IPC-A-610

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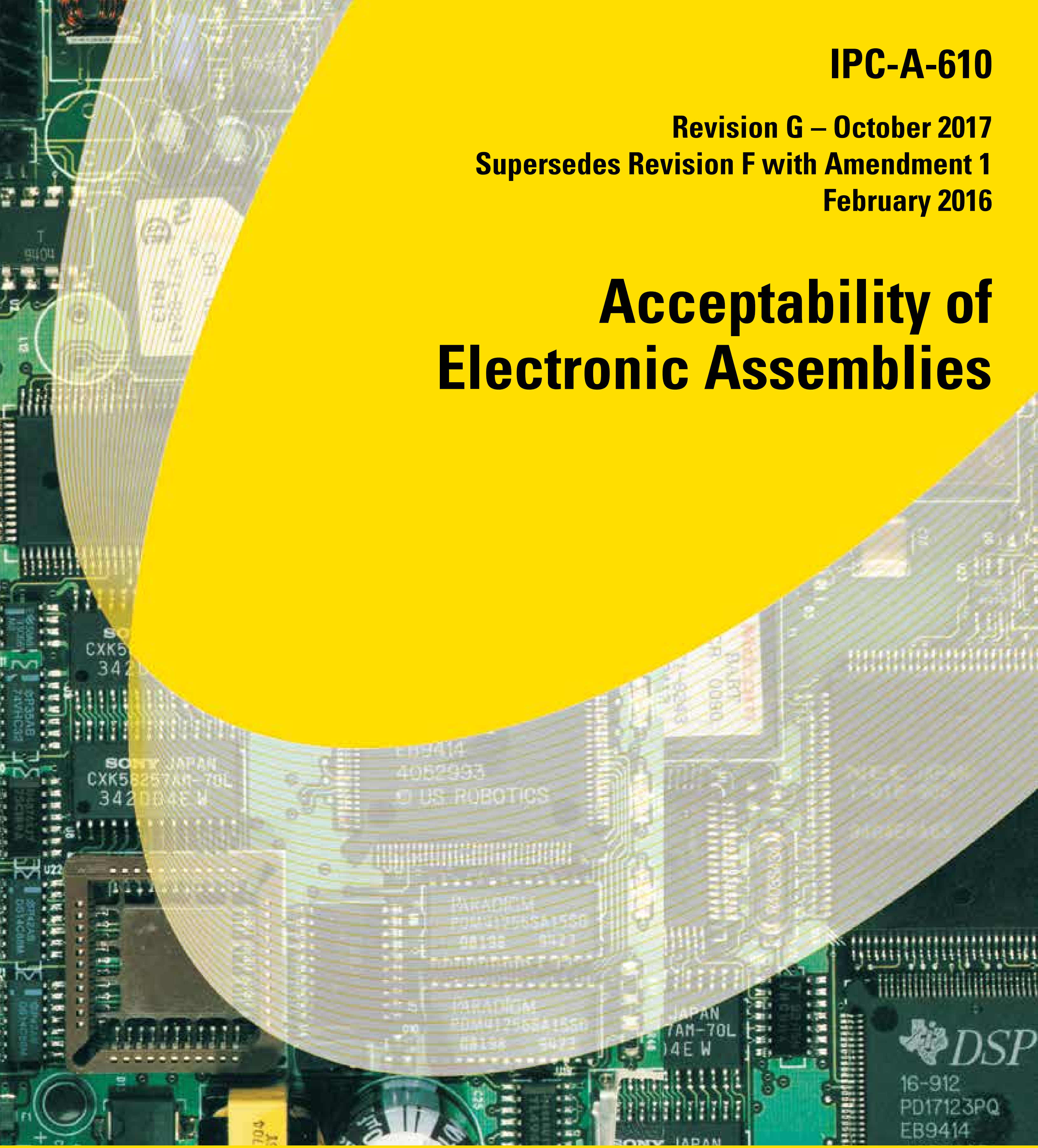
Acceptability of Electronic Assemblies



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- Contain simple (simplified) language
- Just include spec information
- Focus on end product performance
- Include a feedback system on use and problems for future improvement

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IPC-A-610G

Acceptability of Electronic Assemblies

If a conflict occurs between the English language and translated versions of this document, the English version will take precedence.

Developed by the IPC-A-610 Task Group (7-31b) of the Acceptability Subcommittee (7-31) of the Product Assurance Committee (7-30) of IPC

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Users of this publication are encouraged to participate in the development of future revisions.

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General

The following topics are addressed in this section:

General (cont.)

1.1 Scope This Standard is a collection of visual quality acceptability requirements for electronic assemblies. This Standard does not provide criteria for cross-section evaluation.

This document presents acceptance requirements for the manufacture of electrical and electronic assemblies. Historically, electronic assembly standards contained a more comprehensive tutorial addressing principles and techniques. For a more complete understanding of this document's recommendations and requirements, one may use this document in conjunction with IPC-HDBK-001, IPC-AJ-820 and IPC J-STD-001.

The criteria in this Standard are not intended to define processes to accomplish assembly operations nor is it intended to authorize repair/modification or change of the customer's product. For instance, the presence of criteria for adhesive bonding of components does not imply/authorize/require the use of adhesive bonding and the depiction of a lead wrapped clockwise around a terminal does not imply/authorize/require that all leads/wires be wrapped in the clockwise direction.

Users of this Standard should be knowledgeable of the applicable requirements of the document and how to apply them, see 1.3.

IPC-A-610 has criteria outside the scope of IPC J-STD-001 defining handling, mechanical and other workmanship requirements. Table 1-1 is a summary of related documents.

IPC-AJ-820 is a supporting document that provides information regarding the intent of this specification content and explains or amplifies the technical rationale for transition of limits through Target to Defect condition criteria. In addition, supporting information is provided to give a broader understanding of the process considerations that are related to performance but not commonly distinguishable through visual assessment methods.

Table 1-1 Summary of Related Documents

Document Purpose	Spec.#	Definition
Design Standard	IPC-2220-FAM IPC-7351 IPC-CM-C770	Design requirements reflecting three levels of complexity (Levels A, B, and C) indicating finer geometries, greater densities, more process steps to produce the product. Component and Assembly Process Guidelines to assist in the design of the bare board and the assembly where the bare board processes concentrate on land patterns for surface mount and the assembly concentrates on surface mount and through-hole principles which are usually incorporated into the design process and the documentation.
PCB – Printed Circuit Board – Requirements	IPC-6010-FAM IPC-A-600	Requirements and acceptance documentation for rigid, rigid flex, flex and other types of substrates.
End Item Documentation	IPC-D-325	Documentation depicting bare board specific end product requirements designed by the customer or end item assembly requirements. Details may or may not reference industry specifications or workmanship standards as well as customer's own preferences or internal standard requirements.
Process Requirement Standard	J-STD-001	Requirements for soldered electrical and electronic assemblies depicting minimum end product acceptable characteristics as well as methods for evaluation (test methods), frequency of testing and applicable ability of process control requirements.
Acceptability Standard	IPC-A-610	Pictorial interpretive document indicating various characteristics of the board and/or assembly as appropriate relating to desirable conditions that exceed the minimum acceptable characteristics indicated by the end item performance standard and reflect various out-of-control (process indicator or defect) conditions to assist the shop process evaluators in judging need for corrective action.
Training Programs (Optional)		Documented training requirements for teaching and learning process procedures and techniques for implementing acceptance requirements of either end item standards, acceptability standards, or requirements detailed on the customer documentation.
Rework and Repair	IPC-7711/7721	Documentation providing the procedures to accomplish conformal coating and component removal and replacement, solder resist repair, and modification/repair of laminate material, conductors, and plated through-holes.

General (cont.)

The explanations provided in IPC-AJ-820 should be useful in determining disposition of conditions identified as Defect, processes associated with Process Indicators, as well as answering questions regarding clarification in use and application for defined content of this specification. Contractual reference to IPC-A-610 does not additionally impose the content of IPC-AJ-820 unless specifically referenced in contractual documentation.

1.2 Purpose The visual standards in this document reflect the requirements of existing IPC and other applicable specifications. In order for the user to apply and use the content of this document, the assembly/product should comply with other existing IPC requirements, such as IPC-7351, IPC-2220-FAM, IPC-6010-FAM and IPC-A-600. If the assembly does not comply with these or with equivalent requirements, the acceptance criteria **shall** be defined between the customer (User) and Supplier.

The illustrations in this document portray specific points noted in the title of each page. A brief description follows each illustration. It is not the intent of this document to exclude any acceptable procedure for component placement or for applying flux and solder used to make the electrical connection, however, the methods used **shall** produce completed solder connections conforming to the acceptability requirements described in this document.

In the case of a discrepancy, the description or written criteria always takes precedence over the illustrations.

Standards may be updated at any time, including with the use of amendments. The use of an amendment or newer revision is not automatically required.

1.3 Classification The customer (User) has the ultimate responsibility for identifying the class to which the assembly is evaluated. If the User does not establish and document the acceptance class, the Manufacturer may do so.

Accept and/or reject decisions **shall** be based on applicable documentation such as contracts, drawings, specifications, standards and reference documents. Criteria defined in this document reflect three classes, which are as follows:

Class 1 – General Electronic Products
Includes products suitable for applications where the major requirement is function of the completed assembly.

Class 2 – Dedicated Service Electronic Products
Includes products where continued performance and extended life is required, and for which uninterrupted service is desired but not critical. Typically the end-use environment would not cause failures.

Class 3 – High Performance Electronic Products
Includes products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems.

1.4 Measurement Units and Applications This Standard uses International System of Units (SI) units per ASTM SI10-10, IEEE/ASTM SI 10, Section 3 [Imperial English equivalent units are in brackets for convenience]. The SI units used in this Standard are millimeters (mm) [in] for dimensions and dimensional tolerances, Celsius (°C) [°F] for temperature and temperature tolerances, grams (g) [oz] for weight, and lux (lx) [footcandles] for illuminance.

Note: This Standard uses other SI prefixes (ASTM SI10-10, Section 3.2) to eliminate leading zeroes (for example, 0.0012 mm becomes 1.2 µm) or as alternative to powers-of-ten (3.6×10^3 mm becomes 3.6 m).

1.4.1 Verification of Dimensions Actual measurement of specific part mounting and solder fillet dimensions and determination of percentages are not required except for referee purposes. For determining conformance to the specifications in this Standard, round all observed or calculated values ''to the nearest unit'' in the last right-hand digit used in expressing the specification limit, in accordance with the rounding method of ASTM Practice E29. For example, specifications of 2.5 mm max, 2.50 mm max, or 2.500 mm max, round the measured value to the nearest 0.1 mm, 0.01 mm, or 0.001 mm, respectively, and then compare to the specification number cited.

1.5 Definition of Requirements This document provides acceptance criteria for completed electronic assemblies. Where a requirement is presented that cannot be defined by the acceptable, process indicator, and defect conditions, the word ''**shall**'' is

General (cont.)

used to identify the requirement. Unless otherwise specified herein, the word ‘‘**shall**’’ in this document invokes a requirement for manufacturers of all classes of product, and failure to comply with the requirement is a noncompliance to this Standard.

Many of the examples (illustrations) shown are grossly exaggerated in order to depict the reasons for this rating.

It is necessary that users of this Standard pay particular attention to the subject of each section to avoid misinterpretation.

1.5.1 Acceptance Criteria Criteria are given for each class in four conditions: Target, Acceptable, Defect or Process Indicator. ‘‘Not Established’’ means that there are no specified criteria for that class and may need to be established between Manufacturer and User.

1.5.1.1 Target Condition A condition that is close to perfect/preferred, however, it is a desirable condition and not always achievable and may not be necessary to ensure reliability of the assembly in its service environment.

1.5.1.2 Acceptable Condition This characteristic indicates a condition that, while not necessarily perfect, will maintain the integrity and reliability of the assembly in its service environment.

1.5.1.3 Defect Condition A defect is a condition that may be insufficient to ensure the form, fit or function of the assembly in its end use environment. Defect conditions **shall** be dispositioned by the manufacturer based on design, service, and customer requirements.

It is the responsibility of the User to define unique defect categories applicable to the product.

A defect for Class 1 automatically implies a defect for Class 2 and 3. A defect for Class 2 implies a defect for Class 3. (Note this would not be the case where criteria for a particular class have not been established).

1.5.1.3.1 Disposition The determination of how defects should be treated. Dispositions include, but are not limited to, rework, use as is, scrap or repair. Repair or ‘‘use as is’’ may require customer concurrence.

1.5.1.4 Process Indicator Condition A process indicator is a condition (not a defect) that identifies a characteristic that does not affect the form, fit or function of a product:

- Such condition is a result of material, design and/or operator/machine related causes that create a condition that neither fully meets the acceptance criteria nor is a defect.
- Process indicators should be monitored as part of the process control system. When the number of process indicators indicate abnormal variation in the process or identify an undesirable trend, then the process should be analyzed. This may result in action to reduce the variation and improve yields.
- Disposition of individual process indicators is not required.

1.5.1.5 Combined Conditions Cumulative conditions **shall** be considered in addition to the individual characteristics for product acceptability even though they are not individually considered defective. The significant number of combinations that could occur does not allow full definition in the content and scope of this specification but manufacturers should be vigilant for the possibility of combined and cumulative conditions and their impact upon product performance.

Conditions of acceptability provided in this specification are individually defined and created with separate consideration for their impact upon reliable operation for the defined production classification. Where related conditions can be combined, the cumulative performance impact for the product may be significant, e.g., minimum solder fillet quantity when combined with maximum side overhang and minimum end overlap may cause a significant degradation of the mechanical attachment integrity. The Manufacturer is responsible for identification of such conditions.

The User is responsible to identify combined conditions where there is significant concern based upon end use environment and product performance requirements.

1.5.1.6 Conditions Not Specified Conditions that are not specified as defective or as a process indicator may be considered acceptable unless it can be established that the condition affects user defined form, fit or function.

General (cont.)

1.5.1.7 Specialized Designs IPC-A-610, as an industry consensus document, cannot address all of the possible components and product design combinations. Where uncommon or specialized technologies are used, it may be necessary to develop unique acceptance criteria. However, where similar characteristics exist, this document may provide guidance for product acceptance criteria. Often, unique definition is necessary to consider the specialized characteristics while considering product performance criteria. The development should include customer involvement or consent. For Classes 2 and 3 the criteria **shall** include agreed definition of product acceptance.

Whenever possible these criteria should be submitted to the IPC Technical Committee to be considered for inclusion in upcoming revisions of this Standard.

1.6 Process Control Methodologies Process control methodologies should be used in the planning, implementation and evaluation of the manufacturing processes used to produce soldered electrical and electronic assemblies. The philosophy, implementation strategies, tools and techniques may be applied in different sequences depending on the specific company, operation, or variable under consideration to relate process control and capability to end product requirements. The manufacturer needs to maintain objective evidence of a current process control/continuous improvement plan that is available for review.

1.7 Order of Precedence When IPC-A-610 is cited or required by contract as a stand-alone document for inspection and/or acceptance, the requirements of IPC J-STD-001 ''Requirements for Soldered Electrical and Electronic Assemblies'' do not apply unless separately and specifically required.

In the event of conflict, the following order of precedence applies:

1. Procurement as agreed and documented between customer and supplier.
2. Master drawing or master assembly drawing reflecting the customer's detailed requirements.
3. When invoked by the customer or per contractual agreement, IPC-A-610.

When documents other than IPC-A-610 are cited, the order of precedence **shall** be defined in the procurement documents.

The User has the opportunity to specify alternate acceptance criteria.

1.7.1 Clause References When a clause in this document is referenced, its subordinate clauses also apply.

1.7.2 Appendices Appendices to this Standard are not binding requirements unless separately and specifically required by the applicable contracts, assembly drawing(s), documentation or purchase orders.

1.8 Terms & Definitions Items noted with an * are quoted from IPC-T-50.

1.8.1 Board Orientation The following terms are used throughout this document to determine the board side. The source/destination side **shall** be considered when applying some criteria, such as that in Tables 7-4, 7-5 and 7-7.

1.8.1.1 *Primary Side The side of a packaging and interconnecting structure that is so defined on the master drawing. (It is usually the side that contains the most complex or the most number of components.) (This side is sometimes referred to as the component side or solder destination side in through-hole mounting technology.)

1.8.1.2 *Secondary Side That side of a packaging and interconnecting structure that is opposite the primary side. (This side is sometimes referred to as the solder side or solder source side in through-hole mounting technology.)

1.8.1.3 Solder Source Side The solder source side is that side of the PCB to which solder is applied. The solder source side is normally the secondary side of the PCB when wave, dip, or drag soldering are used. The solder source side may be the primary side of the PCB when hand soldering operations are conducted.

1.8.1.4 Solder Destination Side The solder destination side is that side of the PCB that the solder flows toward in a through-hole application. The destination is normally the primary side of the PCB when wave, dip or drag soldering is used. The destination side may be the secondary side of the PCB when hand-soldering operations are conducted.

General (cont.)

1.8.2 *Cold Solder Connection A solder connection that exhibits poor wetting, and that is characterized by a grayish porous appearance. (This is due to excessive impurities in the solder, inadequate cleaning prior to soldering, and/or the insufficient application of heat during the soldering process.)

1.8.3 Diameter

- **Conductor Diameter** The conductor diameter is the outside diameter of wire, either stranded or solid, without the insulation.
- **Wire Diameter** Wire diameter is the outside diameter of wire, either stranded or solid, including insulation if present.

1.8.4 Electrical Clearance Throughout this document the minimum spacing between non-common uninsulated conductors, e.g., patterns, materials, hardware, or residue, is referred to as ''minimum electrical clearance.'' It is defined in the applicable design standard or on the approved or controlled documentation. Insulating material needs to provide sufficient electrical isolation. In the absence of a known design standard use Appendix A (derived from IPC-2221). Any violation of minimum electrical clearance is a defect condition for all classes.

1.8.5 FOD (Foreign Object Debris) A generic term for a substance, debris, particulate matter or article alien to the assembly or system.

1.8.6 High Voltage The term ''high voltage'' will vary by design and application. The high voltage criteria in this document are only applicable when specifically required in the drawings/procurement documentation.

1.8.7 Intrusive Solder A process in which the solder paste for the through-hole components is applied using a stencil or syringe to accommodate through-hole components that are inserted and reflow-soldered together with the surface-mount components.

1.8.8 Locking Mechanism A method of preventing loosening or disconnection of a mated part, e.g., a fastener or connector, either by use of a device integral to the part, e.g., a polymer insert, a design feature, e.g., a spring clip, latch, twist detent, or push-pull, or an additive material, e.g., threadlocking adhesive, safety wire.

1.8.9 Meniscus (Component) Sealant or encapsulant on a lead, protruding from the seating plane of the component. This includes materials such as ceramic, epoxy or other composites, and flash from molded components.

1.8.10 *Nonfunctional Land A land that is not connected electrically to the conductive pattern on its layer.

1.8.11 Pin-in-Paste See Intrusive Solder

1.8.12 Solder Balls Solder balls are spheres of solder that remain after the soldering process. This includes small balls of solder paste that have splattered around the connection during the reflow process.

1.8.13 *Stress Relief Slack in a component lead or wire that is formed in such a way as to minimize mechanical stresses.

1.8.14 Wire Overlap A wire/lead that is wrapped more than 360° and crosses over itself, i.e., does not remain in contact with the terminal post, Figure 6-67B.

1.8.15 Wire Overwrap A wire/lead that is wrapped more than 360° and remains in contact with the terminal post, Figure 6-67A.

1.9 Requirements Flowdown When this Standard is contractually required, the applicable requirements of this Standard (including product class, see 1.3) **shall** be imposed on all applicable subcontracts, assembly drawing(s), documentation and purchase orders. Unless otherwise specified the requirements of this Standard are not imposed on the procurement of commercial-off-the-shelf (COTS or catalog) assemblies or subassemblies.

General (cont.)

When a part is adequately defined by a specification, then the requirements of this Standard should be imposed on the Manufacturer of that part only when necessary to meet end-item requirements. When it is unclear where flowdown should stop, it is the responsibility of the Manufacturer to establish that determination with the User.

When an assembly, e.g., daughterboard, is procured, that assembly should meet the requirements of this Standard. The connections from the procured assembly to the manufactured assembly **shall** meet the requirements of this Standard. If the assembly is manufactured by the same manufacturer, the solder requirements are as stated in the contract for the entire assembly.

The design and workmanship of COTS items should be evaluated and modified as required to ensure the end-item meets contract performance requirements. Modifications **shall** meet the applicable requirements of this Standard.

1.10 Personnel Proficiency All instructors, operators, and inspection personnel **shall** be proficient in the tasks to be performed. Objective evidence of that proficiency **shall** be maintained and available for review. Objective evidence should include records of training to the applicable job functions being performed, work experience, testing to the requirements of this Standard, and/or results of periodic reviews of proficiency. Supervised on-the-job training is acceptable until proficiency is demonstrated.

1.11 Acceptance Requirements All products **shall** meet the requirements of the assembly drawing(s)/ documentation and the requirements for the applicable product class specified herein. Missing hardware or components are a Defect for all classes.

1.12 Inspection Methodology Accept and/or reject decisions **shall** be based on applicable documentation such as contract, drawings, specifications and referenced documents.

The use of any non-visual inspection methods, other than those already detailed in Sections 8.3.12 and 8.3.13 are not specifically covered by this Standard and **shall** be used as agreed between User and Manufacturer.

The inspector does not select the class for the assembly under inspection, see 1.3. Documentation that specifies the applicable class for the assembly under inspection **shall** be provided to the inspector.

Automated Inspection, e.g., AOI, AXI, is a viable support to visual inspection and complements automated test equipment. Many characteristics in this document can be inspected with an automated system.

If the customer desires the use of industry standard requirements for frequency of inspection and acceptance, J-STD-001 is recommended for further soldering requirement details.

1.12.1 Lighting Lighting **shall** be adequate for the feature being inspected.

Illumination at the surface of workstations should be at least 1000 lux [approximately 93 foot-candles]. Light sources should be selected to prevent shadows.

Note: In selecting a light source, the color temperature of the light is an important consideration. Light ranges from 3000-5000 K enable users to distinguish conditions and colors of various printed circuit assembly features and contaminates with increased clarity.

1.12.2 Magnification Aids For visual inspection, some individual specifications may call for magnification aids for examining printed board assemblies.

The tolerance for magnification aids is ± 15% of the selected magnification power. Magnification aids, if used for inspection, **shall** be appropriate with the item by the being inspected. Unless magnification requirements are otherwise specified by contractual documentation, the magnifications in Tables 1-2, 1-3, and 1-4 are determined by the feature being inspected.

If the presence of a defect cannot be determined at the appropriate magnification power defined in Tables 1-2, 1-3, or 1-4, the item is acceptable. The referee magnification power is intended for use only after a defect has been determined but is not completely identifiable at the inspection power.

For assemblies with mixed land sizes, the greater magnification power may be used for the entire assembly. For assemblies with mixed wire sizes, the greater magnification power may be used.

General (cont.)

Table 1-2 Inspection Magnification (Land Width)

Land Widths or Land Diameters[1]	Magnification Power	
	Inspection Range	Maximum Referee
> 1 mm [0.04 in]	1.5X to 3X	4X
> 0.5 to ≤ 1 mm [0.02 to 0.04 in]	3X to 7.5X	10X
≥ 0.25 to ≤ 0.5 mm [0.01 to 0.02 in]	7.5X to 10X	20X
< 0.25 mm [0.01 in]	20X	40X

Note 1: A portion of a conductive pattern used for the connection and/or attachment of components.

Table 1-3 Magnification Aid Applications For Wires And Wire Connections[1]

Wire Size AWG Diameter mm [inch]	Magnification Power	
	Inspection Range	Maximum Referee
larger than 14 AWG >1.63 mm [0.064 in]	N/A	1.75X
14 to 22 AWG 1.63 – 0.64 mm [0.064 to 0.025 in]	1.5X – 3X	4X
< 22 to 28 AWG < 0.64 mm – 0.32 mm [< 0.025 – 0.013 in]	3X – 7.5X	10X
Smaller than 28 AWG < 0.32 mm [< 0.013 in]	10X	20X

Note 1: Referee magnification power is to be used only to verify a product rejected at the inspection magnification. For assemblies with mixed wire size, the greater magnification may be (but is not required to be) used.

Table 1-4 Magnification Aid Applications – Other

Cleanliness (with or without cleaning processes)	Magnification not required, see Note 1
Cleanliness (no-clean processes)	Note 1
Conformal Coating/Encapsulation, Staking	Note 2
Marking	Note 2
Other (Component and wire damage, etc.)	Note 1

Note 1: Visual inspection may require the use of magnification, e.g. when fine pitch or high density assemblies are present, magnification may be needed to determine if contamination affects form, fit or function.

Note 2: If magnification is used it is limited to 4X maximum.

2 Applicable Documents

The following documents of the issue currently in effect form a part of this document to the extent specified herein.

