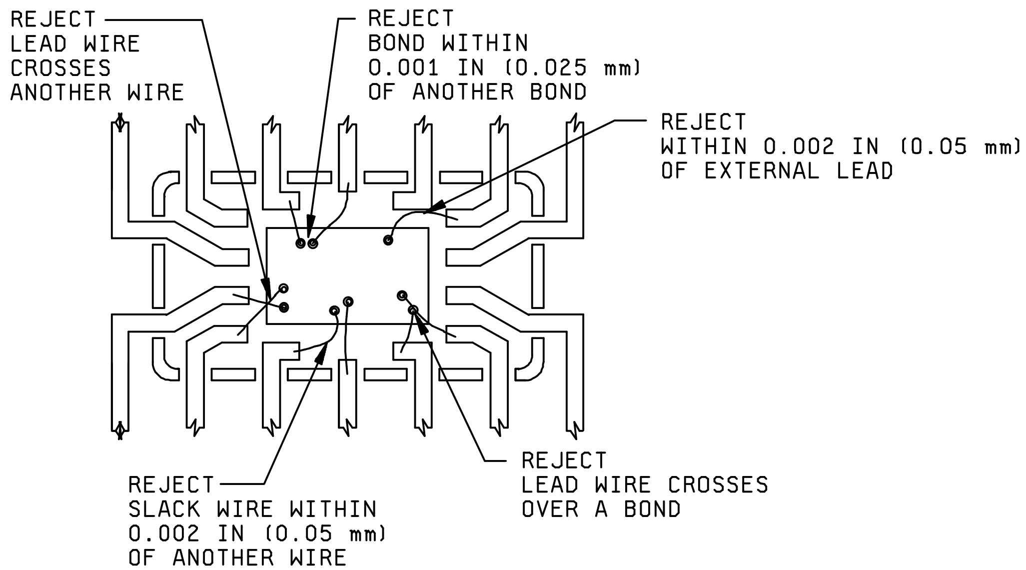


FIGURE 2012-5. Clearance in dual-in-line or flat pack type device.

e. Voids in the lid seal in which the seal is not continuous or is reduced from its design sealing width by more than 75 percent.
NOTE: Sealing voids may not be detectable within power hybrid packages.

f. Inadequate clearance.

* (1) Any wire that comes closer than 0.025 mm (0.001 inch) to another wire (excluding common wires) within a spherical radial distance from the bond perimeter of 0.127 mm (0.005 inch) for ball bonds, or 0.254 mm (0.010 inch) for ultrasonic and thermocompression wedge bonds.
NOTE: Insulated wires defined in the device specification/drawing are excluded from this criteria.

* (2) Excessive loop or sag in any wire so that it comes closer than two wire diameters to another wire, package post, unglassivated operating metallization, die, or portion of a package after a spherical radial distance from the bond perimeter of 0.127 mm (0.005 inch) for ball bonds or 0.254 mm (0.010 inch) for ultrasonic and thermocompression wedge bonds.
NOTE: Insulated wires defined in the device specification/drawing are excluded from this criteria.

* (3) Missing or extra wire(s) or ribbon(s) not in conformance with the bonding diagram except those wire(s) or ribbon(s) designated as microwave tuning devices on the bonding diagram.
NOTE: Extra wires added for statistical process control lot or lot sample bond strength/process machine/operator evaluation in accordance with MIL-PRF-38534 are excluded from this criteria.

(4) Any wire that has no arc and makes a straight line run from die bonding pad to package post.

(5) Wires crossing wires except common conductors or as allowed in 3.2.2e of method 2010 (condition A).

(6) Excessive height in any component or wire loop such that it is closer than 0.127 mm (0.005 inch) to the lid when installed.

(7) Any wires which are broken.
NOTE: Wire bond tails, as defined by method 2017, are excluded from this criteria.

(8) Excessive sag where the wire lies on the substrate for a distance greater than 1/2 the distance between the edge of the substrate bonding pad and the chip to which the wire is bonded, or comes closer than 0.025 mm (0.001 inch) to runout of any conductive epoxy which mounts the chip.

(9) Bonds placed so that the wire exiting from the bond crosses over another bond, except for common bonds.
NOTE: For RF/microwave devices, bonds placed so that the wire exiting from a bond crosses over another bond, except by design, in which case the clearance shall be two wire diameters minimum (common bonds are excluded from this criteria).

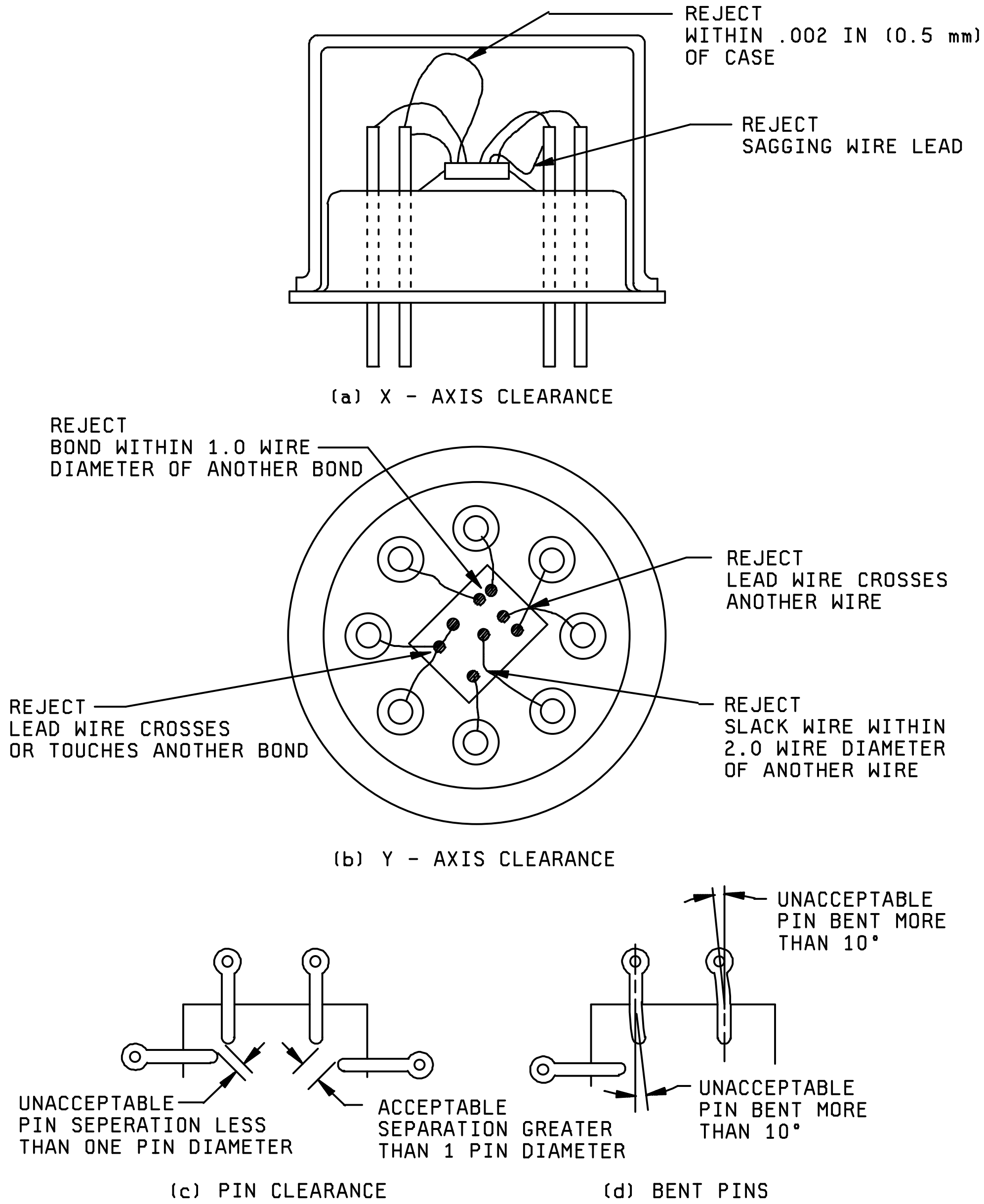
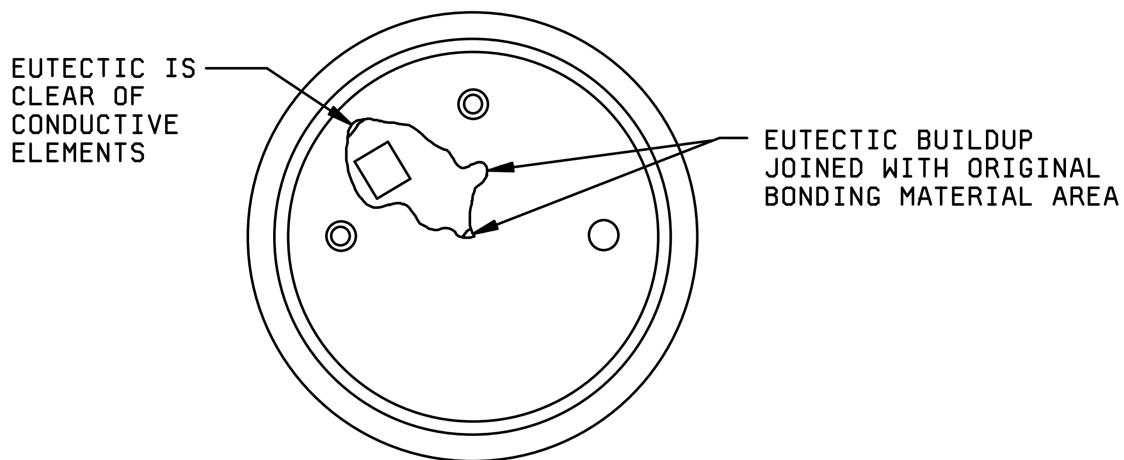