2.1 IPC Documents[1]

IPC-HDBK-001 Handbook & Guide to Supplement J-STD-001

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-CH-65 Guidelines for Cleaning of Printed Boards and Assemblies

IPC-D-279 Design Guidelines for Reliable Surface Mount Technology Printed Board Assemblies

IPC-D-325 Documentation Requirements for Printed Boards

IPC-A-600 Acceptability of Printed Boards

IPC/WHMA-A-620 Requirements & Acceptance for Cable & Wire Harness Assemblies

IPC-TM-650 Test Methods Manual

IPC-CM-770 Component Mounting Guidelines for Printed Boards

IPC-SM-785 Guidelines for Accelerated Reliability Testing of Surface Mount Attachments

IPC-AJ-820 Assembly & Joining Handbook

IPC-CC-830 Qualification and Performance of Electrical Insulating Compound for Printed Board Assemblies

IPC-HDBK-830 Guidelines for Design, Selection and Application of Conformal Coatings

IPC-SM-840 Qualification and Performance of Permanent Solder Mask

IPC-1601 Printed Board Handling and Storage Guidelines

IPC-2220-FAM Design Standards for Printed Boards

IPC-6010-FAM IPC-6010 Printed Board Performance Specifications

IPC-7093 Design and Assembly Process Implementation for Bottom Termination Components

IPC-7095 Design and Assembly Process Implementation for BGAs

IPC-7351 Generic Requirements for Surface Mount Design and Land Pattern Standard

IPC-7711/7721 Rework, Repair and Modification of Electronic Assemblies

IPC-9691 User Guide for the IPC-TM-650, Method 2.6.25, Conductive Anodic Filament (CAF) Resistance Test (Electrochemical Migration Testing)

IPC-9701 Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments

2.2 Joint Industry Documents[2]

J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies

EIA/IPC/JEDEC J-STD-002 Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires

J-STD-003 Solderability Tests for Printed Boards

J-STD-004 Requirements for Soldering Fluxes

IPC/JEDEC J-STD-020 Moisture/Reflow Sensitivity Classification for Plastic Integrated Circuit Surface Mount Devices

IPC/JEDEC J-STD-033 Standard for Handling, Packing, Shipping and Use of Moisture Sensitive Surface Mount Devices

ECA/IPC/JEDEC J-STD-075 Classification of Non-IC Electronic Components for Assembly Processes

1. www.ipc.org
2. www.ipc.org

2.3 Electrostatic Association Documents[3]

ANSI/ESD S8.1 ESD Awareness Symbols

ANSI/ESD-S-20.20 Protection of Electrical and Electronic Parts, Assemblies and Equipment

2.4 JEDEC[4]

JEDEC JESD471 Symbol and Label for Electrostatic Sensitive Devices

2.5 International Electrotechnical Commission Documents[5]

IEC 61340-5-3 Electrostatics – Part 5-3, Protection of Electronic Devices from Electrostatic Phenomena – Properties and Requirements Classification for Packaging Intended for Electrostatic Discharge Sensitive Devices

2.6 ASTM[6]

ASTM E29 Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.7 Military Standards

MIL-STD-1686 Electrostatic Discharge Control Program For Protection Of Electrical And Electronic Parts, Assemblies And Equipment (Excluding Electrically Initiated Explosive Devices)

MIL-STD-2073 Department of Defense Standard Practice for Military Packaging

3. www.esda.org
4. www.jedec.org
5. www.iec.ch
6. www.astm.org

Protecting the Assembly – EOS/ESD and Other Handling Considerations

The following topics are addressed in this section:

Information in this section is intended to be general in nature. Additional information can be found in ANSI/ESD-S-20.20, IEC-61340-5, MIL-STD-1686 and other related documents.

3.1 EOS/ESD Prevention

Electrostatic Discharge (ESD) is the rapid transfer of a static electric charge from one object to another of a different potential that was created from electrostatic sources. When an electrostatic charge is allowed to come in contact with or close to a sensitive component it can cause damage to the component.

Electrical Overstress (EOS) is the internal result of an unwanted application of electrical energy that results in damaged components. This damage can be from many different sources, such as electrically powered process equipment or ESD occurring during handling or processing.

Electrostatic Discharge Sensitive (ESDS) components are those components that are affected by these high-electrical energy surges. The relative sensitivity of a component to ESD is dependent upon its construction and materials. As components become smaller and operate faster, the sensitivity increases.

ESDS components can fail to operate or change in value as a result of improper handling or processing. These failures can be immediate or latent. The result of immediate failure can be additional testing and rework or scrap. However, the consequences of latent failure are the most serious. Even though the product may have passed inspection and functional test, it may fail after it has been delivered to the customer.

It is important to build protection for ESDS components into circuit designs and packaging. In the manufacturing and assembly areas, work is often done with unprotected electronic assemblies (such as test fixtures) that are attached to the ESDS components. It is important that ESDS items be removed from their protective enclosures only at EOS/ESD safe workstations within Electrostatic Protected Areas (EPA). This section is dedicated to safe handling of these unprotected electronic assemblies.

3.1.1 EOS/ESD Prevention – Electrical Overstress (EOS)

Electrical components can be damaged by unwanted electrical energy from many different sources. This unwanted electrical energy can be the result of ESD potentials or the result of electrical spikes caused by the tools we work with, such as soldering irons, soldering extractors, testing instruments or other electrically operated process equipment. Some devices are more sensitive than others. The degree of sensitivity is a function of the design of the device. Generally speaking, higher speed and smaller devices are more susceptible than their slower, larger predecessors. The purpose or family of the device also plays an important part in component sensitivity. This is because the design of the component can allow it to react to smaller electrical sources or wider frequency ranges. With today’s products in mind, we can see that EOS is a more serious problem than it was even a few years ago. It will be even more critical in the future.

When considering the susceptibility of the product, we must keep in mind the susceptibility of the most sensitive component in the assembly. Applied unwanted electrical energy can be processed or conducted just as an applied signal would be during circuit performance.

Before handling or processing sensitive components, it is important to be sure that tools and equipment will not generate damaging energy, including spike voltages. Current research indicates that voltages and spikes less than 0.5 volt are acceptable. However, an increasing number of extremely sensitive components require that soldering irons, solder extractors, test instruments and other equipment must never generate spikes greater than 0.3 volt.

As required by most ESD specifications, periodic testing may be warranted to preclude damage as equipment performance may degrade with use over time. Maintenance programs are also necessary for process equipment to ensure the continued ability to not cause EOS damage.

EOS damage is certainly similar in nature to ESD damage, since damage is the result of undesirable electrical energy.

3.1.2 EOS/ESD Prevention – Electrostatic Discharge (ESD)

The best ESD damage prevention is a combination of preventing static charges and eliminating static charges if they do occur. All ESD protection techniques and products address one or both of the two issues.

ESD damage is the result of electrical energy that was generated from static sources either being applied or in close proximity to ESDS devices. Static sources are all around us. The degree of static generated is relative to the characteristics of the source. To generate energy, relative motion is required. This could be contacting, separation, or rubbing of the material.

Most of the serious offenders are insulators since they concentrate energy where it was generated or applied rather than allowing it to spread across the surface of the material. See Table 3-1. Common materials such as plastic bags or Styrofoam containers are serious static generators and are not appropriate in processing areas especially static safe/Electrostatic Protected Areas (EPA). Peeling adhesive tape from a roll can generate 20,000 volts. Even compressed air nozzles that move air over insulating surfaces generate charges.

Table 3-1 Typical Static Charge Sources

Work surfaces	Waxed, painted or varnished surfaces Untreated vinyl and plastics Glass
Floors	Sealed concrete Waxed or finished wood Floor tile and carpeting
Clothes and personnel	Non-ESD smocks Synthetic materials Non-ESD Shoes Hair
Chairs	Finished wood Vinyl Fiberglass Nonconductive wheels
Packaging and handling materials	Plastic bags, wraps, envelopes Bubble wrap, foam Styrofoam Non-ESD totes, trays, boxes, parts bins
Assembly tools and materials	Pressure sprays Compressed air Synthetic brushes Heat guns, blowers Copiers, printers

Destructive static charges are often induced on nearby conductors, such as human skin, and discharged into conductors on the assembly. This can happen when a person having an electrostatic charge potential touches a printed board assembly. The electronic assembly can be damaged as the discharge passes through the conductive pattern to an ESDS component. Electrostatic discharges may be too low to be felt by humans (less than static 3500 volts), and still damage ESDS components.

Typical static voltage generation is included in Table 3-2.

Table 3-2 Typical Static Voltage Generation

Source	10-20% Humidity	65-90% Humidity
Walking on carpet	35,000 volts	1,500 volts
Walking on vinyl flooring	12,000 volts	250 volts
Worker at a bench	6,000 volts	100 volts
Vinyl envelopes (work instructions)	7,000 volts	600 volts
Plastic bag picked up from the bench	20,000 volts	1,200 volts
Work chair with foam pad	18,000 volts	1,500 volts

3.1.3 EOS/ESD Prevention – Warning Labels

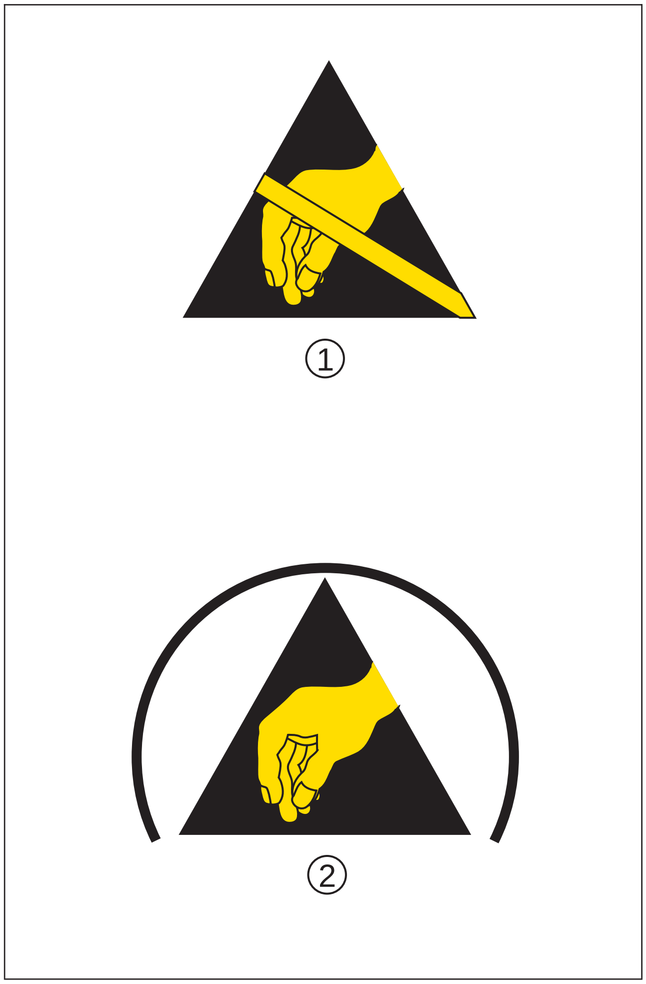


Figure 3-1
1. ESD Susceptibility Symbol
2. ESD Protective Symbol

Warning labels are available for posting in facilities and placement on devices, assemblies, equipment and packages to alert people to the possibility of inflicting electrostatic or electrical overstress damage to the devices they are handling. Examples of frequently encountered labels are shown in Figure 3-1.

Symbol (1) ESD susceptibility symbol is a triangle with a reaching hand and a slash across it. This is used to indicate that an electrical or electronic device or assembly is susceptible to damage from an ESD event.

Symbol (2) ESD protective symbol differs from the ESD susceptibility symbol in that it has an arc around the outside of the triangle and no slash across the hand. This is used to identify items that are specifically designed to provide ESD protection for ESD sensitive assemblies and devices.

Symbols (1) and (2) identify devices or an assembly as containing devices that are ESD sensitive, and that they must be handled accordingly. The design and use of these symbols is detailed in ANSI/ESD S8.1 as well as in IEC 61340-5-1, JEDEC DESD471, MIL-STD-2073, and other standards.

Note that the absence of a symbol does not necessarily mean that the assembly is not ESD sensitive. ***When doubt exists about the sensitivity of an assembly, it must be handled as a sensitive device until it is determined otherwise.***

3.1.4 EOS/ESD Prevention – Protective Materials

ESDS components and assemblies must be protected from static sources when not being worked on in static safe environments or workstations. This protection could be conductive static-shielding boxes, protective caps, bags or wraps.

ESDS items must be removed from their protective enclosures only at static safe workstations.

It is important to understand the difference between the three types of protective enclosure material: (1) static shielding (or barrier packaging), (2) antistatic, and (3) static dissipative materials.

Static shielding packaging will prevent an electrostatic discharge from passing through the package and into the assembly causing damage.

Antistatic (low charging) packaging materials are used to provide inexpensive cushioning and intermediate packaging for ESDS items. Antistatic materials do not generate charges when motion is applied. However, if an electrostatic discharge occurs, it could pass through the packaging and into the part or assembly, causing EOS/ESD damage to ESDS components.

Static dissipative materials have enough conductivity to allow applied charges to dissipate over the surface relieving hot spots of energy. Parts leaving an EOS/ESD protected work area must be overpacked in static shielding materials, which normally also have static dissipative and antistatic materials inside.

Do not be misled by the ''color'' of packaging materials. It is widely assumed that ''black'' packaging is static shielding or conductive and that ''pink'' packaging is antistatic in nature. While that may be generally true, it can be misleading. In addition, there are many clear materials now on the market that may be antistatic and even static shielding. At one time, it could be assumed that clear packing materials introduced into the manufacturing operation would represent an EOS/ESD hazard. This is not necessarily the case now.

Caution: *Some static shielding and antistatic materials and some topical antistatic solutions may affect the solderability of assemblies, components, and materials in process. Care should be taken to select only packaging and handling materials that will not contaminate the assembly and use them with regard for the vendor's instructions. Solvent cleaning of static dissipative or antistatic surfaces can degrade their ESD performance. Follow the manufacturer's recommendations for cleaning.*

3.2 EOS/ESD Safe Workstation/EPA

An EOS/ESD safe workstation prevents damage to sensitive components from spikes and static discharges while operations are being performed. Safe workstations should include EOS damage prevention by avoiding spike generating repair, manufacturing or testing equipment. Soldering irons, solder extractors and testing instruments can generate energy of sufficient levels to destroy extremely sensitive components and seriously degrade others.

For ESD protection, a path-to-ground must be provided to neutralize static charges that might otherwise discharge to a device or assembly. ESD safe workstations/EPAs also have static dissipative or antistatic work surfaces that are connected to a common ground. Provisions are also made for grounding the worker's skin, preferably via a wrist strap to eliminate charges generated on the skin or clothing.

Provision must be made in the grounding system to protect the worker from live circuitry as the result of carelessness or equipment failure. This is commonly accomplished through resistance in line with the ground path, which also slows the charge decay time to prevent sparks or surges of energy from ESD sources. Additionally, a survey must be performed of the available voltage sources that could be encountered at the workstation to provide adequate protection from personnel electrical hazards.

For maximum allowable resistance and discharge times for static safe operations, see Table 3-3.

Table 3-3 Maximum Allowable Resistance and Discharge Times for Static Safe Operations

Reading from Operator Through	Maximum Tolerable Resistance	Maximum Acceptable Discharge Time
Floor mat to ground	1000 Megohms	less than 1 sec.
Table mat to ground	1000 Megohms	less than 1 sec.
Wrist strap to ground	35 Megohms	less than 0.1 sec.

Note: The selection of resistance values is based on the available voltages at the station to ensure personnel safety as well as to provide adequate decay or discharge time for ESD potentials.

3.2 EOS/ESD Safe Workstation/EPA (cont.)

Examples of acceptable workstations are shown in Figures 3-2 and 3-3. When necessary, air ionizers may be required for more sensitive applications. The selection, location, and use procedures for ionizers must be followed to ensure their effectiveness.

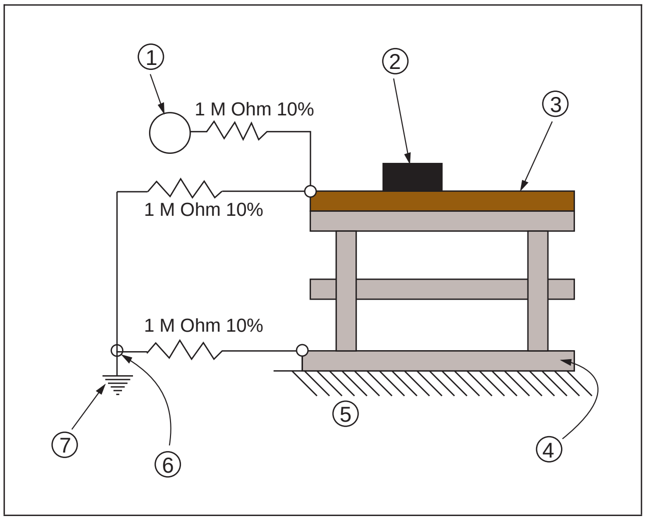


Figure 3-2 Series Connected Wrist Strap

1. **Personal wrist strap**
2. **EOS protective trays, shunts, etc.**
3. **EOS protective table top**
4. **EOS protective floor or mat**
5. **Building floor**
6. **Common ground point**
7. **Ground**

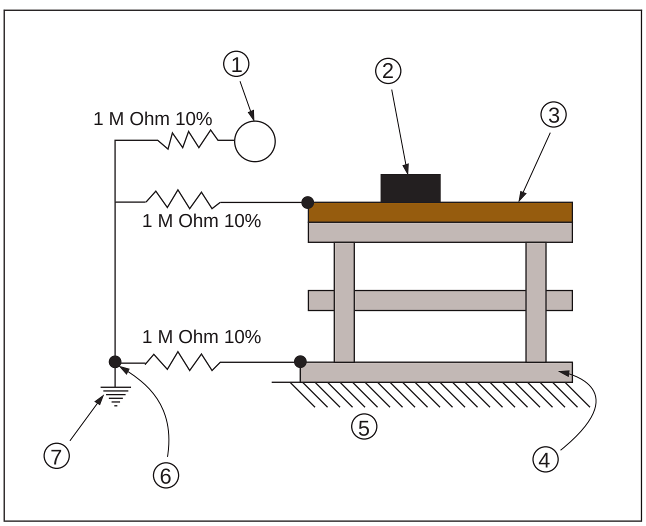


Figure 3-3 Parallel Connected Wrist Strap

1. **Personal wrist strap**
2. **EOS protective trays, shunts, etc.**
3. **EOS protective table top**
4. **EOS protective floor or mat**
5. **Building floor**
6. **Common ground point**
7. **Ground**

Keep workstation(s) free of static generating materials such as Styrofoam, plastic solder removers, sheet protectors, plastic or paper notebook folders, and employees' personal items.

Periodically check workstations/EPAs to make sure they work. EOS/ESD assembly and personnel hazards can be caused by improper grounding methods or by an oxide build-up on grounding connectors. Tools and equipment must be periodically checked and maintained to ensure proper operation.

Note: Because of the unique conditions of each facility, particular care must be given to ''third wire'' ground terminations. Frequently, instead of being at workbench or earth potential, the third wire ground may have a ''floating'' potential of 80 to 100 volts. This 80 to 100 volt potential between an electronic assembly on a properly grounded EOS/ESD workstation/EPA and a third wire grounded electrical tool may damage EOS sensitive components or could cause injury to personnel. Most ESD specifications also require these potentials to be electrically common. The use of ground fault interrupter (GFI) electrical outlets at EOS/ESD workstations/EPAs is highly recommended.

3.3 Handling Considerations

3.3.1 Handling Considerations – Guidelines

Avoid contaminating solderable surfaces prior to soldering. Whatever comes in contact with these surfaces must be clean. When boards are removed from their protective wrappings, handle them with great care. Touch only the edges away from any edge connector tabs. Where a firm grip on the board is required due to any mechanical assembly procedure, gloves meeting EOS/ESD requirements may be required. These principles are especially critical when no-clean processes are employed.

Care must be taken during assembly and acceptability inspections to ensure product integrity at all times. Table 3-4 provides general guidance.

Table 3-4 Recommended Practices for Handling Electronic Assemblies

1. Keep workstations clean and neat. There must not be any eating, drinking, or use of tobacco products, including the use of e-cigarettes, in the work area.
2. Minimize the handling of electronic assemblies and components to prevent damage.
3 When gloves are used, change as frequently as necessary to prevent contamination from dirty gloves.
4. Do not handle solderable surfaces with bare hands or fingers. Body oils and salts reduce solderability, promote corrosion and dendritic growth. They can also cause poor adhesion of subsequent coatings or encapsulants.
5. Do not use hand creams or lotions containing silicone since they can cause solderability and conformal coating adhesion problems.
6. Never stack electronic assemblies or physical damage may occur. Special racks may be provided in assembly areas for temporary storage.
7. Always assume the items are ESDS even if they are not marked.
8. Personnel must be trained and follow appropriate ESD practices and procedures.
9. Never transport ESDS devices unless proper packaging is applied.

Printed circuit boards and commonly used plastic components absorb and release moisture at different rates. During the soldering process heat causes expansion of the moisture that can damage the ability of the materials to perform as required for the product requirements. This damage (crack, internal delamination, popcorning) may not be visible and can occur during original soldering as well as during rework operations.

To prevent laminate issues, if the level of moisture is unknown, PCBs should be baked to reduce the internal moisture content. The baking temperature selection and duration should be controlled to prevent reduction of solderability through intermetallic growth, surface oxidation or other internal component damage.

Moisture sensitive components (as classified by IPC/JEDEC J-STD-020, ECA/IPC/JEDEC J-STD-075 or equivalent documented procedure) should be handled in a manner consistent with IPC/JEDEC J-STD-033 or an equivalent documented procedure. IPC-1601 provides moisture control, handling and packing of PCBs.

3.3.2 Handling Considerations – Physical Damage

Improper handling can readily damage components and assemblies, e.g., cracked, chipped or broken components and connectors, bent or broken terminals, badly scratched board surfaces and conductor lands. Physical damage of this type can ruin the entire assembly or attached components.

3.3.3 Handling Considerations – Contamination

Many times product is contaminated during the manufacturing process due to careless or poor handling practices causing soldering and coating problems; body salts and oils, and unauthorized hand creams are typical contaminants. Body oils and acids can reduce solderability, promote corrosion and dendritic growth. They can also cause poor adhesion of subsequent coatings or encapsulants. Normal cleaning procedures may not remove all contaminants. Therefore, it is important to minimize the opportunities for contamination. The best solution is prevention. ***Frequently washing ones hands and handling boards only by the edges without touching the lands or pads will aid in reducing contamination. When required, the use of pallets and carriers will also aid in reducing contamination during processing.***

The use of gloves or finger cots many times creates a false sense of protection and within a short time can become more contaminated than bare hands. When gloves or finger cots are used they should be discarded and replaced often. Gloves and finger cots need to be carefully chosen and properly utilized.

3.3.4 Handling Considerations – Electronic Assemblies

Even if no ESDS markings are on an assembly, it still should to be handled as if it were an ESDS assembly. However, ESDS components and electronic assemblies need to be identified by suitable EOS/ESD labels, see Figure 3-1. Many sensitive assemblies will also be marked on the assembly itself, usually on an edge connector. To prevent ESD and EOS damage to sensitive components, all handling, unpacking, assembly and testing **shall** be performed at a static controlled workstation, see Figures 3-2 and 3-3.

3.3.5 Handling Considerations – After Soldering

After soldering and cleaning operations, the handling of electronic assemblies still requires great care. Fingerprints are extremely hard to remove and will often show up in conformally coated boards after humidity or environmental testing. Gloves or other protective handling devices may be used to prevent such contamination. Use mechanical racking or baskets with full ESD protection when handling during cleaning operations.

3.3.6 Handling Considerations – Gloves and Finger Cots

The use of gloves or finger cots may be required under contract to prevent contamination of parts and assemblies. Gloves and finger cots must be carefully chosen to maintain EOS/ESD protection.

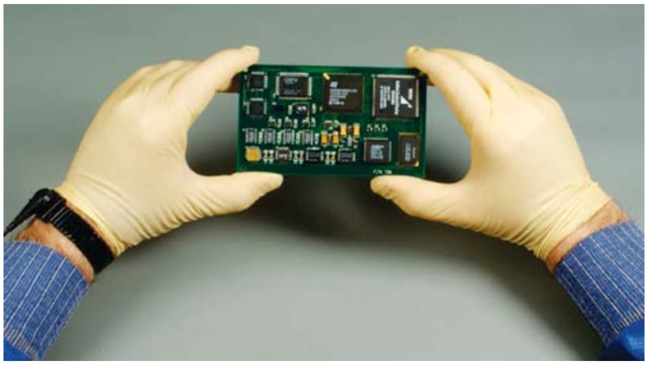


Figure 3-4

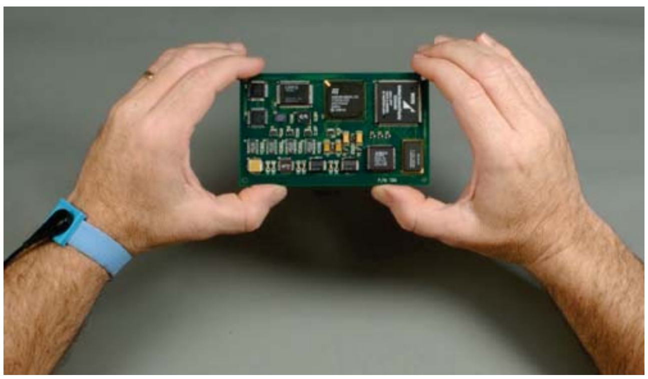


Figure 3-5

Figure 3-4 and 3-5 provide examples of:

- Handling with clean gloves and full EOS/ESD protection.
- Handling during cleaning procedures using solvent resistant gloves meeting all EOS/ESD requirements.
- Handling with clean hands by board edges using full EOS/ESD protection.

Note: Any assembly related component if handled without EOS/ESD protection may damage electrostatic sensitive components. This damage could be in the form of latent failures, or product degradation not detectable during initial test or catastrophic failures found at initial test.

4 Hardware

This section illustrates several types of hardware used to mount electronic devices to a printed circuit assembly (PCA) or any other types of assemblies requiring the use of any of the following: screws, bolts, nuts, washers, fasteners, clips, component studs, tie downs, rivets, connector pins, etc. This section is primarily concerned with visual assessment of proper securing (tightness), and also with damage to the devices, hardware, and the mounting surface that can result from hardware mounting.

Process documentation (drawings, prints, parts list and build process) will specify what to use; deviations need to have prior customer approval.

Note: Criteria in this section do not apply to attachments with self-tapping screws.

Visual inspection is performed in order to verify the following conditions:

a. Correct parts and hardware.
b. Correct sequence of assembly.
c. Correct security and tightness of parts and hardware.
d. No discernible damage.
e. Correct orientation of parts and hardware.

The following topics are addressed in this section:

4.1 Hardware Installation

4.1.1 Hardware Installation – Electrical Clearance

Also see 1.8.4.

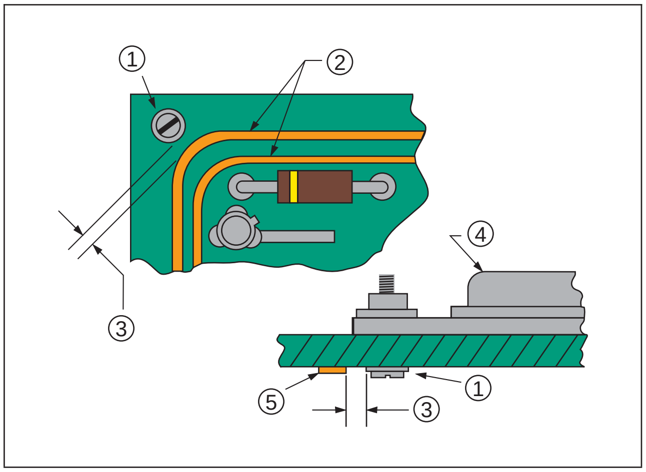


Figure 4-1
1. **Metallic hardware**
2. **Conductive pattern**
3. **Specified minimum electrical clearance**
4. **Mounted component**
5. **Conductor**

Acceptable – Class 1,2,3

- Spacing between noncommon conductors does not violate specified minimum electrical clearance (3). This is shown in Figure 4-1 as the distances between (1) & (2) and (1) & (5).

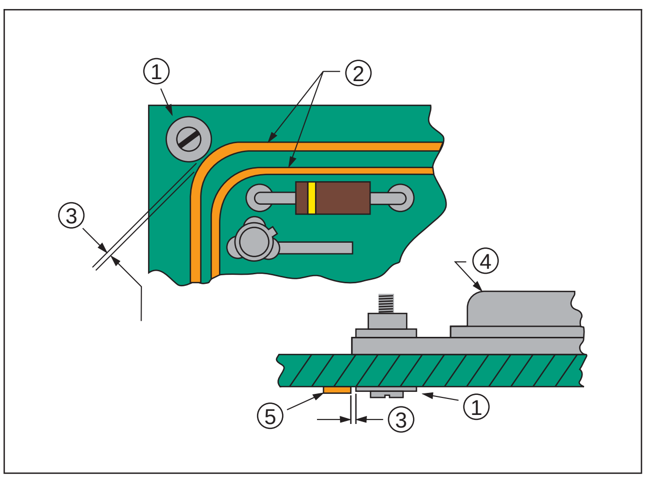


Figure 4-2
1. **Metallic hardware**
2. **Conductive pattern**
3. **Spacing less than electrical clearance requirements**
4. **Mounted component**
5. **Conductor**

Defect – Class 1,2,3

- Hardware reduces spacing to less than specified minimum electrical clearance.

4.1.2 Hardware Installation – Interference

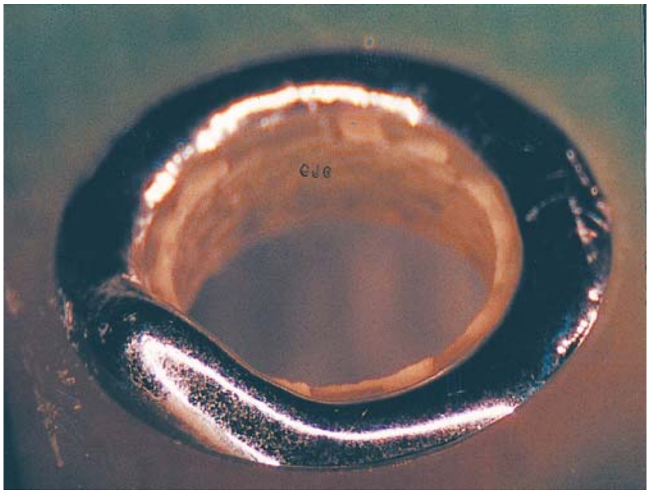


Figure 4-3

Acceptable – Class 1,2,3

- Mounting area clear of obstructions to assembly requirements.

Defect – Class 1,2,3

- Excess solder (uneven) on mounting holes where mechanical assembly will be affected.
- Anything that interferes with mounting of required hardware.

4.1.3 Hardware Installation – Component Mounting – High Power

Figures 4-4 and 4-5 show typical mounting parts.

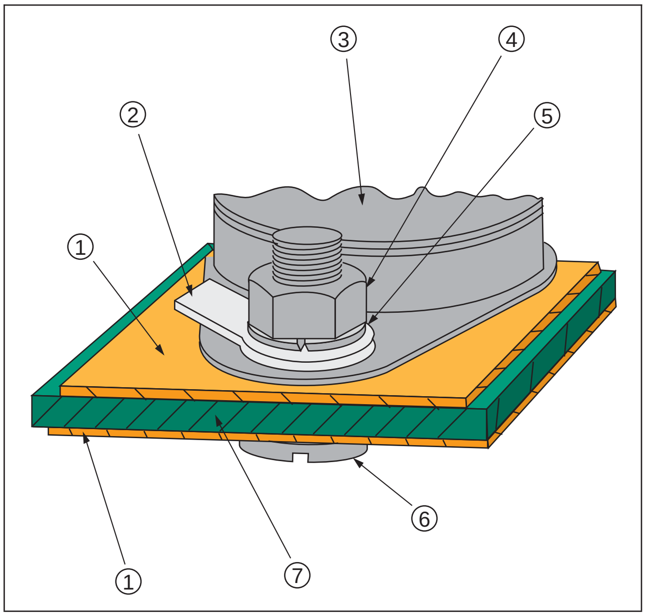


Figure 4-4

1. **Metal**
2. **Terminal lug**
3. **Component case**
4. **Nut**
5. **Lock washer**
6. **Screw**
7. **Nonmetal**

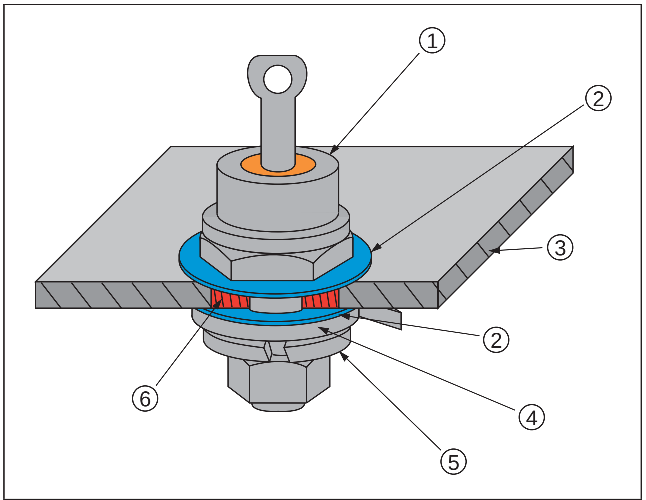


Figure 4-5

1. **High power component**
2. **Insulating washer (when required)**
3. **Heat sink (may be metal or nonmetal)**
4. **Terminal lug**
5. **Lock washer**
6. **Insulator sleeve**

Acceptable – Class 1,2,3

- Hardware in proper sequence.
- Leads on components attached by fastening devices are not clinched (not shown).
- Insulating washer provides electrical isolation when required.
- Thermal compound, if used, does not interfere with formation of required solder connections.

Note: Where a thermal conductor is specified, it is placed between mating surfaces of the power device and the heat sink. Thermal conductors may consist of a thermally conductive washer or of an insulating washer with a thermally conductive compound.

4.1.3 Hardware Installation – Component Mounting – High Power (cont.)

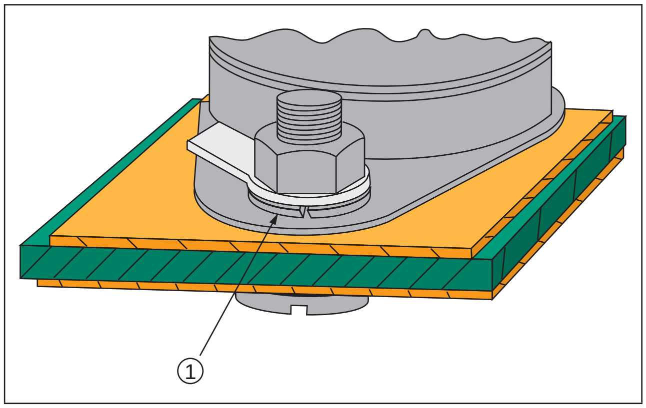


Figure 4-6
1. Lock washer between terminal lug and component case

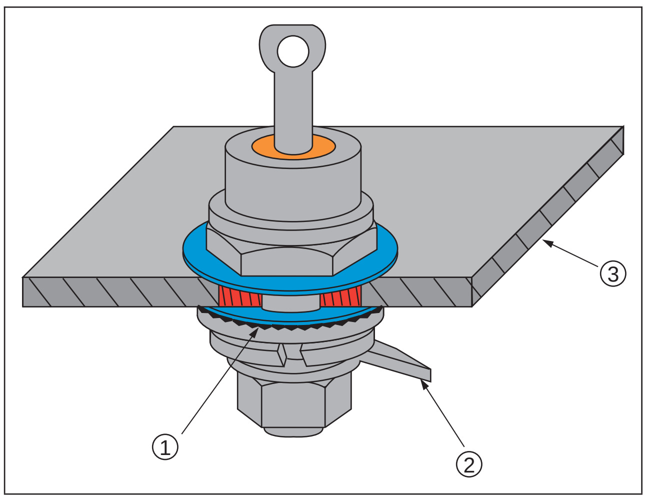


Figure 4-7
1. Sharp edge of washer against insulator
2. Terminal lug
3. Metal heat sink

Defect – Class 1,2,3

- Improper hardware sequence, see Figure 4-6.
- Sharp edge of washer is against insulator, see Figure 4-7.
- Hardware is not secure.
- Thermal compound, if used, does not permit formation of required solder connections.

4.1.4 Hardware Installation – Heatsinks

4.1.4.1 Hardware Installation – Heatsinks – Insulators and Thermal Compounds

This section illustrates various types of heatsink mounting. Bonding with thermally conductive adhesives may be specified in place of hardware.

Visual inspection includes hardware security, component damage, and correct sequence of assembly.

The following additional issues **shall** be considered:

- The component has good contact with the heatsink.
- The hardware secures the component to the heatsink.
- The component and heatsink are flat and parallel to each other.
- The thermal compound/insulator (mica, silicone grease, plastic film, etc.) is applied properly.

4.1.4.1 Hardware Installation – Heatsinks – Insulators and Thermal Compounds (cont.)

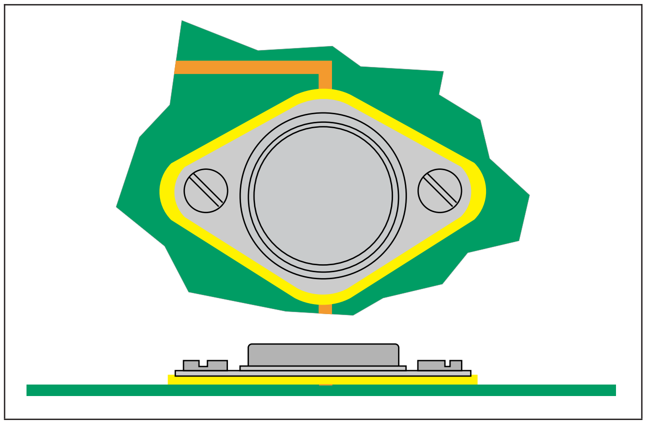


Figure 4-8

Target – Class 1,2,3

- Uniform border of mica, plastic film or thermal compound showing around edges of component.

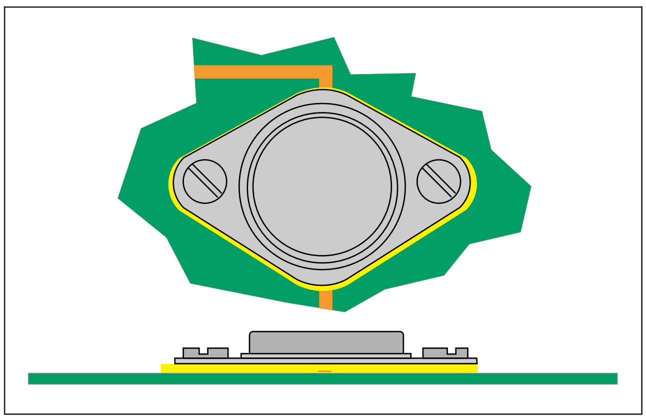


Figure 4-9

Acceptable – Class 1,2,3

- Not uniform but evidence of mica, plastic film or thermal compound showing around edges of component.

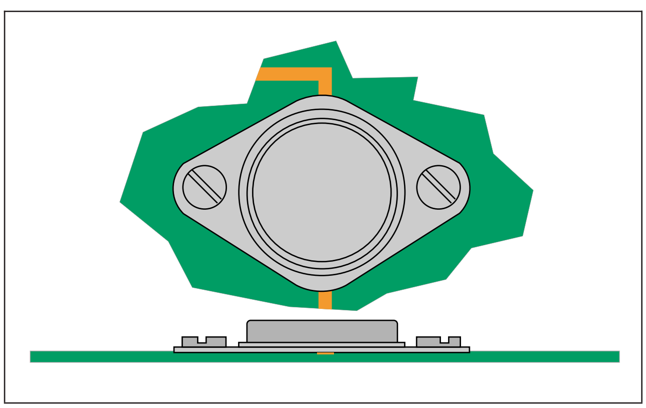


Figure 4-10

Defect – Class 1,2,3

- No evidence of insulating materials, or thermal compound (if required).
- Thermal compound precludes formation of required solder connection.

4.1.4.2 Hardware Installation – Heatsinks – Contact

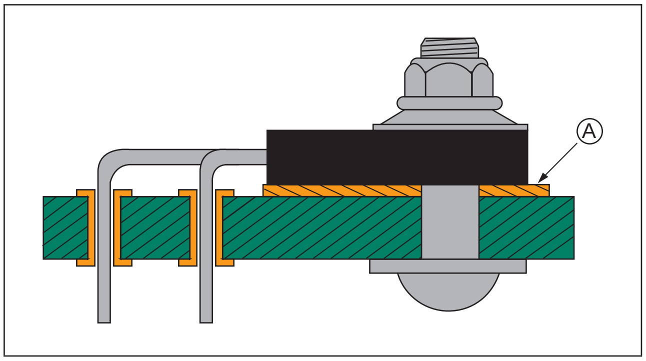


Figure 4-11

Target – Class 1,2,3

- Component and heatsink are in full contact with the mounting surface, see Figure 4-11-A.
- Hardware meets specified attachment requirements.

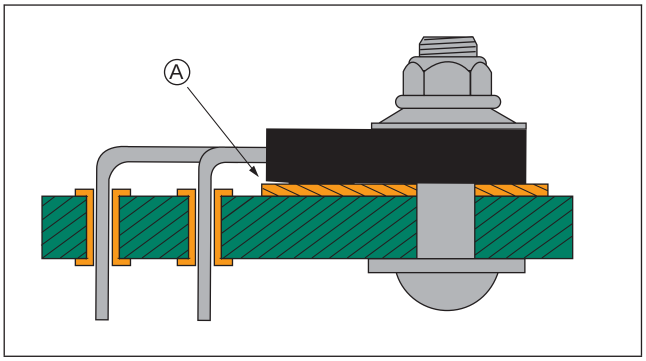


Figure 4-12

Acceptable – Class 1,2,3

- Component not flush, see Figure 4-12-A.
- Minimum 75% contact with mounting surface.
- Hardware meets mounting torque requirements if specified.

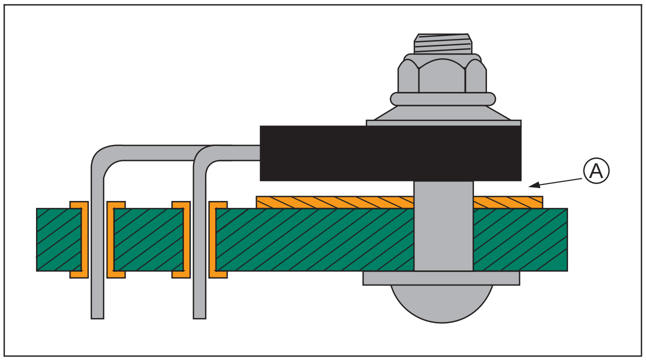


Figure 4-13

Defect – Class 1,2,3

- Component has less than 75% contact with mounting surface, see Figure 4-13-A.
- Hardware is loose.

4.1.5 Hardware Installation – Threaded Fasteners and Other Threaded Hardware

Both the order and orientation of mounting hardware need to be considered during assembly. Devices such as ''star'' or ''tooth'' washers may have one side with sharp edges intended to cut into the mating surface to keep the hardware from coming loose in operation. Figure 4-15 is an example of this kind of lock washer. Unless otherwise specified the sharp edges of the lock washer should be against the flat washer.

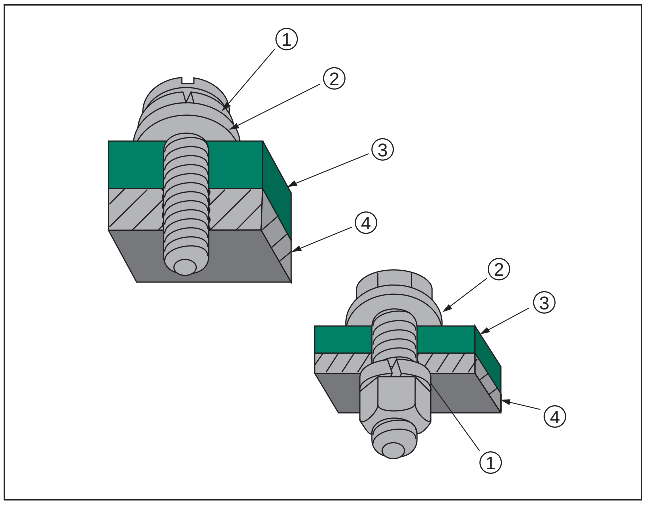


Figure 4-14
1. **Lock washer, sharp edge showing towards flat washer**
2. **Flat washer**
3. **Nonconductive material (laminate, etc.)**
4. **Metal (not conductive pattern or foil)**

Acceptable – Class 1,2,3

- Proper hardware sequence and orientation, see Figures 4-14 and 4-15.
- Slot or hole are covered with flat washer, see Figure 4-16.

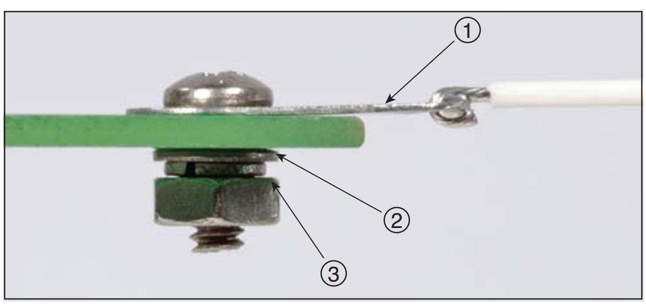


Figure 4-15
1. **Solder lug**
2. **Flat washer**
3. **Lock washer, sharp edge towards flat washer**

Acceptable – Class 1
Defect – Class 2,3

- Less than one and one-half threads extend beyond the threaded hardware, e.g., nut, unless otherwise specified by engineering drawing.

4.1.5 Hardware Installation – Threaded Fasteners and Other Threaded Hardware (cont.)

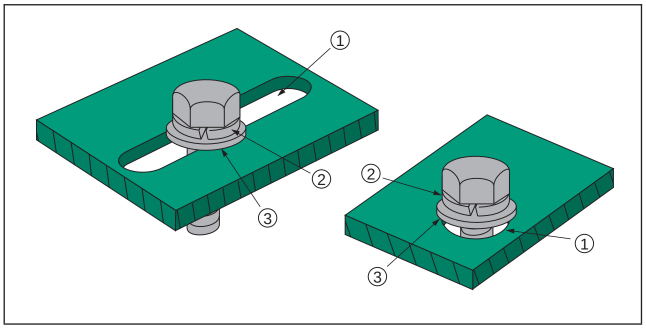


Figure 4-16
1. Slot or hole
2. Lock washer
3. Flat washer

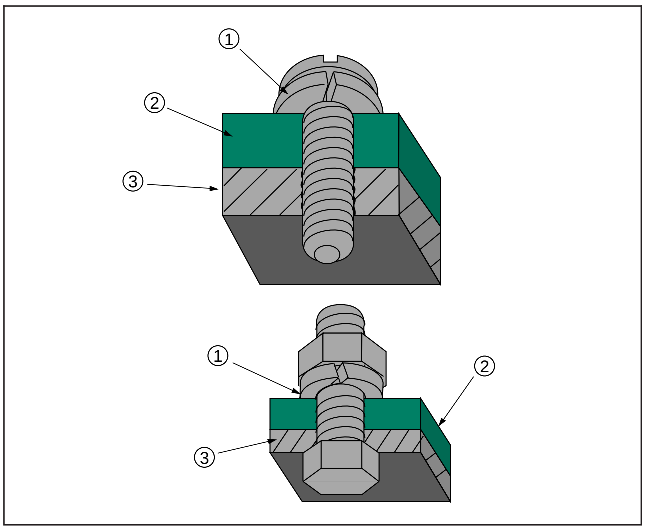


Figure 4-17
1. Lock washer
2. Nonmetal
3. Metal (not conductive pattern or foil)

Defect – Class 1,2,3

- Thread extension interferes with adjacent component.
- Hardware material or sequence not in conformance with drawing.
- Lock washer against nonmetal/laminate.
- Flat washer missing, see Figures 4-17 and 4-18.
- Hardware missing or improperly installed, see Figure 4-19.
- Hardware is not seated, see Figure 4-22.

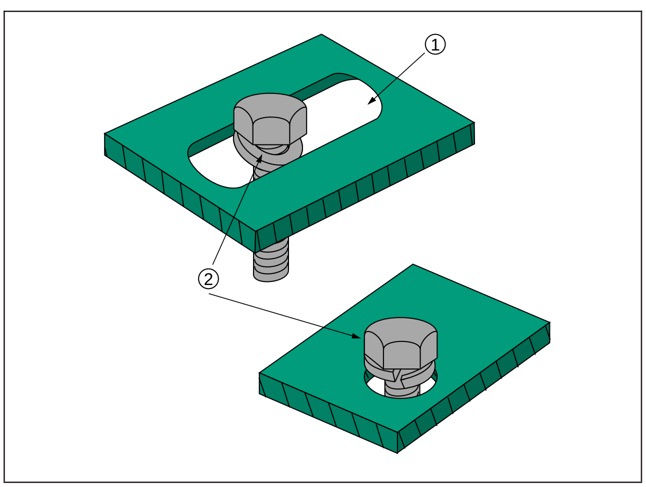


Figure 4-18
1. Slot or hole
2. Lock washer

Figure 4-19

4.1.5.1 Hardware Installation – Threaded Fasteners and Other Threaded Hardware – Torque

In addition to threaded fasteners used for installation of an item onto an assembly, there are other types of threaded items that may be used on individual parts within an assembly. These may require tightening to a specified torque value, or standard industry practice, to preclude loosening or part damage. Such items include, but are not limited to, connector coupling nuts, connector strain relief clamps/potting/molding boots, etc., fuse holder mounting nuts, and any other similar threaded items.

Where torque requirements are not specified, follow standard industry practices. However, some of these threaded items may be made of plastic or other material that can be damaged if excessive torque is applied during assembly, and for these items, it may be necessary to tighten the item to a specified torque value.

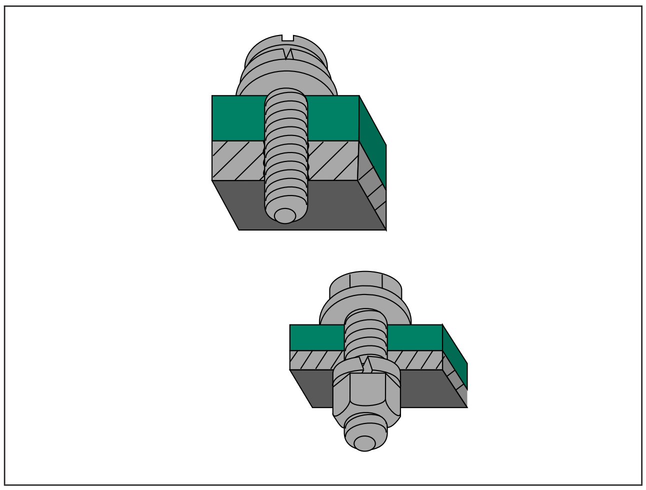


Figure 4-20

Figure 4-21

Acceptable – Class 1,2,3

- Fasteners are tight and split-ring lock washers, when used, are fully compressed.
- Fastener torque value, if specified, is within limits.
- No evidence of damage resulting from over-tightening of the threaded item.
- Torque stripe on fasteners (witness/anti-tampering stripe), when required, see Figure 4-21:
  - Is continuous between the fastener and the substrate.
  - Extends from the top of the fastener onto the adjacent substrate (at minimum).
  - Is aligned with the center line of the fastener.
  - Is undisturbed (indicating no movement of the fastener and stripe after torquing).

4.1.5.1 Hardware Installation – Threaded Fasteners and Other Threaded Hardware – Torque (cont.)

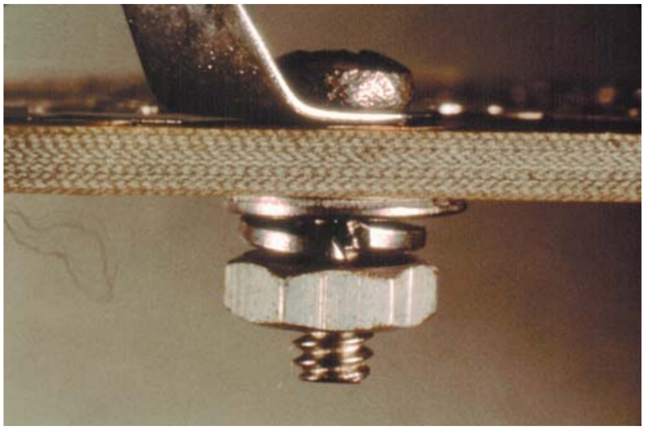


Figure 4-22

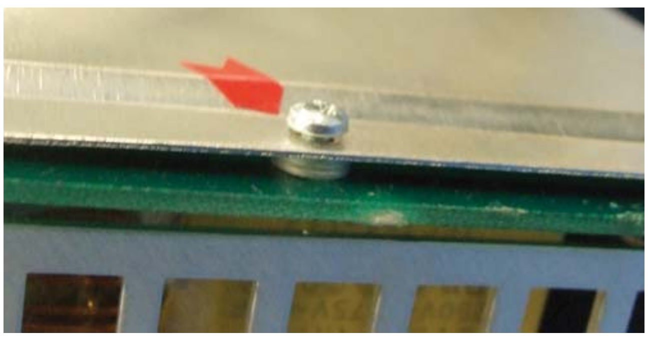


Figure 4-23

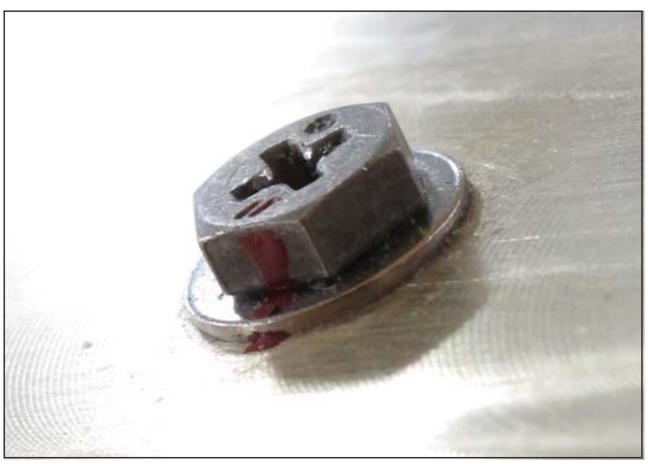


Figure 4-24

Defect – Class 1,2,3

- Split ring lock washer, if used, is not compressed, see Figure 4-22.
- Fastener torque value, if specified, is not within limits.
- Hardware is loose, see Figure 4-22.
- Evidence of damage to the parts being secured.
- Required torque stripe is not continuous between the fastener and the substrate.
- Required torque stripe does not extend from the top of the fastener onto the adjacent substrate (at minimum).
- Required torque stripe is not aligned with the center line of the fastener.
- Required torque stripe is disturbed (indicating movement of the fastener and stripe after torquing).