FIGURE 2012-6. Clearance in round or box transistor type device.



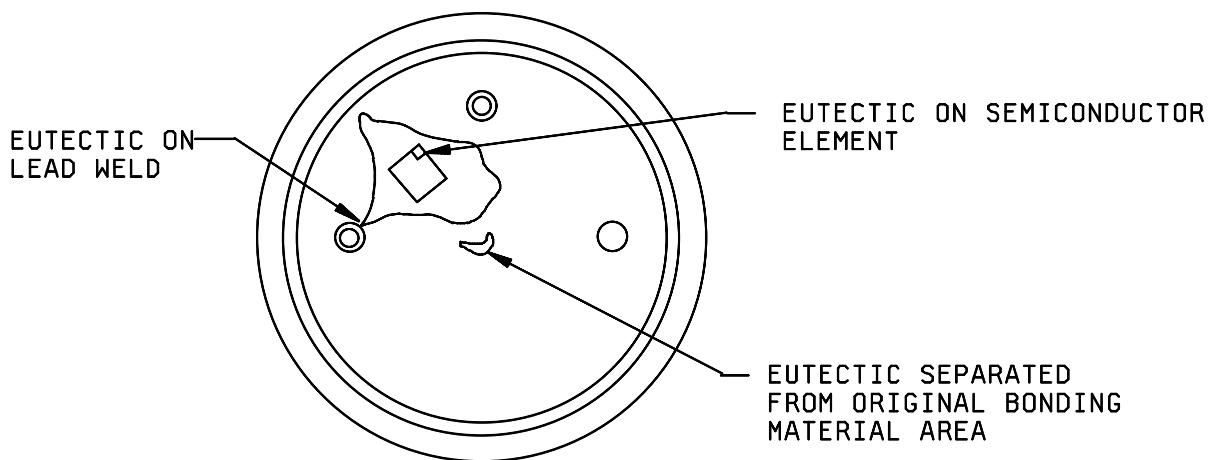
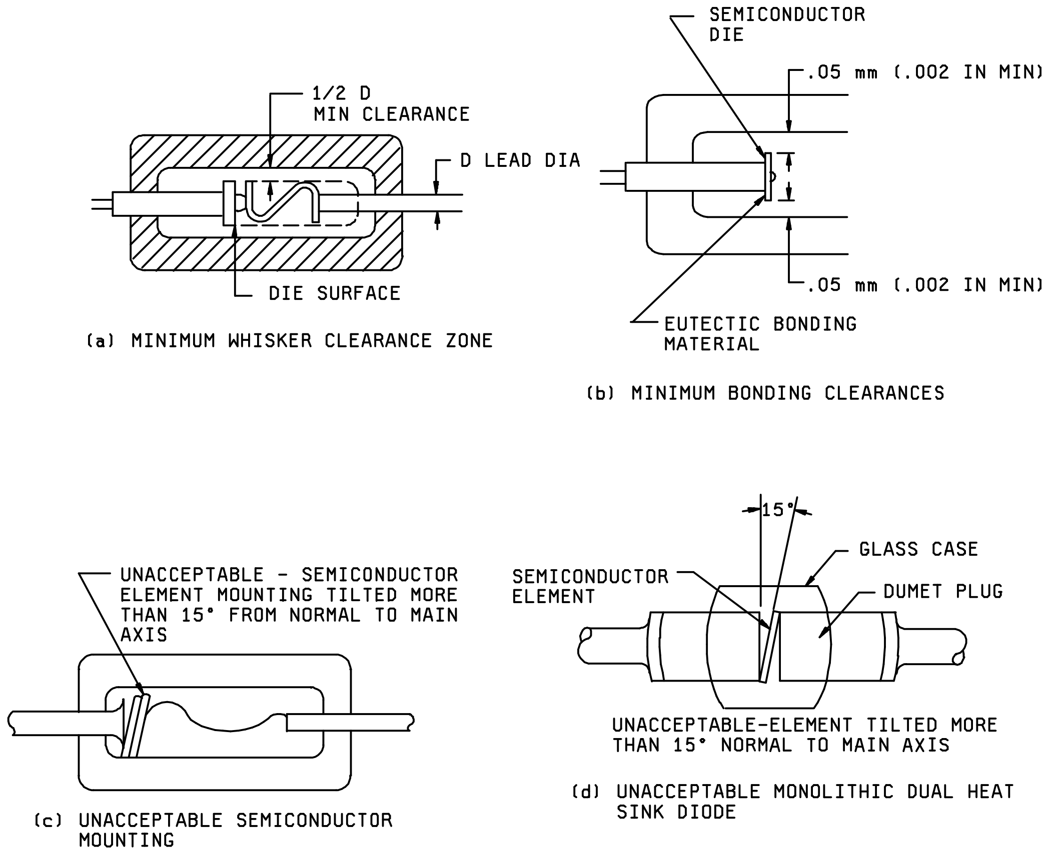


FIGURE 2012-7. Acceptable and unacceptable excess material.



* FIGURE 2012-8. Clearance in cylindrical axail lead type device.

4. Summary. The following details shall be specified in the applicable acquisition document:

a. Number of views, if other than indicated in 3.1.1.

b. Radiograph submission, if applicable (see 3.9.2).

c. Marking, if other than indicated in 3.3 and marking of samples to indicate they have been radiographed, if required (see 3.3.3).

d. Defects to be sought in the samples and criteria for acceptance or rejection, if other than indicated in 3.10.

e. Radiograph and report retention, if applicable (see 3.9.3).

* f. Test reports when required for class level B.