4.1.5.2 Hardware Installation – Threaded Fasteners and Other Threaded Hardware – Wires

When the use of terminal lugs is not required, wires are wrapped around screw type terminals in a manner that precludes loosening when the screw is tightened, and the ends of the wire are kept short to preclude shorting to ground or other current carrying conductors.

If a washer is used, the wire/lead is mounted under the washer.

Unless otherwise noted, all requirements apply to both stranded and solid wires.

Special hardware staking/securing criteria may be required.

Figure 4-25

Target – Class 1,2,3

- Original lay of the strands is not disturbed (stranded wire).
- Wire wrapped a minimum of 270° around the screw body.
- Wire end secured under screw head.
- Wire wrapped in the correct direction.
- All strands are under screw head.

4.1.5.2 Hardware Installation – Threaded Fasteners and Other Threaded Hardware – Wires (cont.)

Figure 4-26

Figure 4-27

Acceptable – Class 1,2,3

- Less than one-third of the wire diameter protrudes from under the screw head.
- Wire extending outside the screw head does not violate minimum electrical clearance.
- Mechanical attachment of the wire is in contact between the screw head and the contact surface for a minimum of 180° around the screw head.
- No insulation in the contact area.
- Wire does not overlap itself.

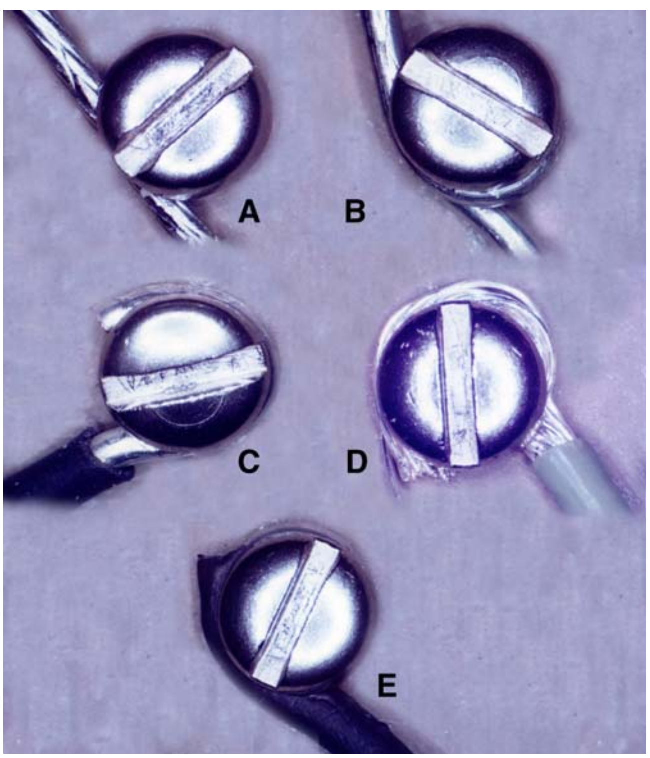


Figure 4-28

Defect – Class 1,2,3

- More than one-third of the wire diameter protrudes from under the screw head.
- Wire not wrapped around screw body, see Figure 4-28-A.
- Wire is wrapped more than 360°, see Figure 4-28-B.
- Solid wire wrapped in wrong direction, see Figure 4-28-C.
- Stranded wire wrapped in wrong direction (tightening the screw unwinds the twisted wire), see Figure 4-28-D.
- Insulation in the contact area, see Figure 4-28-E.
- Stranded wire is tinned, see Figure 4-28-A.
- Missing solder or adhesive as required per customer requirements (not shown).

4.2 Jackpost Mounting

This section covers the height relationship of the face of the jackpost to the associated connector face. This is critical to obtain maximum connector pin contact.

Note: ''C'' style retaining clips will add the thickness of the clip to the jackpost height.

Note: A trial mating may be required for final acceptance.

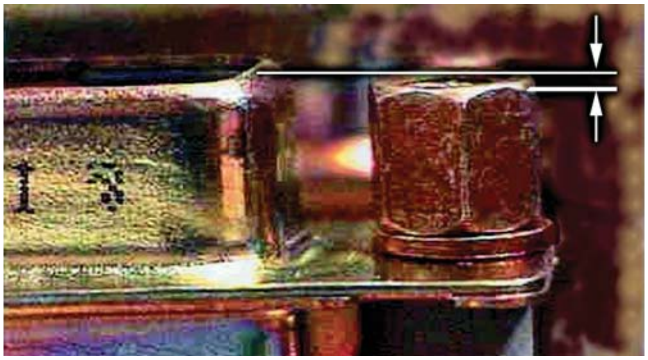


Figure 4-29

Acceptable – Class 1,2,3

- The jackposts can be above or below the face of the connector, depending on the design, providing the connector and jackposts mate correctly.
- Height is obtained by adding or removing washers in accordance with manufacturer's instructions.

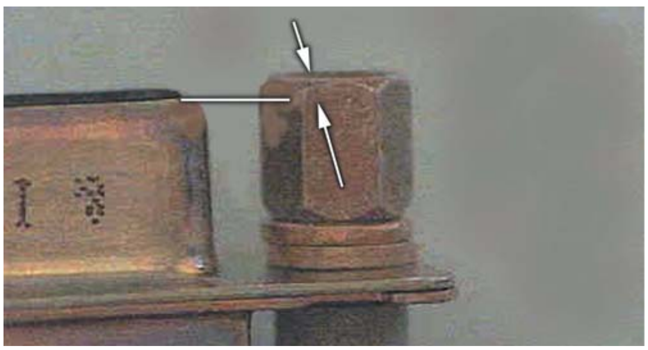


Figure 4-30

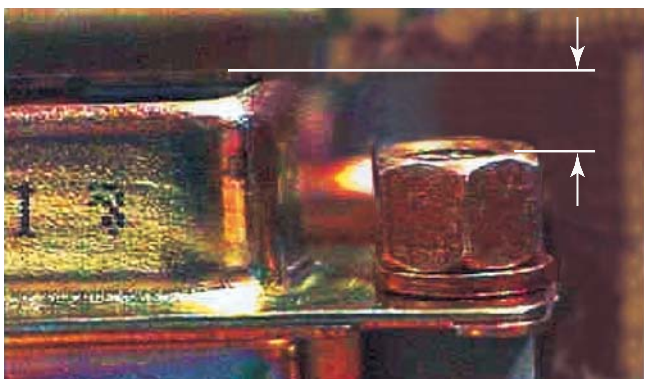


Figure 4-31

Defect – Class 1,2,3

- The jackposts are above or below the face of the connector, depending on the design, and the connector and jackposts do not mate correctly. (No figure showing the defect condition.)

4.3 Connector Pins

This section covers two types of pin installations; edge connector pins and press fit connector pins. Installation of these devices is usually done with automated equipment. Visual inspection of this mechanical operation includes: correct pins, damaged pins, bent and broken pins, damaged spring contacts and damage to the substrate or conductive pattern. For connector mounting criteria see 7.1.8. For connector damage criteria see 9.5.

4.3.1 Connector Pins – Edge Connector Pins

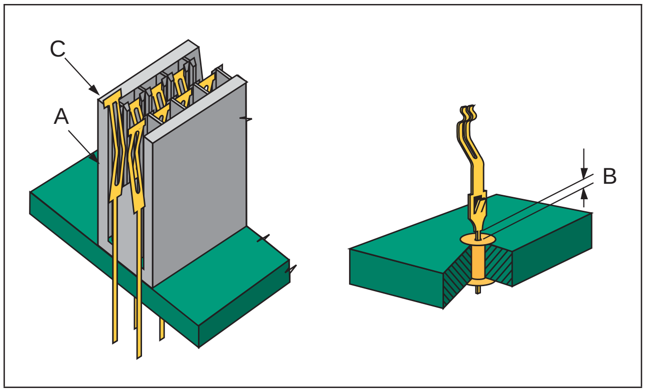


Figure 4-32

Acceptable – Class 1,2,3

- Contact is contained within the insulator, see Figure 4-32-A.
- Gap is within specified tolerance, see Figure 4-32-B.

Note: To provide allowance for an extraction tool, the gap between the contact shoulder and the land needs to be adequate for each manufacturer's repair tooling.

Defect – Class 1,2,3

- Contact is above insulator, see Figure 4-32-C.
- Gap between contact shoulder and land is greater than specified, see Figure 4-32-B.

4.3.2 Connector Pins – Press Fit Pins

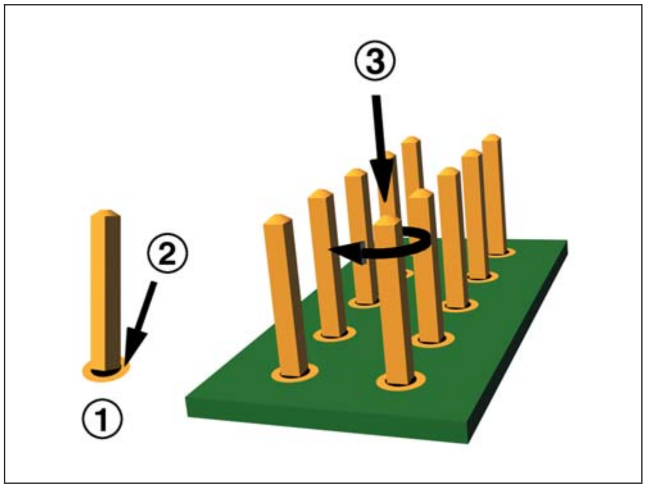


Figure 4-33
1. No discernible damage
2. Land
3. No discernible twist

Target – Class 1,2,3

- Pins are straight, not twisted and properly seated.

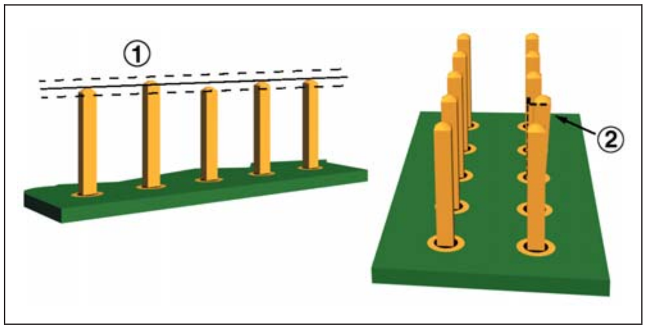


Figure 4-34
1. Pin height tolerance
2. Less than 50% pin thickness

Acceptable – Class 1,2,3

- Pins are bent off center by 50% pin thickness or less.
- Pin height is within tolerance.

Note: Nominal height tolerance is per pin connector or master drawing specification. The connector pins and mating connector must have a good electrical contact.

4.3.2 Connector Pins – Press Fit Pins (cont.)

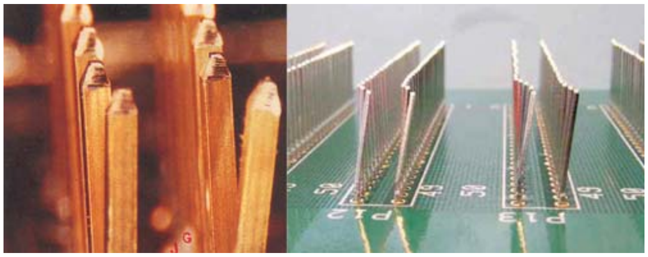


Figure 4-35

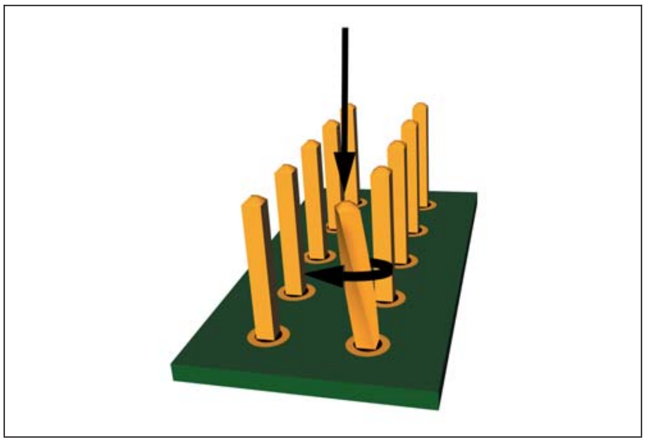


Figure 4-36

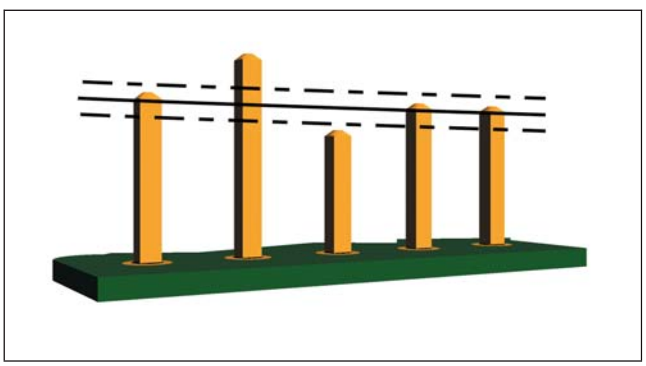


Figure 4-37

Defect – Class 1,2,3

- Pin is bent out of alignment – bent off center greater than 50% pin thickness, see Figure 4-35.
- Pin visibly twisted, see Figure 4-36.
- Pin height is out of tolerance as to specification, see Figure 4-37.

4.3.2 Connector Pins – Press Fit Pins (cont.)

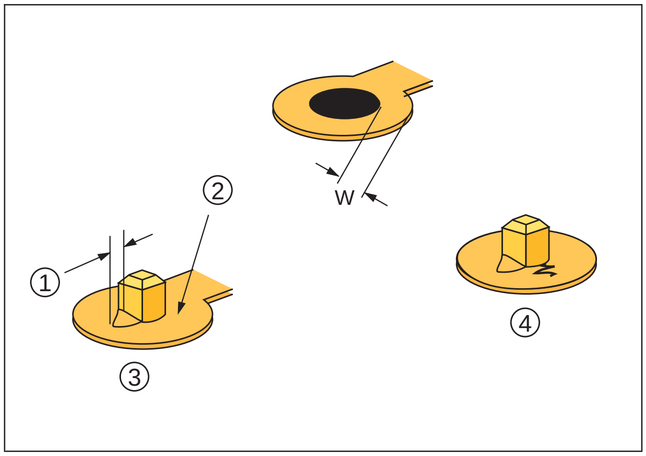


Figure 4-38
1. **Land lifted 75% ring or less**
2. **Land with conductor**
3. **Land not fractured**
4. **Land lifted, fractured but firmly attached land without conductor (nonfunctional)**

Target – Class 1,2,3

• No lifted or fractured annular rings with press fit pins.

Acceptable – Class 1,2

• Protrusion side land lifted less than or equal to 75% of the width (W) of the annular ring, Figure 4-38.

Acceptable – Class 2

• No visual evidence of lifted land on insertion side.

Acceptable – Class 3

• No lifted or fractured annular rings.

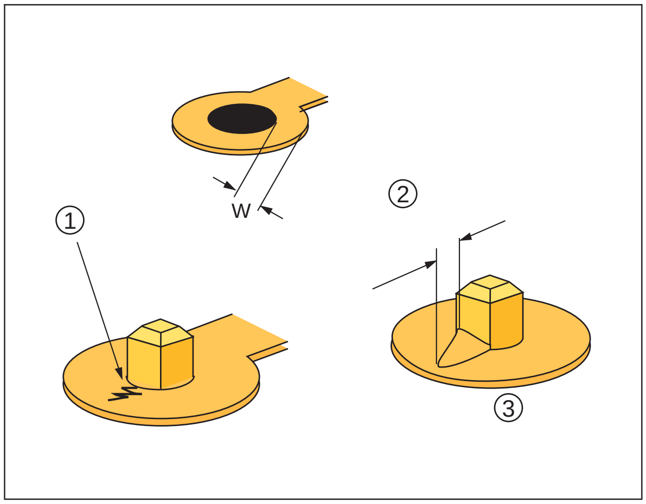


Figure 4-39
1. **Land fractured**
2. **Functional land lifted greater than 75% of land width**
3. **Land lifted**

Defect – Class 1,2

• Any protrusion side functional land lifted more than 75% of the width (W).

Defect – Class 2

• Any evidence of lifted lands on the insertion side.

Defect – Class 3

• Any lifted or fractured annular rings with press fit pins.

Note: For additional information see 10.3.2.

4.3.2.1 Press Fit Pins – Soldering

The term ''press fit pins'' is generic in nature and many types of pressure inserted pins, e.g., connector, staked, etc., are not intended to be soldered. If soldering is required the following criteria are applicable.

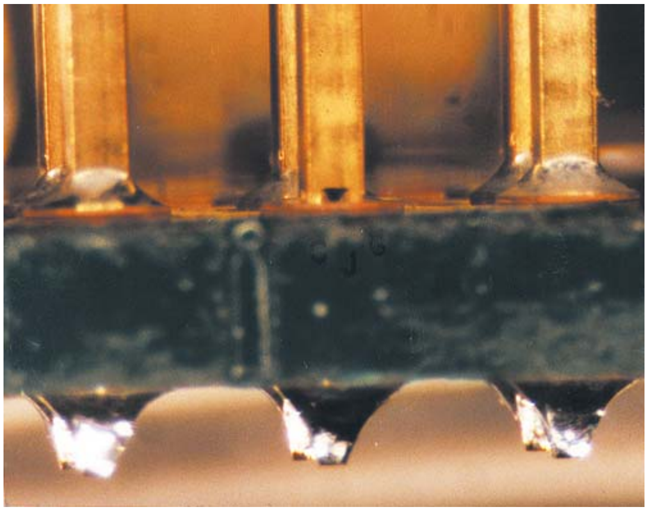


Figure 4-40

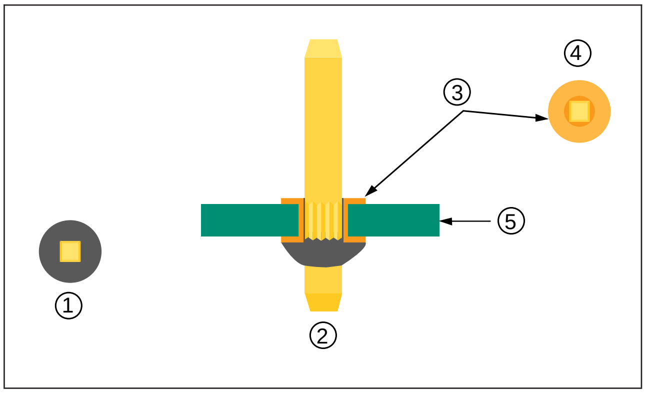


Figure 4-41
1. Bottom view
2. Side view
3. Land
4. Top view
5. PCB

Target – Class 1,2,3

• A 360° solder fillet is evident on the protrusion side of the assembly.

Note: Solder fillet or fill on insertion side is not required.

4.3.2.1 Press Fit Pins – Soldering (cont.)

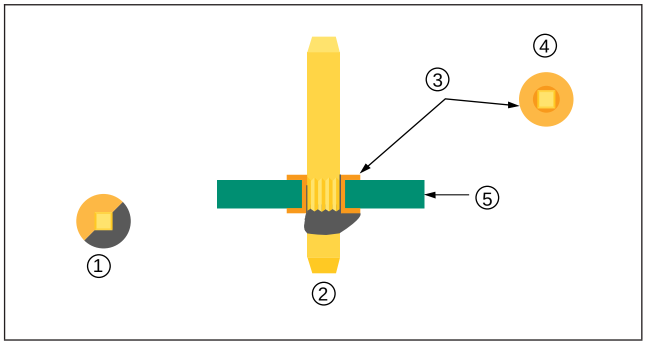


Figure 4-42

1. Bottom view
2. Side view
3. Land
4. Top view
5. PCB

Acceptable – Class 1,2

- Solder fillet or coverage (protrusion side) is present on two adjacent sides of the pin.

Acceptable – Class 3

- A 330° solder fillet is evident on the protrusion side of the assembly.

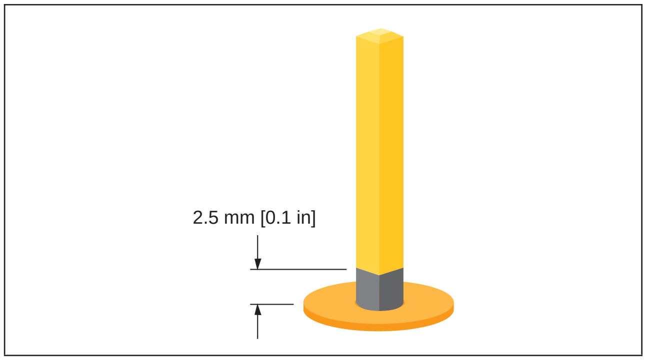


Figure 4-43

Acceptable – Class 1

- Solder wicking is permitted above 2.5 mm [0.1 in] on sides of pins provided there is no solder buildup that interferes with subsequent attachments to the pin.

Acceptable – Class 2,3

- Solder wicking on sides of pins is less than 2.5 mm [0.1 in], provided the solder does not interfere with subsequent attachments to the pin.

4.3.2.1 Press Fit Pins – Soldering (cont.)

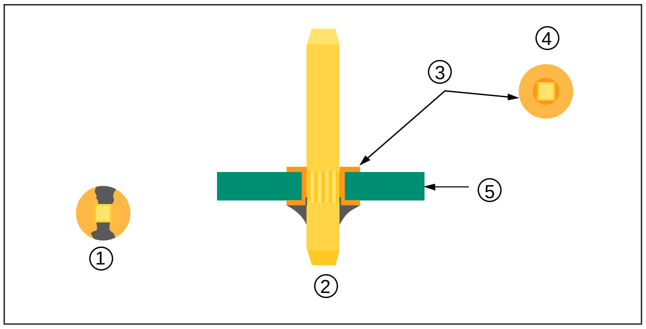


Figure 4-44

1. **Bottom view**
2. **Side view**
3. **Land**
4. **Top view**
5. **PCB**

Defect – Class 1,2

- Solder fillet or coverage is evident on less than two adjacent sides of the pin on the protrusion side.

Defect – Class 3

- Less than 330° solder fillet on the protrusion side of the assembly.

Defect – Class 1,2,3

- Solder build up interferes with subsequent attachments to the pin.

Defect – Class 2,3

- Solder wicking exceeds 2.5 mm [0.1 in].

4.4 Wire Bundle Securing

Additional criteria can be found in IPC/WHMA-A-620.

4.4.1 Wire Bundle Securing – General

Note: Do not subject wax impregnated lacing tape to cleaning solvents. Beeswax is unacceptable for Class 3.

Figure 4-45

Target – Class 1,2,3

- Restraining devices are neat and tight, and spaced to keep the wires secured in a tight neat bundle.
- Restraining devices do not move.
- Restraining devices do not cause noticeable indentation or distortion of the wires of the assembly.

4.4.1 Wire Bundle Securing – General (cont.)

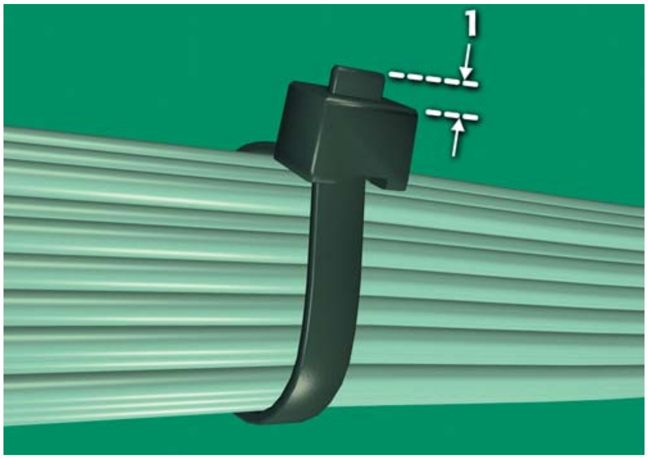


Figure 4-46

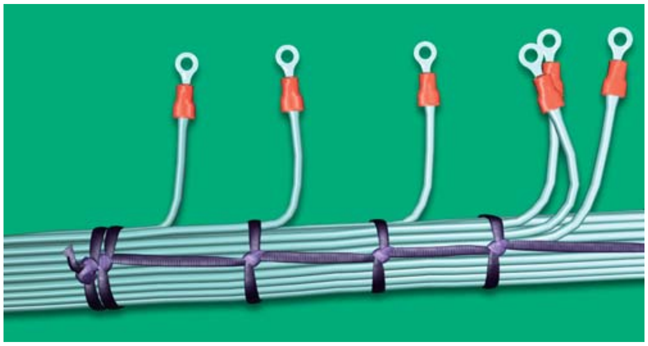


Figure 4-47

Acceptable – Class 1,2,3

- The end of the tie wrap/strap, see Figure 4-46:
  - Protrudes a maximum of one tie wrap/strap thickness.
  - Is cut reasonably square to the face of the wrap.
- The wires are secured in the wire bundle.
- Lacing or tie wraps/straps are placed on both sides of a wire breakout.
- Spot tie wraps/straps are neat and tight, see Figure 4-47.
- The wires are secured in the wire bundle.
- Square knot, surgeons knot or other approved knot is used to secure the lacing.
- Restraining device does not have any longitudinal movement, but may rotate.

4.4.1 Wire Bundle Securing – General (cont.)

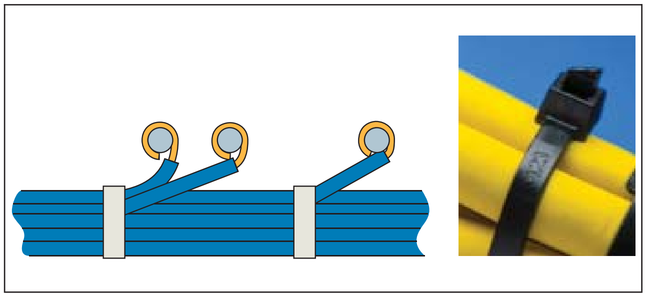


Figure 4-48

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- The wire is under stress at the wrap, see Figure 4-48 left side.
- Spot ties or wraps/straps are under sleeving or markers.
- Cut end of tie wrap/strap is greater than one wrap/strap thickness, see Figure 4-48 right side.

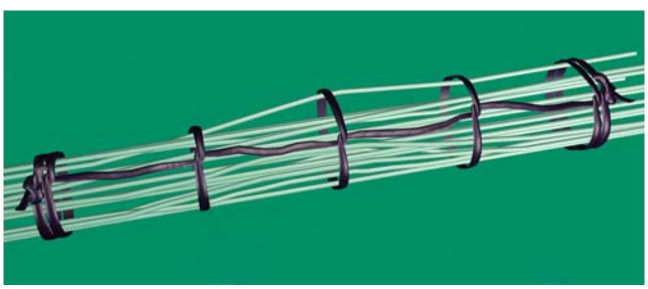


Figure 4-49

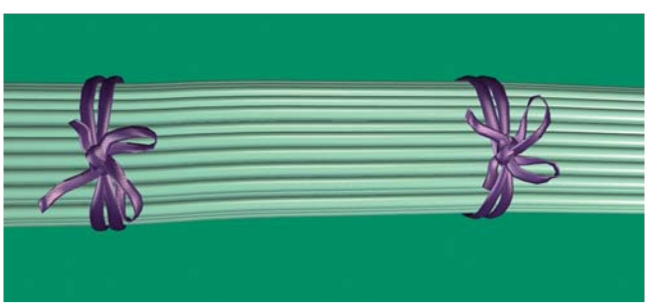


Figure 4-50

Defect – Class 1,2,3

- Spot tie wrap/strap or knot is loose.
- Spot tie wrap/strap cuts into the insulation.
- Wire bundle is loose.
- Cable tied with an improper knot. This tie may eventually loosen.
- Bundle is distorted by the restraining devices.
- Insulation is compressed by more than 20% (see 6.2.1) or damaged by the restraining device.
- Restraining devices move longitudinally.

4.4.2 Wire Bundle Securing – Lacing

Lacing differs from cable ties because it is a continuous lace. Lacing has closer spacing than cable ties. Criteria for cable ties apply to lacing.

Note: Do not subject wax impregnated lacing tape to cleaning solvents. Beeswax is unacceptable for Class 3.

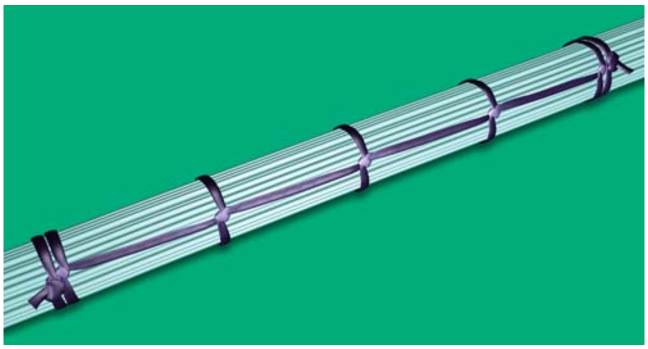


Figure 4-51

Acceptable – Class 1,2,3

- Lacing begins and ends with a locking knot.
- Lacing is tight and wires are kept secure in a neat bundle.

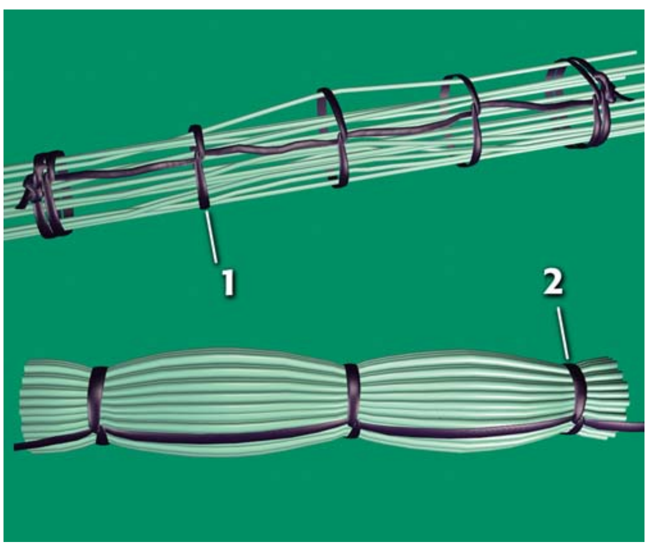


Figure 4-52

Defect – Class 1,2,3

- Lacing is loose, leaving wires loose in the wire bundle (1).
- Wire insulation is damaged, see 6.2.1.

4.4.2.1 Wire Bundle Securing – Lacing – Damage

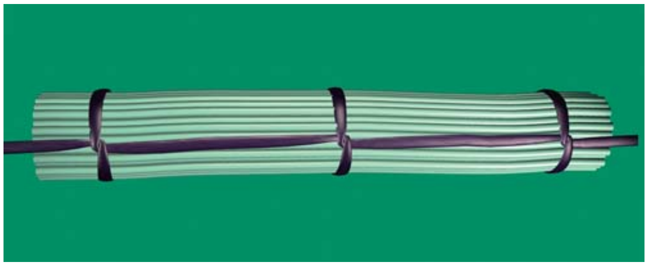


Figure 4-53

Target – Class 1,2,3

- Restraining devices are not worn, frayed, nicked, or broken in any location.
- Restraining devices do not have sharp edges that may be a hazard to personnel or equipment.

Acceptable – Class 1,2

- Restraining devices exhibit minor fraying, nicks, or wear of less than 25% of the device thickness.

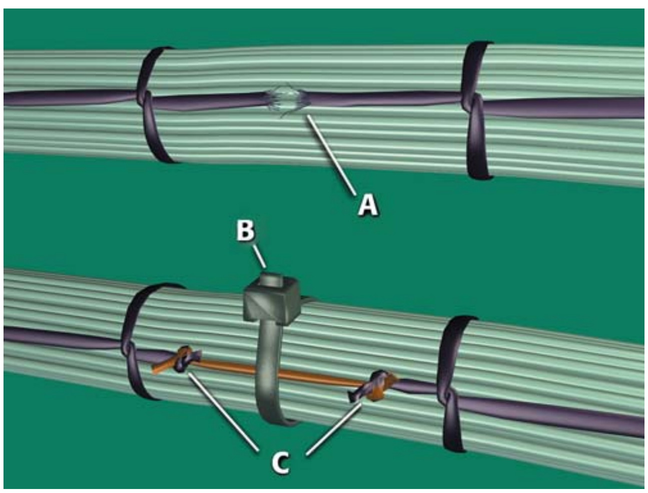


Figure 4-54

Defect – Class 1,2

- Damage or wear to restraining device greater than 25% of the device thickness, see Figure 4-54-A.

Defect – Class 3

- Damage or wear to restraining device, see Figure 4-54-A.
- Cut end of lacing has not been heat seared.
- Heat searing touches knot.
- Ends of lacing tape is frayed.

Defect – Class 1,2,3

- Sharp edges that are a hazard to personnel or equipment, see Figure 4-54-B.
- Broken lacing ends are not tied off using a square knot, surgeons knot, or other approved knot, see Figure 4-54-C.

4.5 Routing – Wires and Wire Bundles

These criteria are applicable to single wires or wire bundles.

Wires in wire bundles are positioned to minimize crossover and maintain a uniform appearance.

4.5.1 Routing – Wires and Wire Bundles – Wire Crossover

Figure 4-55

Target – Class 1,2,3

- Wire lay is essentially parallel to the axis of the bundle with no crossover.
- Coaxial cable secured with tie wraps/straps.

Acceptable – Class 1,2,3

- Wires twist and crossover, but bundle is essentially uniform in diameter.

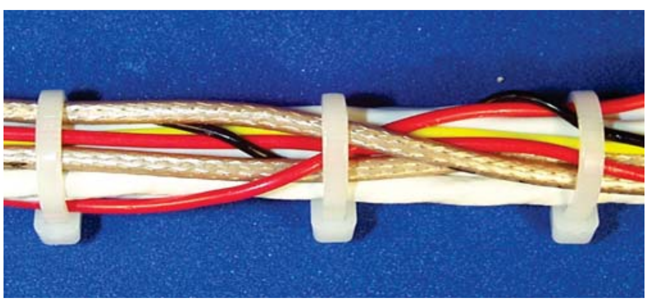


Figure 4-56

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wires twist and crossover underneath a tie wrap/strap.

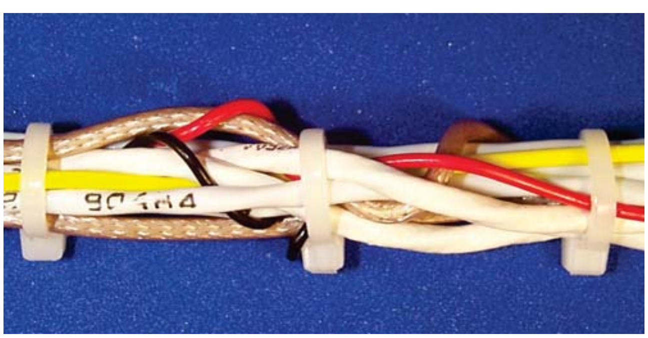


Figure 4-57

Acceptable – Class 1
Defect – Class 2,3

- Bundle is not uniform in diameter.
- Excessive crossover.

Defect – Class 1,2,3

- Any kinks that violate minimum bend radius.
- Wire insulation is damaged, see 6.2.1.

4.5.2 Routing – Wires and Wire Bundles – Bend Radius

Bend radius is measured along the inside curve of the wire or wire bundles.

The minimum bend radius of a harness assembly **shall not** be less than whichever wire/cable in the assembly has the largest bend radius defined in Table 4-1.

Table 4-1 Minimum Bend Radius Requirements

Cable Type	Class 1	Class 2	Class 3
Coaxial Flexible Cable[3]	10X OD[1]	10X OD[1]	10X OD[1]
Coaxial Fixed Cable[2]	5X OD[1]	5X OD[1]	5X OD[1]
Semi-rigid Coax	Not less than manufacturer's stated minimum bend radius		
Cable bundles with coax cables	5X OD[1]	5X OD[1]	5X OD[1]
Cable bundles with no coax cables	2X OD[1]	2X OD[1]	2X OD[1]
Ethernet cable	4X OD[1]	4X OD[1]	4X OD[1]
Shielded Wires and Cables	No Requirement Established		5X OD[1]
Unshielded Cable	No Requirement Established		3X OD for ≤ AWG 10 5X OD for > AWG 10
Insulated wire and flat ribbon cable	2X OD[1]	2X OD[1]	2X OD[1]
Polyimide Insulated Wires (Shielded or Unshielded)	No Requirement Established		10X OD[1]
Bare bus or enamel insulated wire	2X OD[1]	2X OD[1]	2X OD[1]
Fiber Optic Cable – Buffered and Jacketed Single Fiber	25 mm [1 in] or as specified by the manufacturer	25 mm [1 in] or as specified by the manufacturer	25 mm [1 in] or as specified by the manufacturer

Note 1: OD is the outer diameter of the wire or cable, including insulation.
Note 2: **Coaxial Fixed Cable** – Coaxial cable that is secured to prevent movement; not expected to have the cable repeatedly flexed during operation of the equipment.
Note 3: **Coaxial Flexible Cable** – Coaxial cable that is or may be flexed during operation of the equipment.

Acceptable – Class 1,2,3

- Minimum bend radius meets requirements of Table 4-1.

Defect – Class 1,2,3

- Bend radius is less than the minimum bend radius requirements of Table 4-1.

4.5.3 Routing – Wires and Wire Bundles – Coaxial Cable

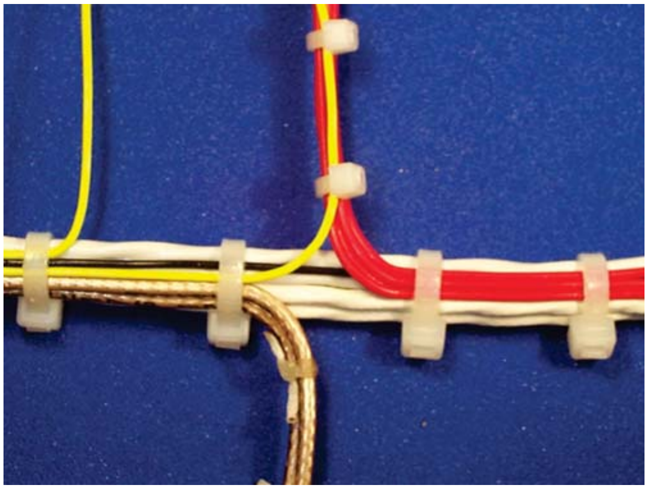


Figure 4-58

Acceptable – Class 1,2,3

- Inside bend radius meets the criteria of Table 4-1.

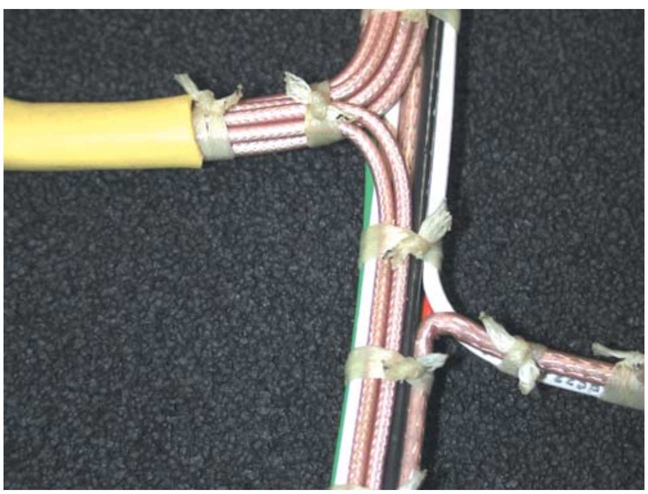


Figure 4-59

Defect – Class 1,2,3

- Inside bend radius does not meet the criteria of Table 4-1.

Defect – Class 3

- Tie wraps/straps that cause any deformation of coaxial cables.

4.5.4 Routing – Wires and Wire Bundles – Unused Wire Termination

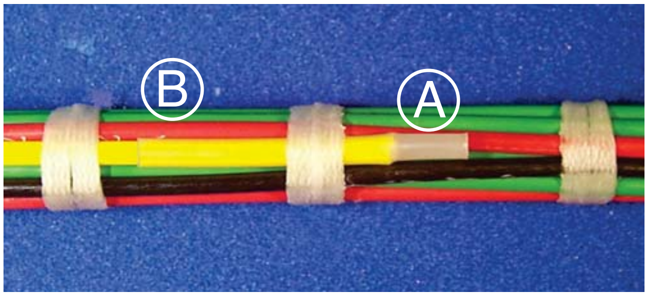


Figure 4-60

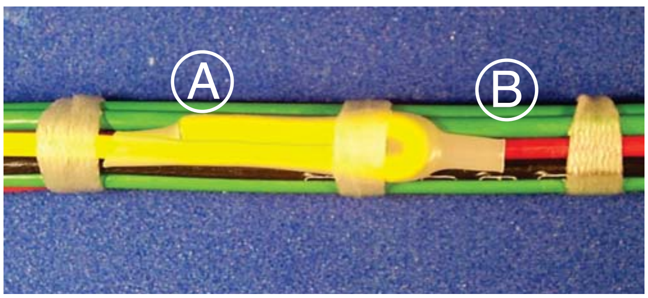


Figure 4-61

Target – Class 1,2,3

- Sleeving extends three wire diameters past end of wire, see Figure 4-60-A.
- Unused wire is folded back and tied into the wire bundle, see Figure 4-61-A.

Acceptable – Class 1,2,3

- Ends of unused wires are covered with shrink sleeving, see Figure 4-60-A.
- Wire may extend straight down length of bundle, see Figure 4-60, or be folded back, see Figure 4-61-A.
- Sleeving extends at least two wire diameters beyond end of wire, see Figure 4-61-B.
- Sleeving extends onto the wire insulation for a minimum of four wire diameters or 6 mm [0.24 in], whichever is greater, see Figure 4-61-B-A.
- Unused wire is tied into the wire bundle.

Process Indicator – Class 2
Defect – Class 3

- Insulating sleeving extends beyond end of wire less than two wire diameters.
- Insulating sleeving extends onto wire insulation less than four wire diameters or 6 mm [0.24 in], whichever is greater.

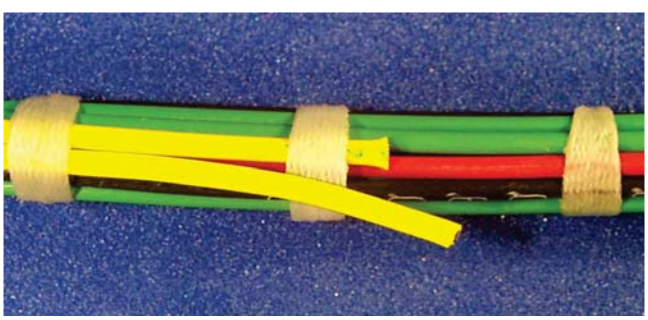


Figure 4-62

Defect – Class 1,2,3

- Ends of unused wires are exposed.
- Unused wire is not tied into the wire bundle.

4.5.5 Routing – Wires and Wire Bundles – Ties over Splices and Ferrules

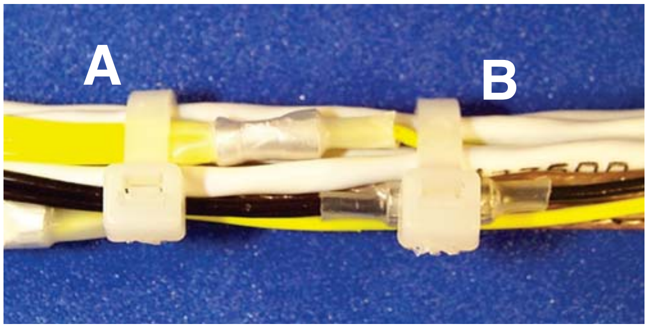


Figure 4-63

Acceptable – Class 1,2,3

- Tie wraps/straps are placed near splices or solder ferrules contained in the wire bundle.
- No stress on wires exiting splices, see Figure 4-63-A.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Tie wraps/straps are placed over splices or solder ferrules contained in the wire bundle, see Figure 4-63-B.

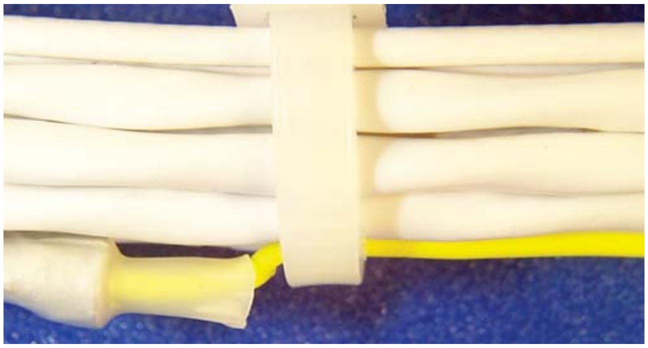


Figure 4-64

Figure 4-65

Defect – Class 1,2,3

- Tie wrap/strap is placing stress on the wire(s) exiting the splice.

5 Soldering

This section establishes the acceptability requirements for soldered connections of all types, e.g., SMT, terminals, through-hole, etc. Although Class 1, 2 and 3 applications and environments have been considered, the nature of the soldering process may dictate that an acceptable connection will have the same characteristics for all three classes, and an unacceptable connection would be rejected for all three classes.

Where appropriate, the type of soldering process used has been addressed specifically in the criteria description. In any case, the connection criteria apply regardless of which methods of soldering have been utilized, for example:

- Soldering irons.
- Resistance soldering apparatus.
- Induction, wave, or drag soldering.
- Reflow soldering.
- Intrusive soldering.

As an exception to the above, there are specialized soldering finishes, e.g., immersion tin, palladium, gold, etc., that require the creation of special acceptance criteria other than as stated in this document. The criteria should be based on design, process capability, and performance requirements.

Wetting cannot always be judged by surface appearance. The wide range of solder alloys in use may exhibit from low or near zero degree contact angles to nearly 90° contact angles as typical. The acceptable solder connection **shall** indicate evidence of wetting and adherence where the solder blends to the soldered surface.

The solder connection wetting angle (solder to component and solder to PCB termination) **shall not** exceed 90°, see Figure 5-1 A, B. As an exception, the solder connection to a termination may exhibit a wetting angle exceeding 90° (convex), see Figure 5-1 C, D, when it is created by the solder contour extending over the edge of the solderable termination area or solder mask.

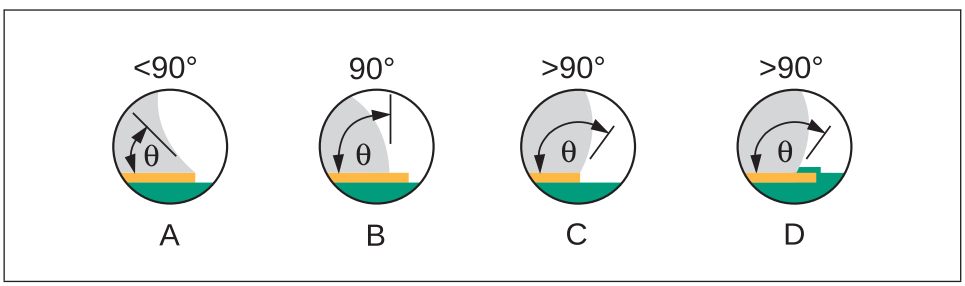


Figure 5-1

5 Soldering (cont.)

The following topics are addressed in this section:

5.1 Soldering Acceptability Requirements

See 5.2 for examples of soldering anomalies.

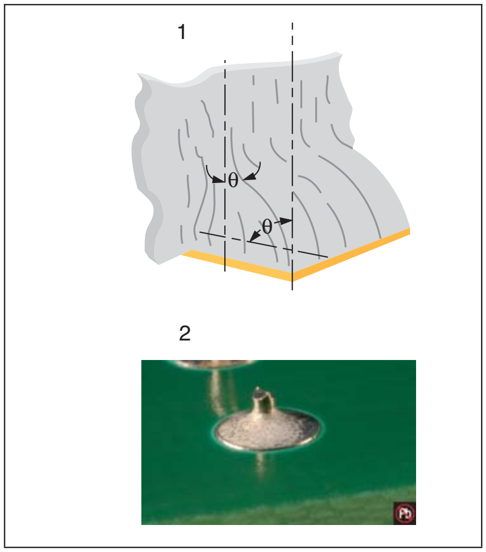


Figure 5-2

Figure 5-3

Target – Class 1,2,3

- Solder fillet appears generally smooth and exhibits good wetting of the solder to the parts being joined.
- Outline of the lead is easily determined.
- Solder at the part being joined creates a feathered edge.
- Fillet is concave in shape.

Acceptable – Class 1,2,3

- There are materials and processes, e.g., lead-free alloys and slow cooling with large mass PCBs, that may produce dull matte, gray, or grainy appearing solders that are normal for the material or process involved. These solder connections are acceptable.
- The solder connection wetting angle (solder to component and solder to PCB termination, see Figure 5-2) do not exceed 90°, see Figure 5-1 A, B.
  - As an exception, the solder connection to a termination may exhibit a wetting angle exceeding 90°, see Figure 5-1 C, D when it is created by the solder contour extending over the edge of the solderable termination area or solder mask.

The primary difference between the solder connections created with processes using tin-lead alloys and processes using lead-free alloys is related to the visual appearance of the solder. This Standard provides visual criteria for inspections of both tin-lead and lead-free connections. In this Standard, figures specific to lead-free connections will be identified with the symbol shown in Figure 5-3.

Acceptable lead-free and tin-lead connections may exhibit similar appearances but lead-free alloys are more likely to have surface roughness (grainy or dull) or greater wetting contact angles.

Solder fillet criteria for SnPb and lead-free alloys are the same.

Typical tin-lead connections have from a shiny to a satin luster, generally smooth appearance and exhibit wetting as exemplified by a concave meniscus between the objects being soldered. High temperature solders may have a dull appearance. Touch-up (rework) of soldered connections is performed with discretion to avoid causing additional problems, and to produce results that exhibit the acceptability criteria of the applicable class.

5.2 Soldering Anomalies

5.2.1 Soldering Anomalies – Exposed Basis Metal

Some printed circuit board and conductor finishes have different wetting characteristics and may exhibit solder wetting only to specific areas. Exposed basis metal or surface finishes should be considered normal under these circumstances, provided the achieved wetting characteristics of the solder connection areas are acceptable.

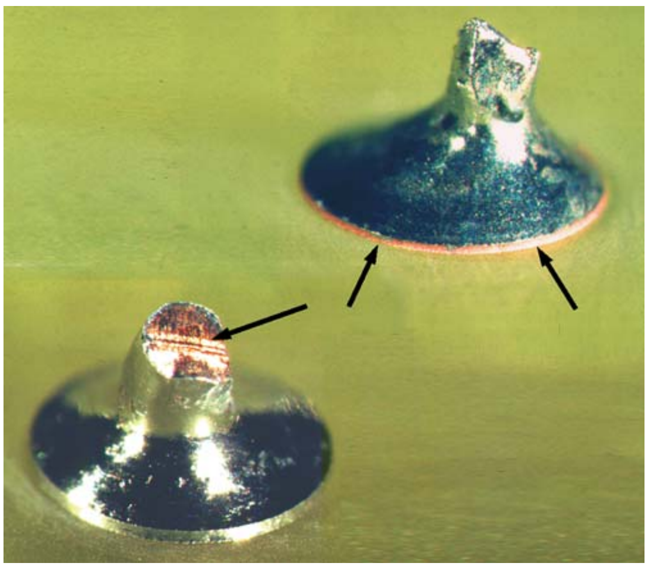


Figure 5-4

Acceptable – Class 1,2,3

- Exposed basis metal on:
  - Vertical conductor edges.
  - Cut ends of component leads or wires.
  - Organic Solderability Preservative (OSP) coated lands.
- Exposed surface finishes that are not part of the required solder fillet area.

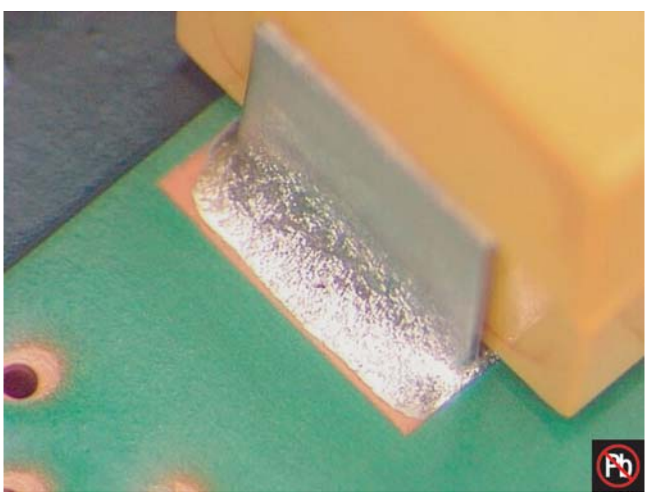


Figure 5-5

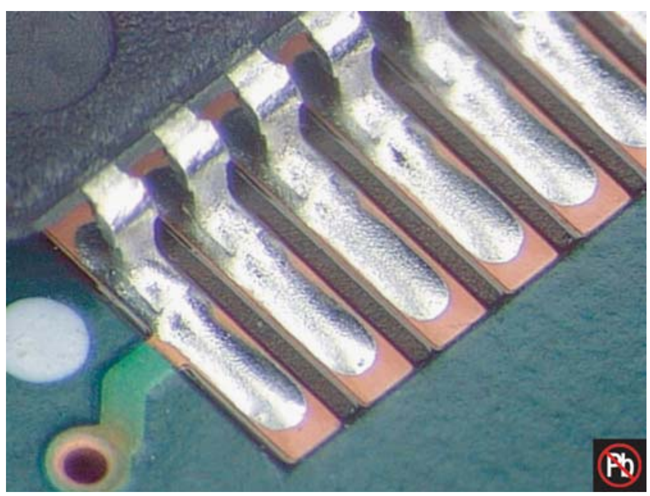


Figure 5-6

5.2.1 Soldering Anomalies – Exposed Basis Metal (cont.)

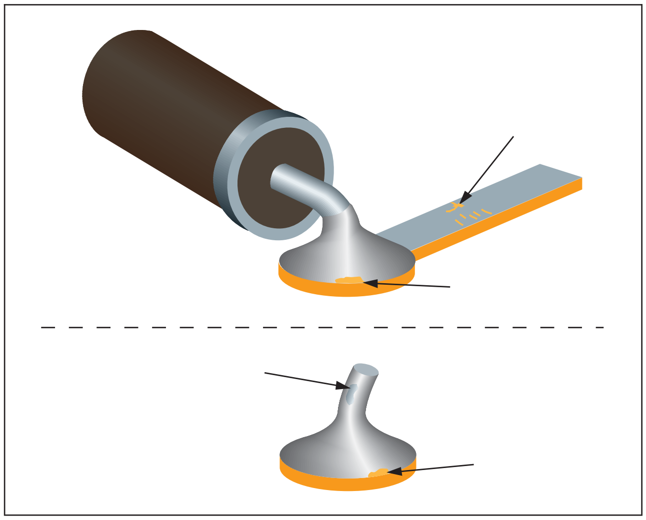


Figure 5-7

Acceptable – Class 1
Process Indicator – Class 2,3

- Exposed basis metal on component leads, conductors or land surfaces from nicks or scratches provided conditions do not exceed the requirements of 7.1.2.4 and 8.2.2 for leads and 10.3.1 for conductors and lands.

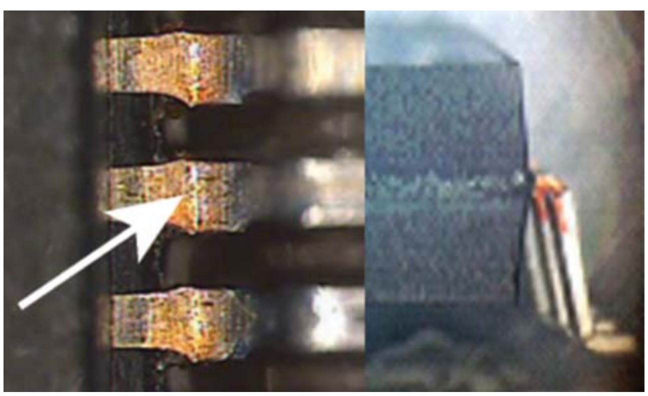


Figure 5-8

Defect – Class 1,2,3

- Exposed basis metal on component leads (see Figure 5-8 arrow), conductors or land surfaces from nicks, scratches or other conditions exceed the requirements of 7.1.2.4 and 8.2.2 for leads and 10.3.1 for conductors and lands.

5.2.2 Soldering Anomalies – Pin Holes/Blow Holes

Figure 5-9

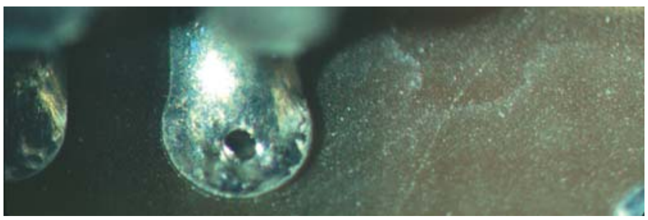


Figure 5-10

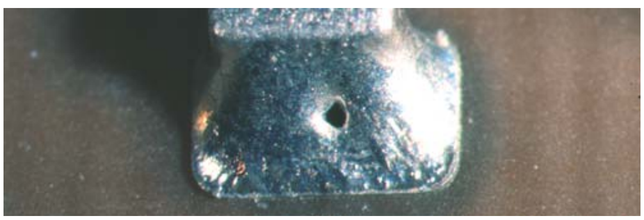


Figure 5-11

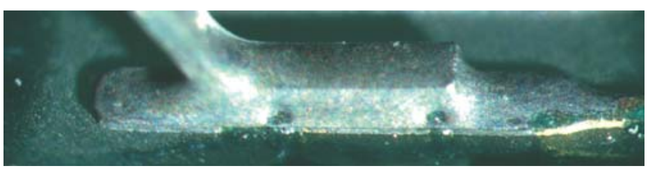


Figure 5-12

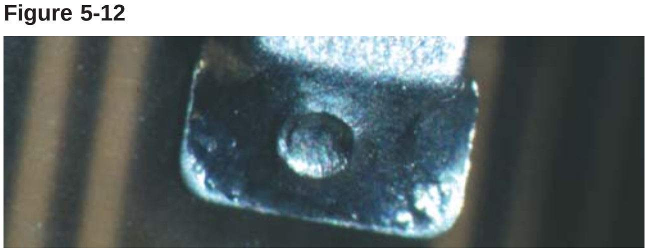


Figure 5-13

Acceptable – Class 1
Process Indicator – Class 2,3

- Blowholes, see Figures 5-9 and 5-10 pinholes, see Figure 5-11 voids, see Figures 5-12, 13, etc., providing the solder connection meets all other requirements.

Defect – Class 1,2,3

- Solder connections where pin holes, blow holes, voids, etc., reduce the connections below minimum requirements (not shown).

5.2.3 Soldering Anomalies – Reflow of Solder Paste

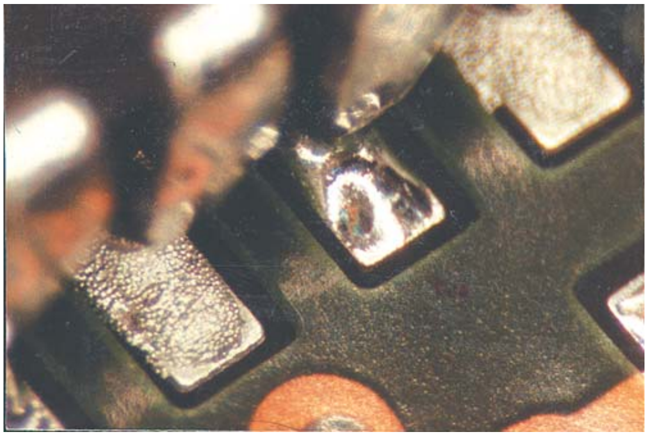


Figure 5-14

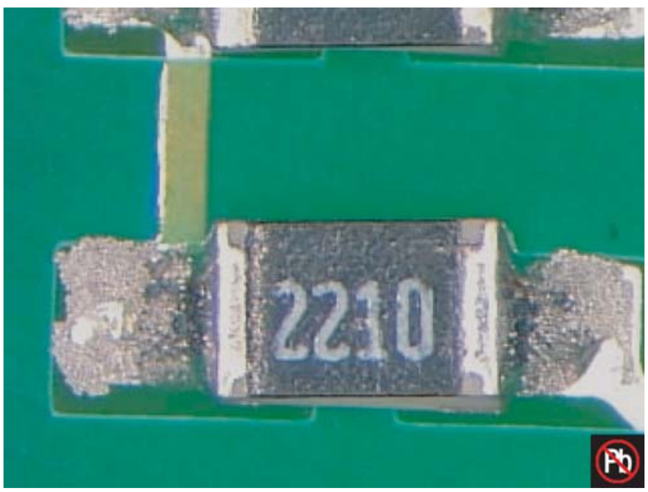


Figure 5-15

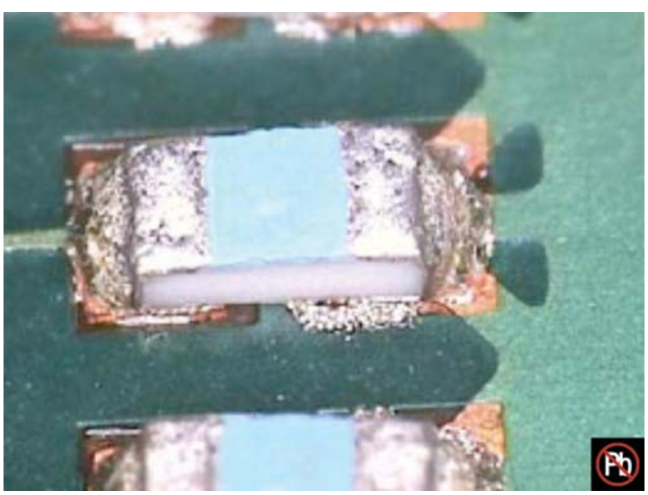


Figure 5-16

Defect – Class 1,2,3

- Incomplete reflow of solder paste.

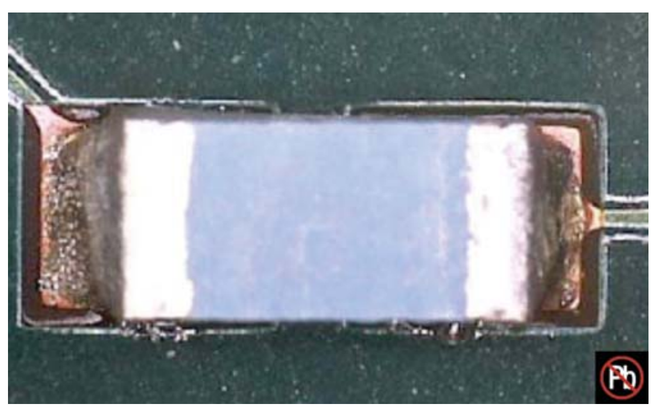


Figure 5-17

5.2.4 Soldering Anomalies – Nonwetting

IPC-T-50 defines nonwetting as the inability of molten solder to form a metallic bond with the basis metal. In this Standard, that includes surface finishes, see 5.2.1.

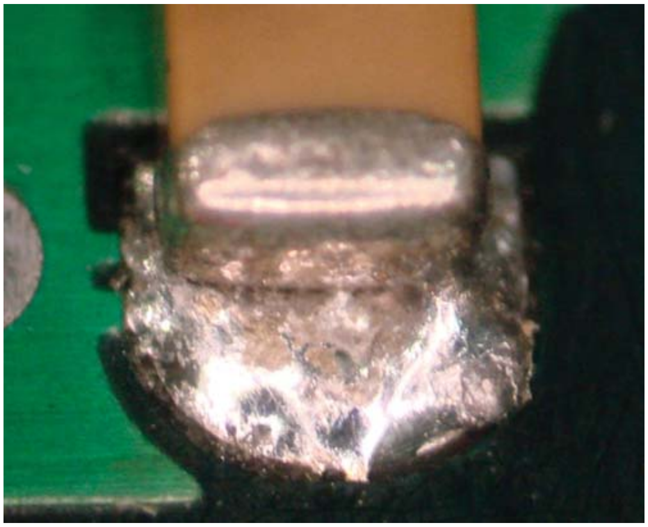


Figure 5-18

Defect – Class 1,2,3

- Solder has not wetted to the land or termination where solder is required, see Figures 5-18, 5-19, 5-20 component terminations, Figure 5-21 shield termination, and Figure 5-22 wire termination.
- Solder coverage does not meet requirements for the termination type.

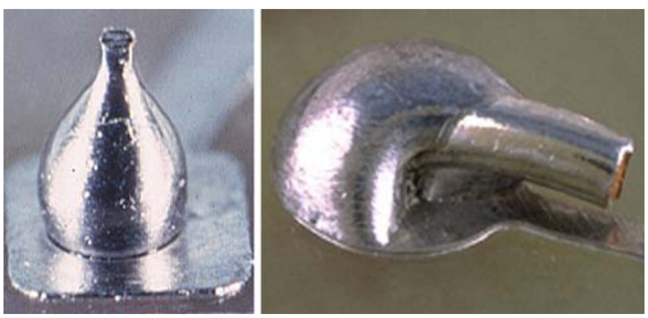


Figure 5-19

Figure 5-20

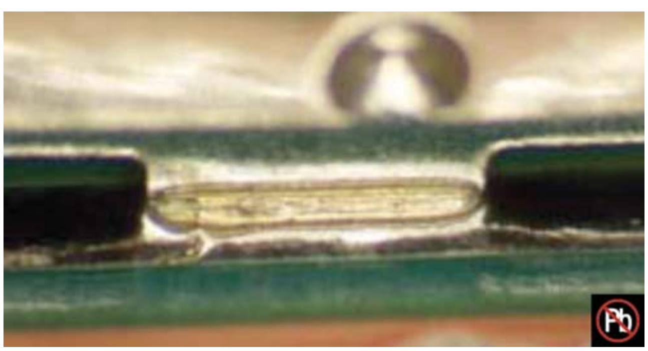


Figure 5-21

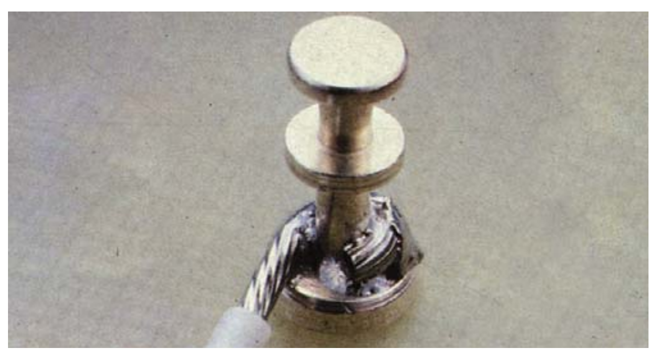


Figure 5-22

5.2.5 Soldering Anomalies – Cold/Rosin Connection

IPC-T-50 defines cold solder connection as ''A solder connection that exhibits poor wetting, and that is characterized by a grayish, porous appearance. (This is due to excessive impurities in the solder, inadequate cleaning prior to soldering, and/or the insufficient application of heat during the soldering process.)'' A rosin solder connection is defined in IPC-T-50 as ''A solder connection that has practically the same appearance as does a cold solder connection, but that also shows evidence of entrapped rosin separating the surfaces to be joined.''

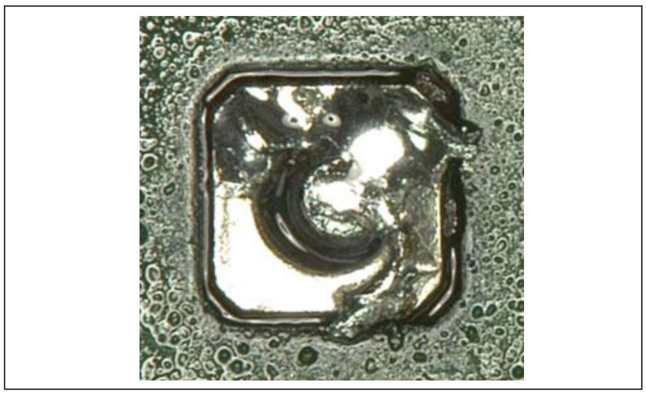


Figure 5-23

Defect – Class 1,2,3

- Nonwetting or incomplete wetting as a result of a cold, see Figure 5-23, or rosin (not shown) connection.

5.2.6 Soldering Anomalies – Dewetting

IPC-T-50 defines dewetting as a condition that results when molten solder coats a surface and then recedes to leave irregularly-shaped mounds of solder that are separated by areas that are covered with a thin film of solder and with the basis metal or surface finish not exposed.

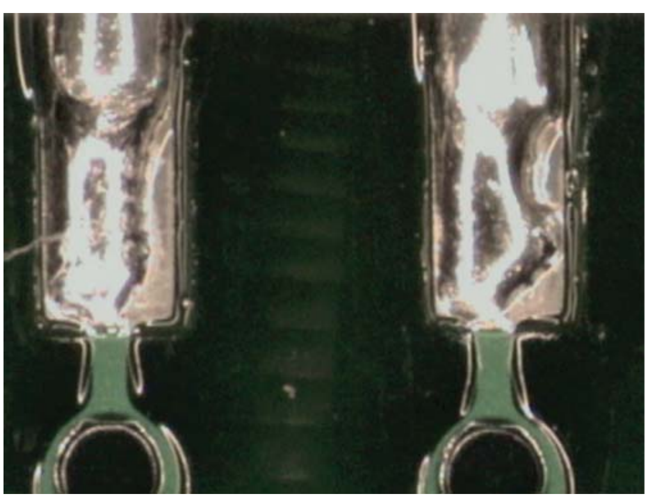


Figure 5-24

Defect – Class 1,2,3

- Evidence of dewetting that causes the solder connection to not meet the fillet requirements.

5.2.6 Soldering Anomalies – Dewetting (cont.)

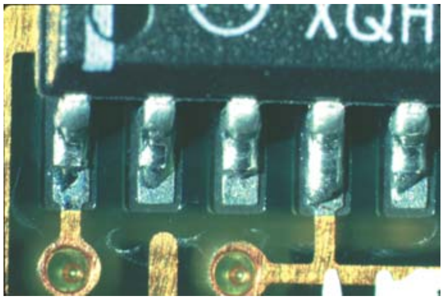


Figure 5-25

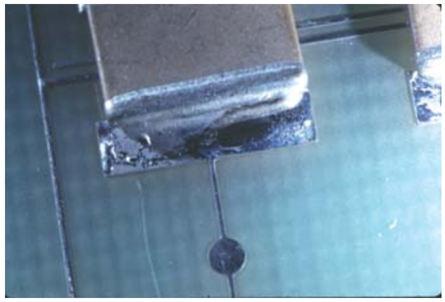


Figure 5-26

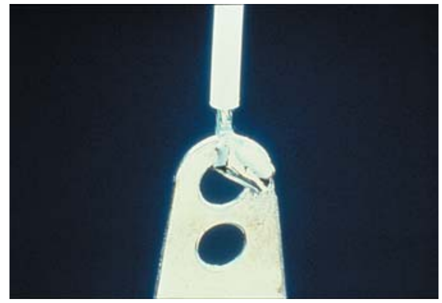


Figure 5-27

5.2.7 Soldering Anomalies – Excess Solder

Figure 5-28

Metal Lidded Components

Solder splashes or tinning on a metalized package body, see Figure 5-28, should be evaluated for impact upon hermetic and radiation hardening performance of the component considering the intended performance environment. Solder splashes on the metalized surfaces may be acceptable if the extended electrical performance is not required or compromised.

In the following criteria, the words ‘‘entrapped,’’ ‘‘encapsulated,’’ and ‘‘attached’’ are intended to mean that the service environment of the product will not cause particulate matter to become dislodged. The method to determine if the FOD could break loose in the service environment should be agreed between the Manufacturer and User.

5.2.7.1 Soldering Anomalies – Excess Solder – Solder Balls

Solder balls are spheres of solder that remain after the soldering process. This includes small balls of the original solder paste metal screen size that have splattered around the connection during the reflow process.

The method used to determine if conductive particulate matter (solder balls, fines, or splash) will become dislodged should be as agreed between Manufacturer and User.

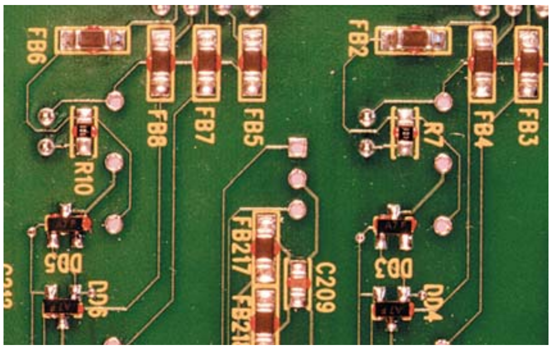


Figure 5-29

Target – Class 1,2,3

- No evidence of solder balls on the printed wiring assembly.

Figure 5-30

Acceptable – Class 1,2,3

- Solder balls are entrapped, encapsulated or attached, e.g., in no-clean residue, with conformal coating, soldered to a metal surface, embedded in the solder mask or under a component.
- Solder balls do not violate minimum electrical clearance.

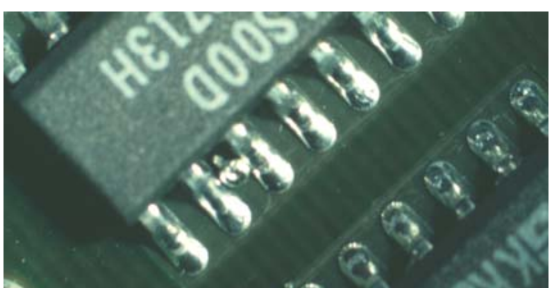


Figure 5-31

Defect – Class 1,2,3

- Solder balls are not entrapped, encapsulated or attached or can become dislodged in the service environment.
- Solder balls violate minimum electrical clearance.

Figure 5-32

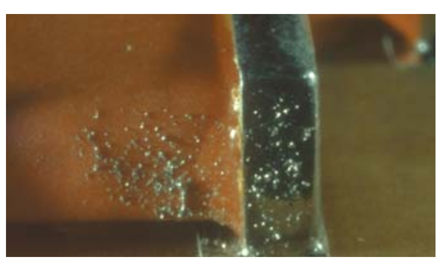


Figure 5-33

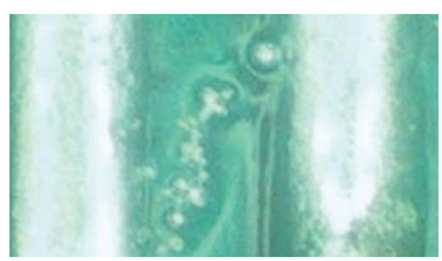


Figure 5-34

5.2.7.2 Soldering Anomalies – Excess Solder – Bridging

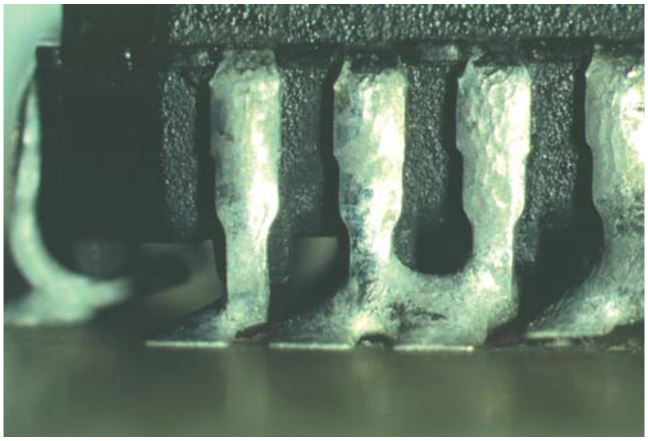


Figure 5-35

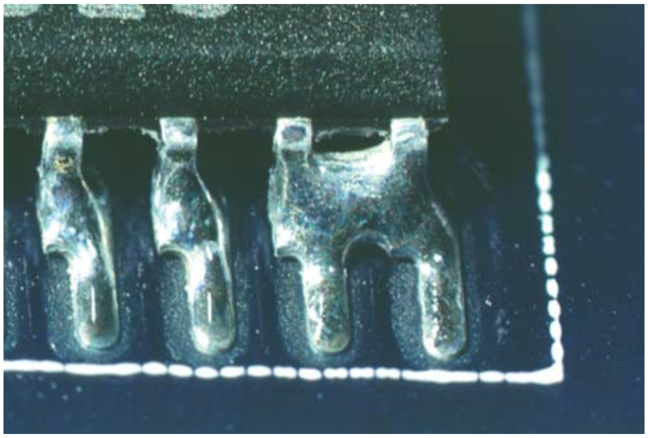


Figure 5-36

Defect – Class 1,2,3

- A solder connection across conductors that should not be joined.
- Solder has bridged to adjacent noncommon conductor or component.

Figure 5-37

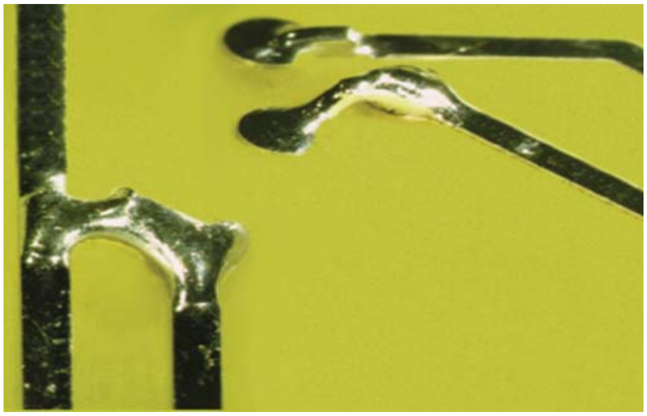


Figure 5-38

5.2.7.3 Soldering Anomalies – Excess Solder – Solder Webbing/Splashes

Target – Class 1,2,3

- No solder splashes or webbing.

Acceptable – Class 1,2,3

- Solder splashes or metallic particles meet the following criteria:
  – Attached/entrapped/encapsulated on the PCA surface or solder mask, or soldered to metallic surface.
  – Do not violate minimum electrical clearance.

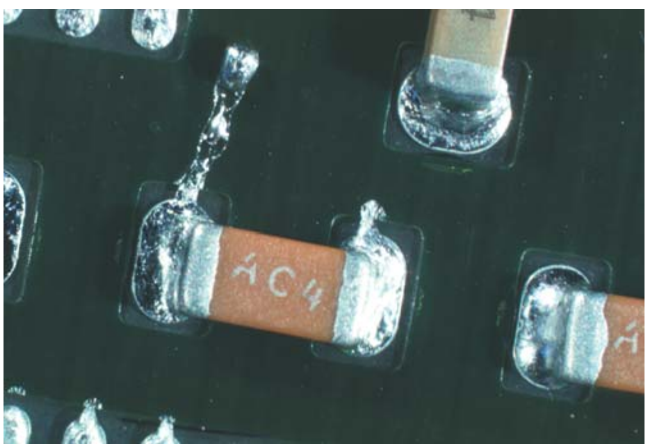


Figure 5-39

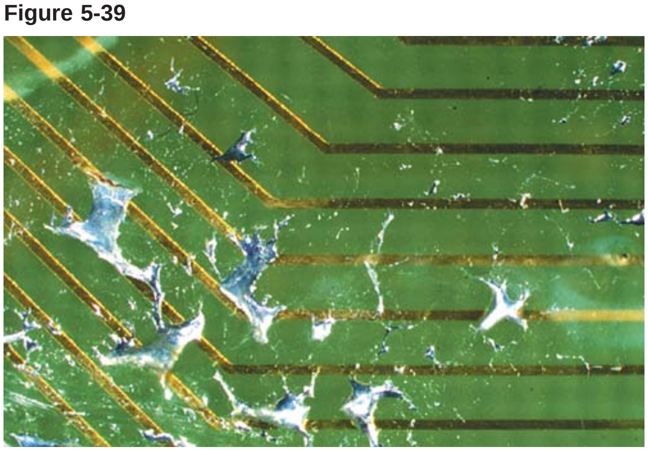


Figure 5-40

Defect – Class 1,2,3

- Solder webbing.
- Solder splashes that are not attached, entrapped, encapsulated.
- Solder splashes on metal component surfaces impact form, fit or function, e.g., damages lid seal on hermetic components.
- Violate minimum electrical clearance.

5.2.8 Soldering Anomalies – Disturbed Solder

Surface appearance with cooling lines as shown in Acceptable Figures 5-41 (lead-free) and 5-42 (SnPb) are more likely to occur in lead-free alloys and are not a disturbed solder condition.

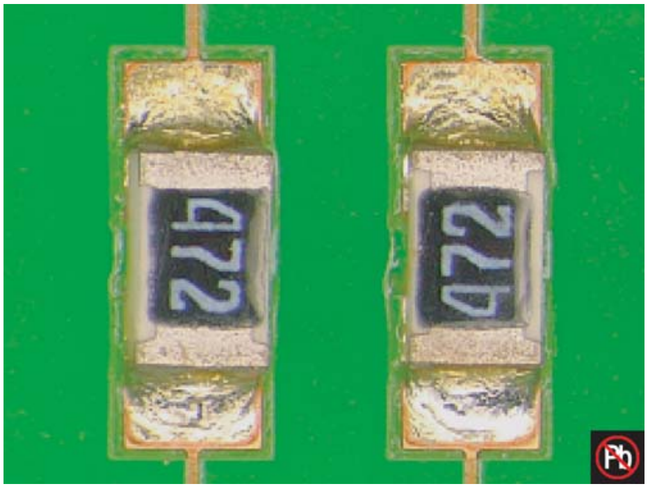


Figure 5-41

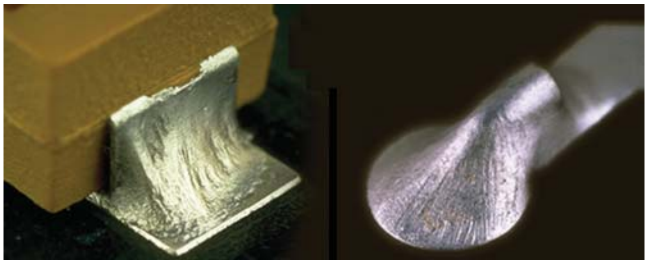


Figure 5-42

Acceptable – Class 1,2,3

- Lead-free and tin-lead solder connections exhibit:
  - Cooling lines, see Figure 5-41.
  - Secondary reflow, see Figure 5-42.

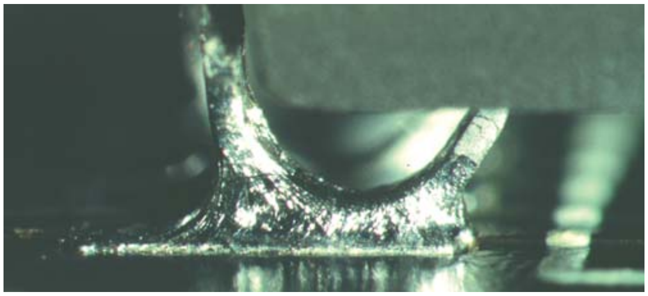


Figure 5-43

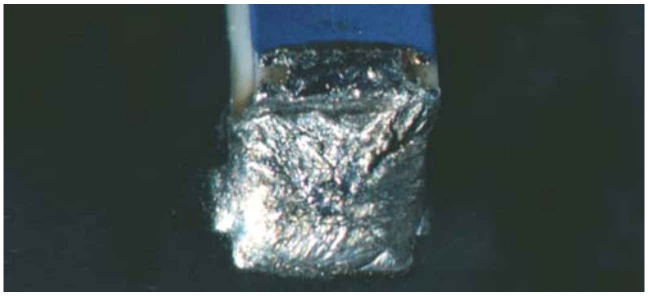


Figure 5-44

Defect – Class 1,2,3

- Disturbed solder joint characterized by uneven surface from movement in the solder connection during cooling.

5.2.9 Soldering Anomalies – Fractured Solder

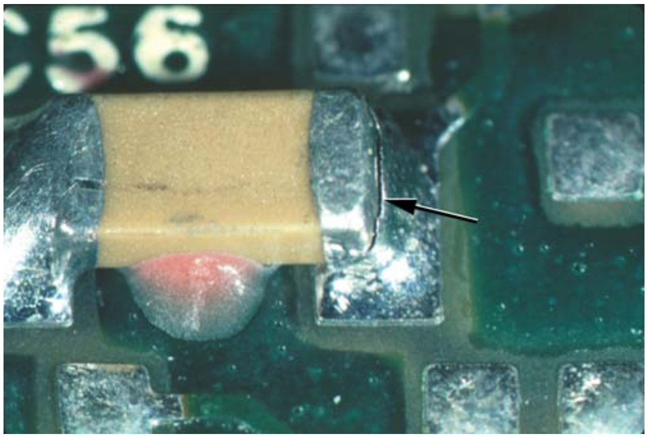


Figure 5-45

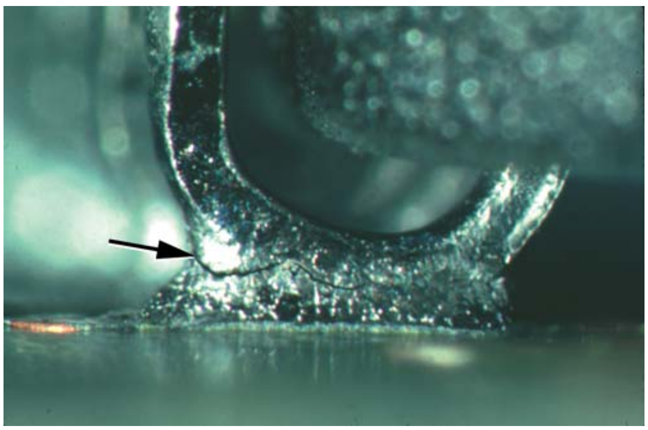


Figure 5-46

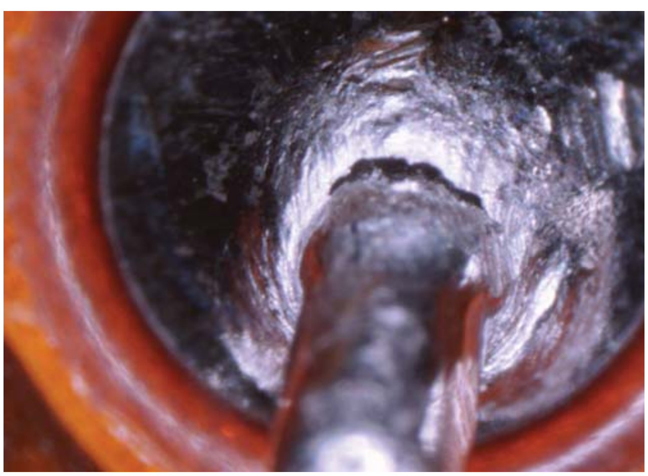


Figure 5-47

Defect – Class 1,2,3

- Fractured or cracked solder.

5.2.10 Soldering Anomalies – Solder Projections

Figure 5-48

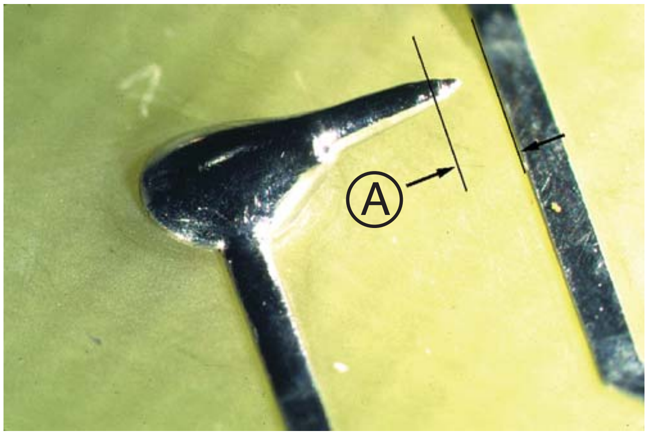


Figure 5-49

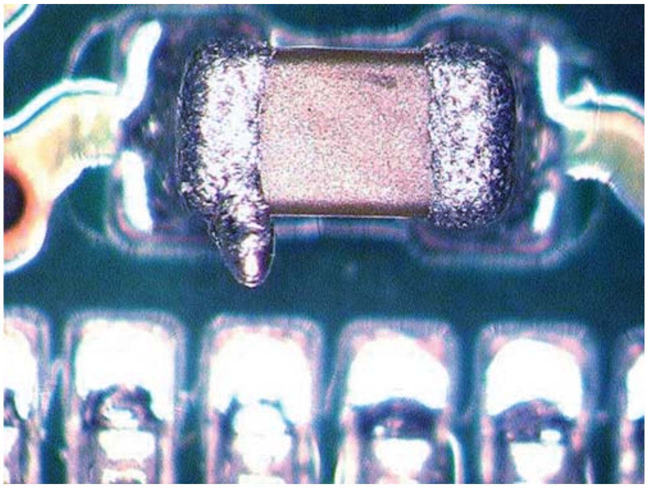


Figure 5-50

Defect – Class 1,2,3

- Solder projection violates assembly maximum height requirements or lead protrusion requirements, see Figure 5-48.
- Projection violates minimum electrical clearance, see Figures 5-49-A and 5-50.

5.2.11 Soldering Anomalies – Lead-Free Fillet Lift

These criteria are applicable to plated through-hole connections.

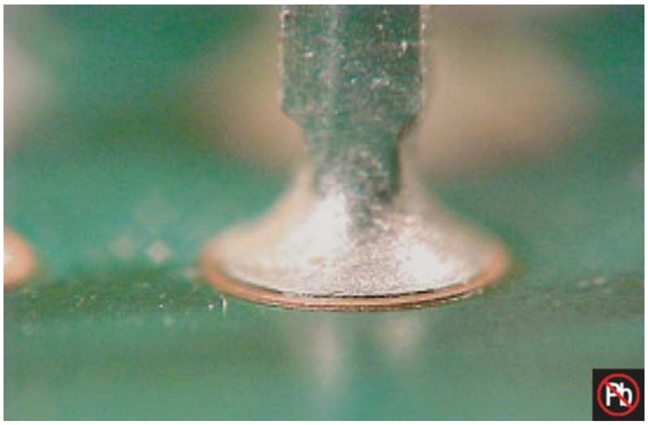


Figure 5-51

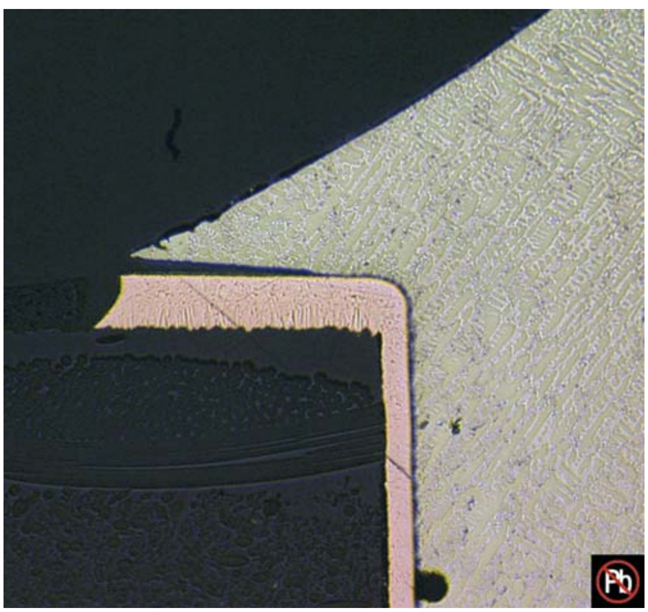


Figure 5-52

Acceptable – Class 1,2.3

- Fillet Lifting – separation of the bottom of the solder and the top of the land. The connection with the lifted fillet must meet all other acceptance criteria.

Note: (From IPC-T-50) Fillet lifting is the phenomenon in which the solder fillet is lifted off from the land on a board mainly during the flow solder process. The phenomenon is more likely to occur on the primary (solder destination) side rather than on the secondary (solder source) side which is exposed to flow soldering. Figure 5-52 is a microsection view of fillet lifting.

There is no defect associated with this anomaly.

Note: See 10.3.2 for criteria related to land damage that may be caused by fillet lifting.

5.2.12 Soldering Anomalies – Lead-Free Hot Tear/Shrink Hole

There is no defect associated with the anomaly provided the connection meets all other acceptance criteria. Figures 5-53 and 5-54 are examples of hot tear. Hot tear/shrinkage voids are generally found on the surface of the solder joint. The connection with the hot tear/shrinkage void **shall** meet all other acceptance criteria.

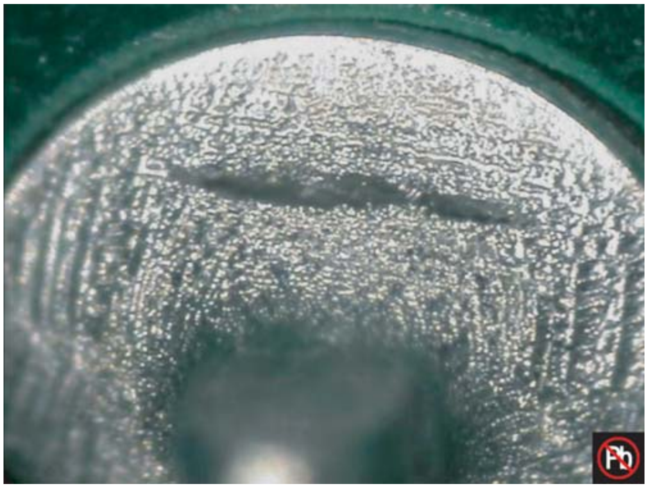


Figure 5-53

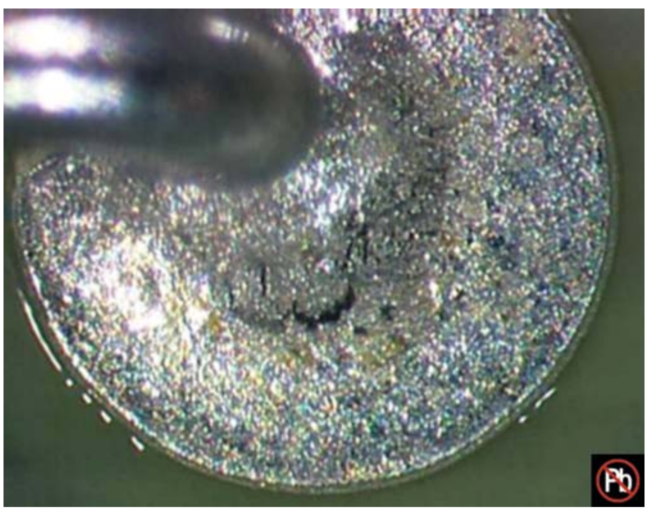


Figure 5-54

Acceptable – Class 1,2,3

- Hot Tear/Shrinkage Void – a crevice or void in the solder joint due to the solidification of the lead-free solder alloy during assembly process.

5.2.13 Probe Marks and Other Similar Surface Conditions in Solder Joints

Target – Class 1,2,3

- The solder joint is free of any probe marks and other similar surface conditions.

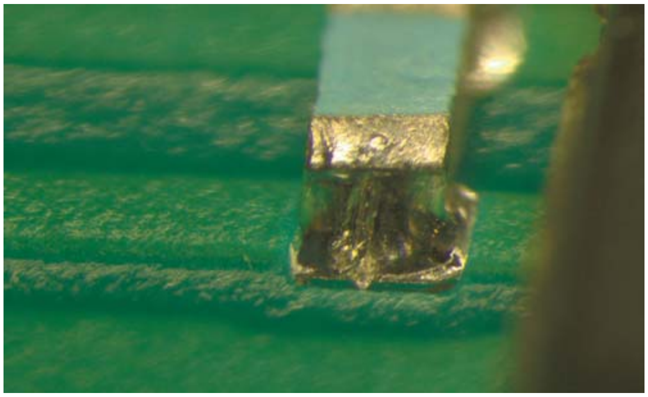


Figure 5-55

Acceptable – Class 1,2,3

- Probe marks and other similar surface conditions that do not violate other requirements.

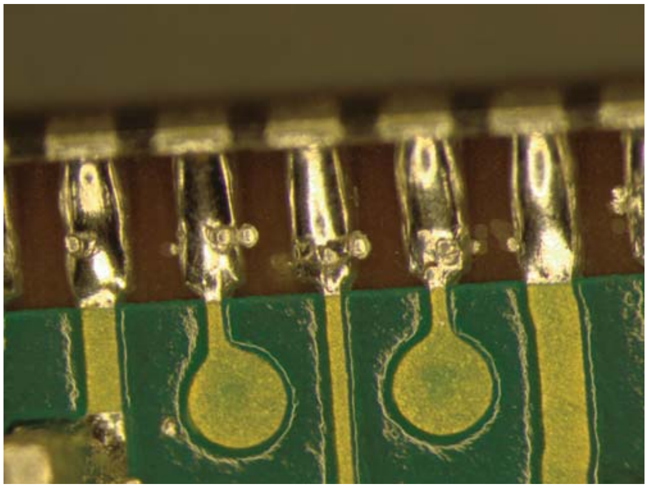


Figure 5-56

Defect – Class 1,2,3

- Probe marks and other similar surface conditions cause damage in excess of requirements.

5.2.14 Partially Visible or Hidden Solder Connections

A partially visible solder connection **shall** be inspected on the visible portion, and **shall** be compliant with the criteria stated herein for that type of connection. The non-visible portion of the connection should be maintained in accordance with Clause 1.6.

Note: Nondestructive evaluation (NDE) may be used or as agreed between Manufacturer and User to verify the specified dimensions that are not visible through normal visual means.

6 Terminal Connections

These criteria apply to both wires and component leads. The target wrap conditions achieve a mechanical connection between the lead/wire and the terminal sufficient to assure that the lead/wire does not move during the soldering operation. Typically the mechanical connection includes a 180° mechanical wrap to effect mechanical connection.

As an exception to the wrap conditions described above, it is acceptable when attaching leads/wires to bifurcated, slotted, pierced, punched or perforated terminals for the lead/wire to extend straight through the opening of the terminal with no wrap. Except for slotted terminals (6.10) leads/wires with no wrap need to be staked, bonded, or constrained to a degree that the attachment is mechanically supported, see 6.9.1 and 6.9.2. The purpose is to prevent transmission of shock, vibration, and movement of the attached wires that could degrade the solder connection.

The criteria in this section are grouped together in sixteen main subsections. Not all combinations of wire/lead types and terminal types can possibly be covered explicitly, so criteria is typically stated in general terms to apply to all similar combinations. For example, a resistor lead and a multistranded jumper wire connected to turret terminals have the same wrap and placement requirements, but only the multistranded wire could be subject to birdcaging.

In addition to the criteria in this section the criteria of Section 5 are applicable.

The following topics are addressed in this section:

6 Terminal Connections (cont.)

6.1 Swaged Hardware

This section contains criteria for the basic types of swaged hardware.

Terminals

Swaged hardware that overhangs the land is acceptable if it does not violate minimum electrical clearance, see 1.8.4.

Solderability

Plating and solderability of swaged hardware should be consistent with appropriate plating and solderability specifications. See EIA/IPC/JEDEC J-STD-002 and IPC J-STD-003 for solderability requirements.

6.1.1 Swaged Hardware – Terminals

This section shows mechanical assembly of turret and bifurcated terminals. Terminals that are to be soldered to a land may be mounted so that they can be turned by hand, but are vertically stable.

6.1.1.1 Swaged Hardware – Terminal Base to Land Separation

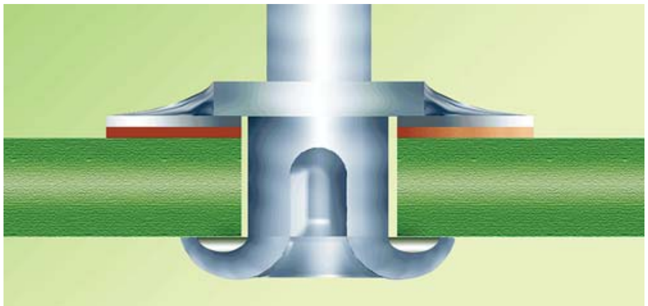


Figure 6-1

Target – Class 1,2,3

- Terminal base circumference is in full contact with the land, with no evidence of mechanical distortion of land.
- Terminal may be rotated by finger force once swaged.
- Terminal is vertically stable (no vertical movement).

Acceptable – Class 1,2,3

- Terminal may be rotated by finger force once swaged.
- Terminal is vertically stable (no vertical movement).

Acceptable – Class 1,2

- Terminal base circumference has more than 180° contact with the land, with separation not exceeding two land thicknesses.

Acceptable – Class 3

- Terminal base circumference has more than 270° contact with the land, with separation not exceeding one land thickness.

6.1.1.1 Swaged Hardware – Terminal Base to Land Separation (cont.)

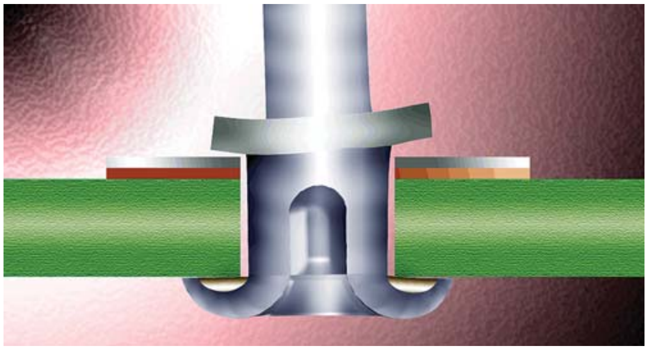


Figure 6-2

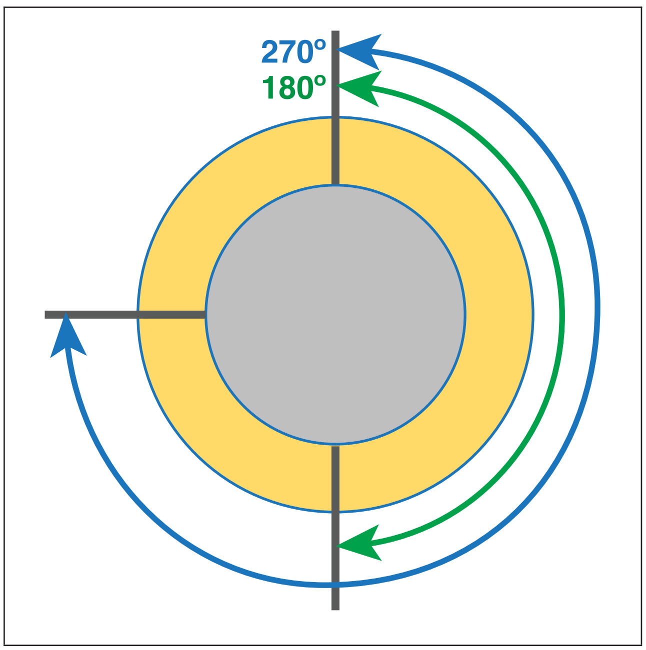


Figure 6-3

Defect – Class 1,2

- Terminal base circumference has less than 180° contact with the land.
- Terminal base has separation exceeding two land thicknesses.

Defect – Class 3

- Terminal base circumference has less than 270° contact with the land.
- Terminal base has separation exceeding one land thickness.

Defect – Class 1,2,3

- Terminal is not vertically stable.

6.1.1.2 Swaged Hardware – Terminals – Turret

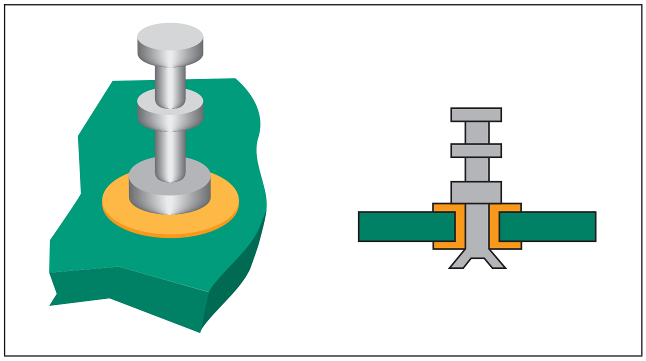


Figure 6-4

Target – Class 1,2,3

• Terminal intact and straight.

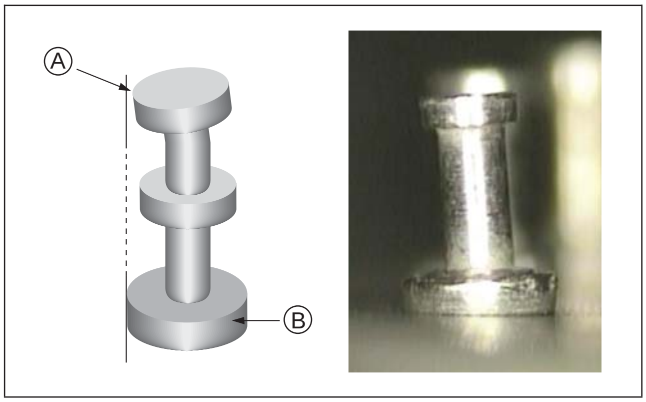


Figure 6-5

Acceptable – Class 1,2,3

• Terminal is bent, but the top edge, see Figure 6-5-A, does not extend beyond the base, see Figure 6-5-B.

Figure 6-6

Acceptable – Class 1
Defect – Class 2,3

• The top edge of the terminal is bent beyond the edge of the base.

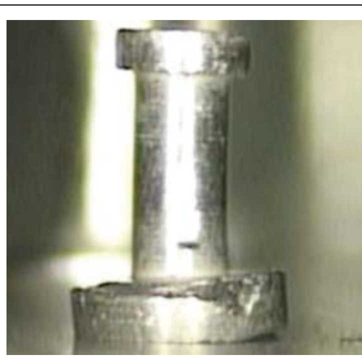


Figure 6-7

Defect – Class 1,2,3

• The center post is fractured.

6.1.1.3 Swaged Hardware – Terminals – Bifurcated

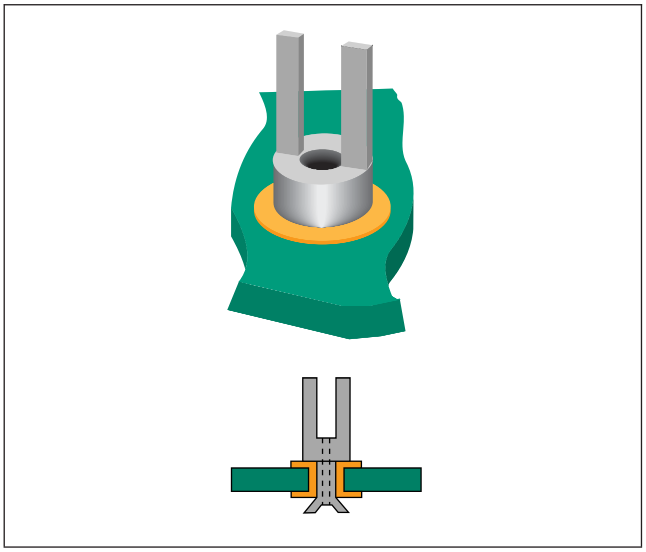


Figure 6-8

Target – Class 1,2,3

- Terminal intact and straight.

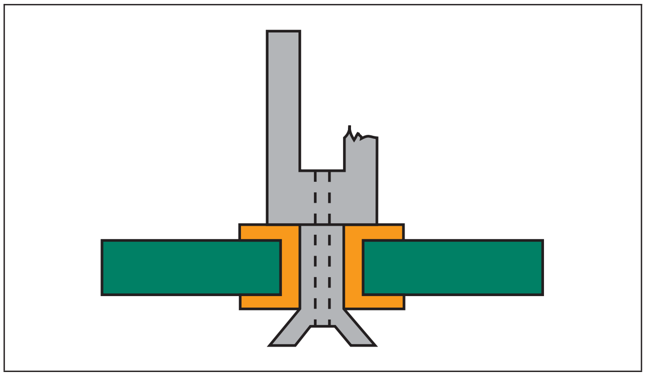


Figure 6-9

Acceptable – Class 1
Defect – Class 2,3

- A post is broken, but sufficient mounting area remains to attach the specified wires/leads.

Defect – Class 1,2,3

- Both posts are broken.

6.1.2 Swaged Hardware – Rolled Flange

The rolled flange terminal is used for mechanical attachments where electrical attachment to a land is not required. Rolled flange attachments are not soldered to a PCB land pattern or installed on active circuitry. They may be installed on inactive and isolated circuitry.

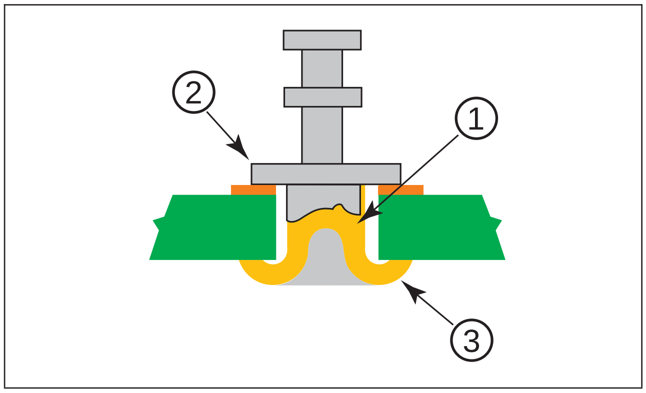


Figure 6-10
1. **Shank**
2. **Terminal base**
3. **Rolled flange**

Target – Class 1,2,3

- Rolled flange is uniformly swaged and concentric to the attachment hole.
- Flange compression is sufficient to support the mechanical attachment of the terminal for the intended performance environment.
- Terminal does not rotate or move once swaged.
- No splits or cracks in the terminal swage.
- Terminal post or attachment is perpendicular to the assembly surface.
- The lip of the rolled flange is in full contact with the base laminate for the full circumference of the flange.
- No laminate damage.

Acceptable – Class 1,2,3

- Burnishing and deformation required to form the terminal swage.
- No more than three radial cracks.
- Any two radial splits or cracks are separated by more than 90°.
- Damage of the substrate is less than limits of 10.2.
- No circumferential splits or cracks.
- Splits or cracks do not enter the terminal shank.

Defect – Class 1,2,3

- Any circumferential splits or cracks.
- Any splits or cracks that enter the terminal shank.
- More than three radial splits or cracks.
- Radial splits or cracks are separated by less than 90°.
- Missing rolled flange pieces.
- Terminals installed on active circuitry or PTHs.
- Soldering of the rolled flange.
- Any mechanical damage of the substrate beyond requirements, see 10.2.

6.1.3 Swaged Hardware – Flared Flange

The shank extending beyond the land surface is swaged to create an inverted cone, uniform in spread, and concentric to the hole.

The flange is not split, cracked or otherwise damaged to the extent that flux, oils, inks, or other liquid substances utilized for processing the printed wiring assemblies can be entrapped within the mounting hole.

Flared flange solder criteria is provided in 6.1.5.

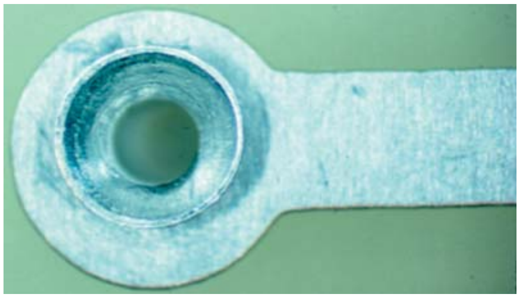


Figure 6-11

Target – Class 1,2,3

- Flared flange is uniformly swaged and concentric to the hole.
- Strain or stress marks caused by flaring are kept to a minimum.
- The flange is swaged sufficiently tight to prevent movement in the Z-axis.

Figure 6-12

Acceptable – Class 1,2,3

- Split in flared flange does not enter into the barrel.
- Not more than three radial splits.
- Radial splits or cracks are separated by at least 90°.

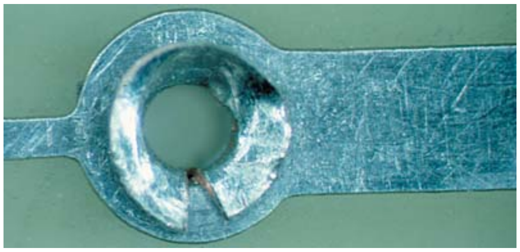


Figure 6-13

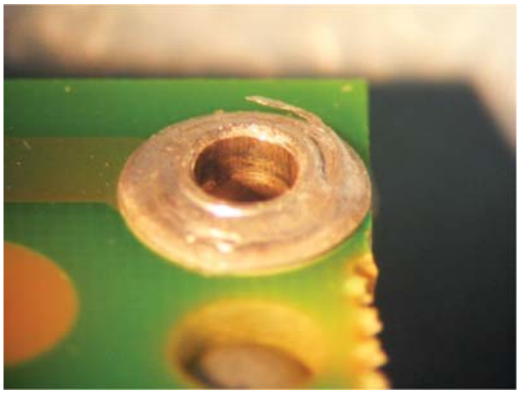


Figure 6-14

Defect – Class 1,2,3

- Flared flange periphery uneven or jagged.
- Split enters into barrel.
- Any circumferential splits/cracks, see Figure 6-14.
- More than three radial splits.
- Radial splits or cracks are separated by less than 90°.
- Missing flared flange pieces.

6.1.4 Swaged Hardware – Controlled Split

This form of swaged hardware is obtained by using scored hardware with a number of uniform segments. When swaged, each segment should conform to a particular angle.

Controlled split hardware is to be soldered as soon as possible after swaging to avoid oxidation.

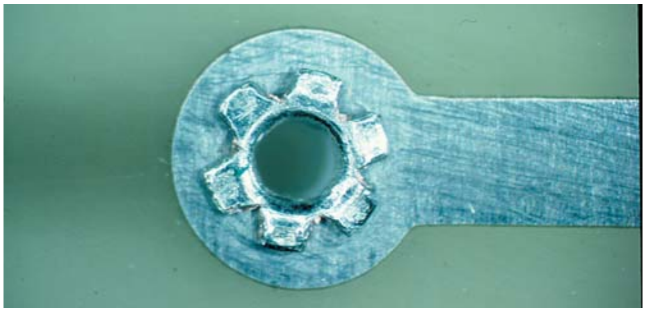


Figure 6-15

Target – Class 1,2,3

- Flange is uniformly split and concentric to the hole.
- Split segments do not extend to the outside diameter of the land.
- Flange is swaged sufficiently tight to prevent movement in the z-axis.

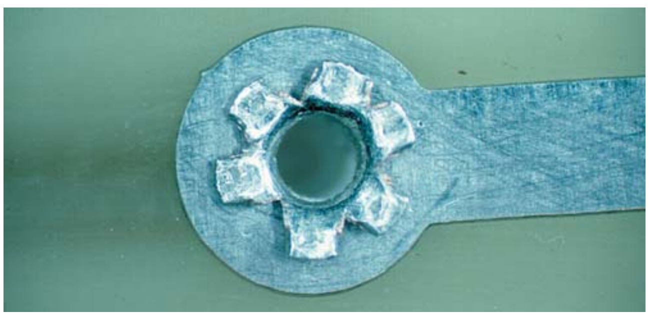


Figure 6-16

Acceptable – Class 1,2,3

- Flange splits down to the board but not into the barrel.

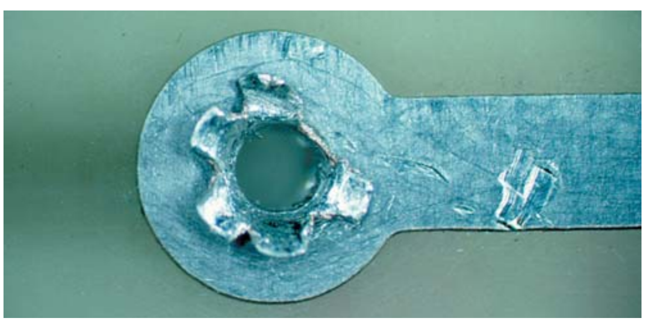


Figure 6-17

Figure 6-18

Defect – Class 1,2,3

- Flange damaged.
- Segments excessively deformed.
- Segment missing.
- Split enters into barrel.
- Circumferential splits/cracks.

6.1.5 Swaged Hardware – Solder

These solder acceptance criteria, summarized in Table 6-1, are applicable to flared flange and flat set swaged hardware.

The flat set flange is not split, cracked or otherwise damaged to the extent that flux, oils, inks, or other liquid substances utilized for processing the printed board can be entrapped within the mounting hole.

Table 6-1 Swaged Hardware Minimum Soldering Requirements

Criteria	Class 1	Class 2	Class 3
A. Circumferential fillet and wetting – solder source side.	270°		330°
B. Percentage of solder source side land area covered with wetted solder.	75%		
C. Height of solder in flared flange.	75%		
D. Height of solder on flat set flange.	100%		

Figure 6-19

Target – Class 1,2,3

- 360° fillet and wetting flange to land.
- The swaged flange is as close to the land as possible to prevent movement in the z-axis.
- Evidence of solder flow is discernible between swaged flange and land of the printed board or other substrate.

Acceptable – Class 1,2,3

- More than 75% of the land area is covered with wetted solder.
- Solder fillet is at least 75% of flare flange height.
- Solder fillet is 100% of flat set flange height.

6.1.5 Swaged Hardware – Solder (cont.)

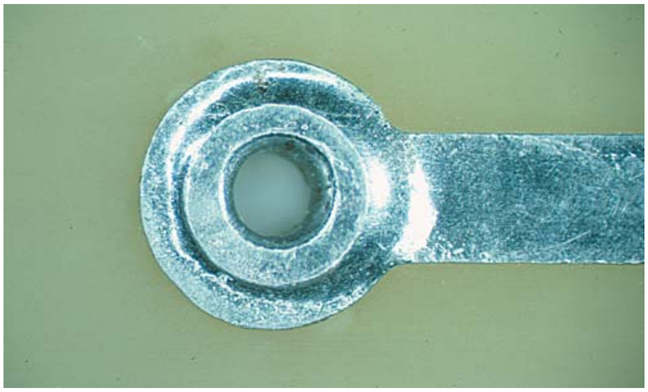


Figure 6-20

Acceptable – Class 1,2

- Minimum of 270° fillet and wetting flange to land.
- Any radial split is filled with solder.

Acceptable – Class 3

- Minimum of 330° fillet and wetting flange to land.

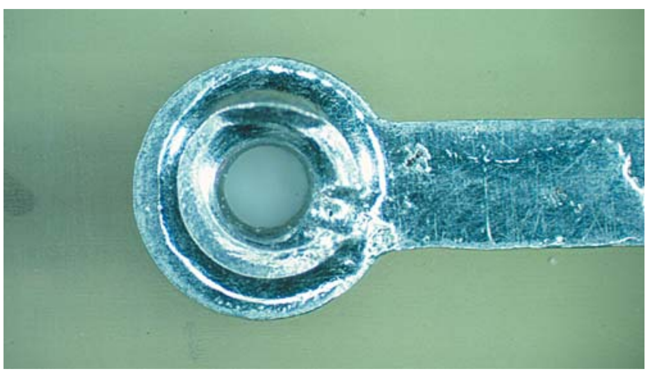


Figure 6-21

Defect – Class 1,2

- Less than 270° fillet and wetting flange or eyelet to land.
- Any radial split not filled with solder.

Defect – Class 1,2,3

- Improperly swaged, flange not seated on terminal area.
- Solder fillet is not 75% of flared flange height.
- Solder fillet is not 100% of flat set flange height.
- Less than 75% of the land area is covered with wetted solder.

Defect – Class 3

- Solder is less than 330° around flange.

6.2 Insulation

6.2.1 Insulation – Damage

6.2.1.1 Insulation – Damage – Presolder

Coatings added over insulation base material such as resin coatings over polyimide are not considered to be part of the insulation and these criteria are not intended to be applicable to those coatings.

The cut ends of some insulation materials, particularly those with a fiberglass barrier, may show fraying. Acceptability of this fraying should be agreed upon between Manufacturer and User.

These criteria are also applicable to post-assembly acceptance. Additional criteria for insulation damage as a result of soldering operations are provided in 6.2.1.2.

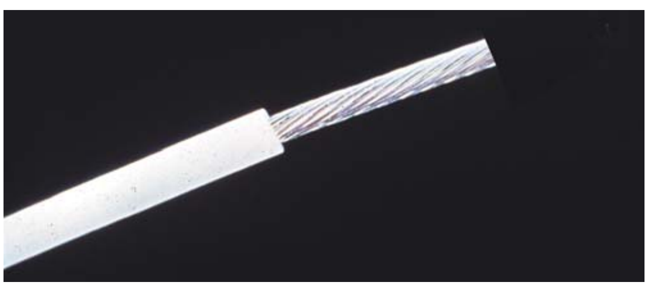


Figure 6-22

Target – Class 1,2,3

- Insulation has been trimmed neatly with no signs of pinching, pulling, fraying, discoloration, charring or burning.

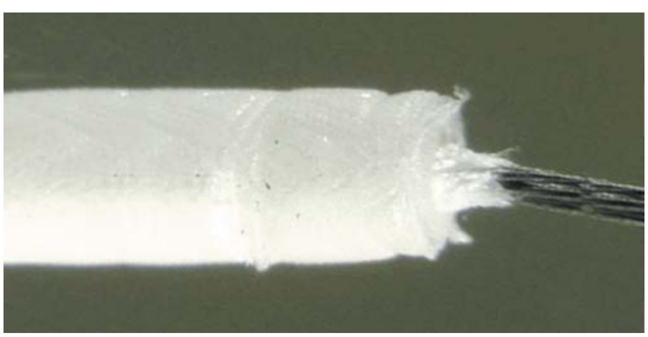


Figure 6-23

Acceptable – Class 1,2,3

- A slight, uniform impression in the insulation from the gripping of mechanical strippers.
- Chemical solutions, paste, and creams used to strip solid wires do not cause degradation to the wire.
- Slight discoloration of insulation resulting from thermal processing provided it is not charred, cracked or split.

6.2.1.1 Insulation – Damage – Presolder (cont.)

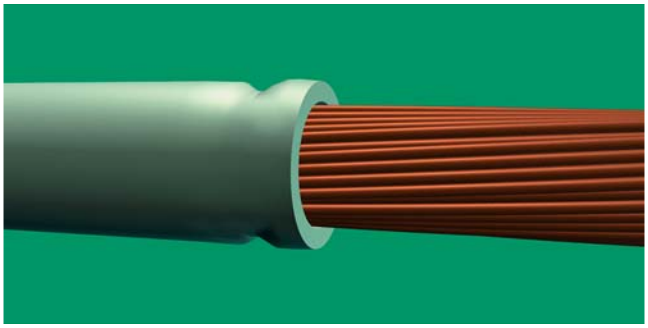


Figure 6-24

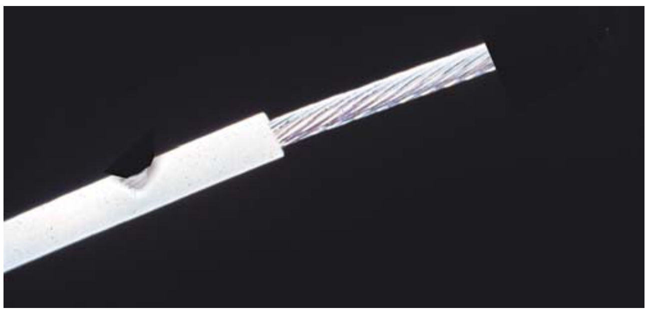


Figure 6-25

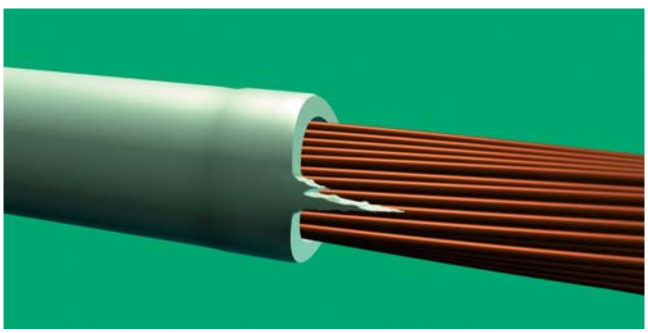


Figure 6-26

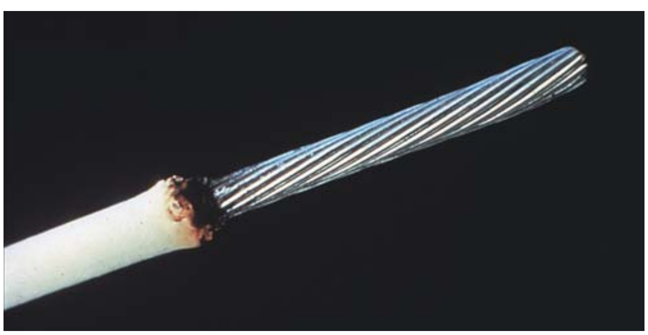


Figure 6-27

Defect – Class 1,2,3

- Any cuts, breaks, cracks or splits in insulation (not shown).
- Insulation is melted into the wire strands (not shown).
- Insulation thickness is reduced by more than 20%, see Figures 6-24, 6-25.
- Uneven or ragged pieces of insulation (frays, tails, and tags) are greater than 50% of the wire diameter or 1 mm [0.04 in] whichever is more, see Figure 6-26.
- Insulation is charred, see Figure 6-27.

6.2.1.2 Insulation – Damage – Post-Solder

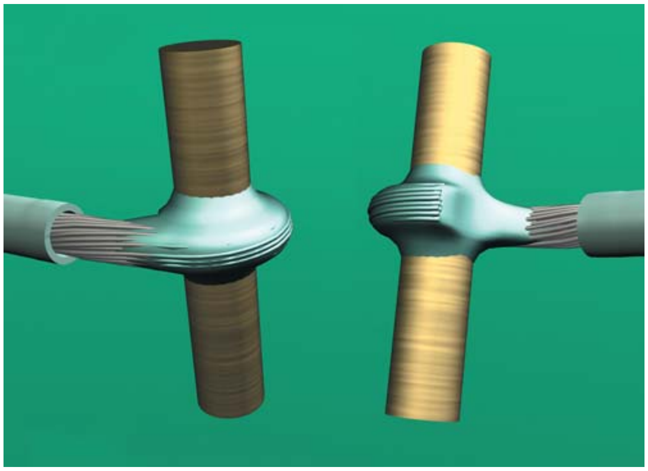


Figure 6-28

Target – Class 1,2,3

- Insulation is not melted, charred or otherwise damaged from the soldering process.

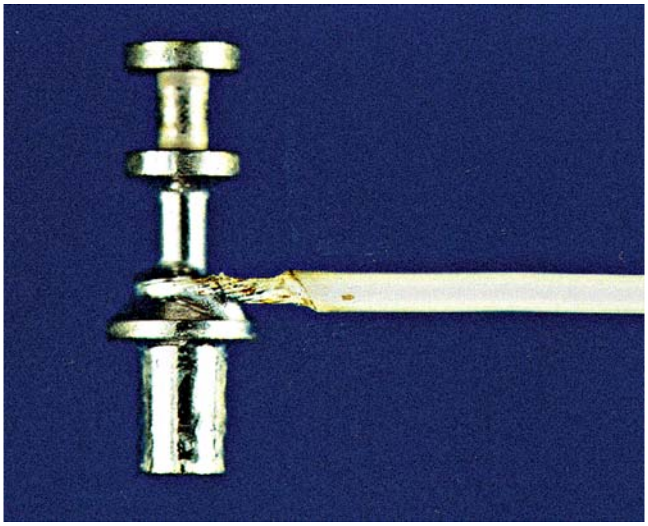


Figure 6-29

Acceptable – Class 1,2,3

- Slight melting of insulation.

Figure 6-30

Defect – Class 1,2,3

- Insulation charred.

6.2.2 Insulation – Clearance

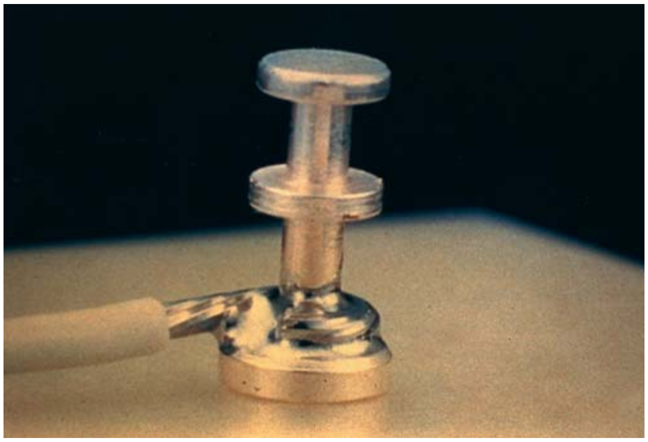


Figure 6-31

Target – Class 1,2,3

- There is visible insulation clearance (C) less than one wire diameter (D) between the end of the insulation and the solder fillet.

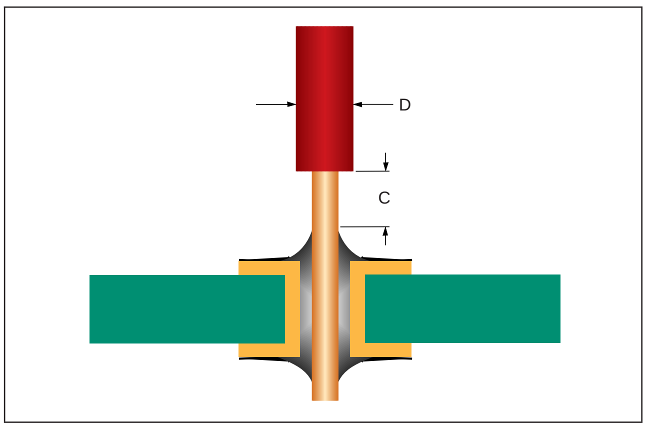


Figure 6-32

Acceptable – Class 1,2,3

- The insulation clearance (C) is two wire diameters or less including insulation or 1.5 mm [0.06 in], whichever is greater.
- Insulation clearance (C) does not permit violation of minimum electrical clearance to adjacent noncommon conductors.
- The insulation is in contact with the solder but does not interfere with formation of an acceptable connection.

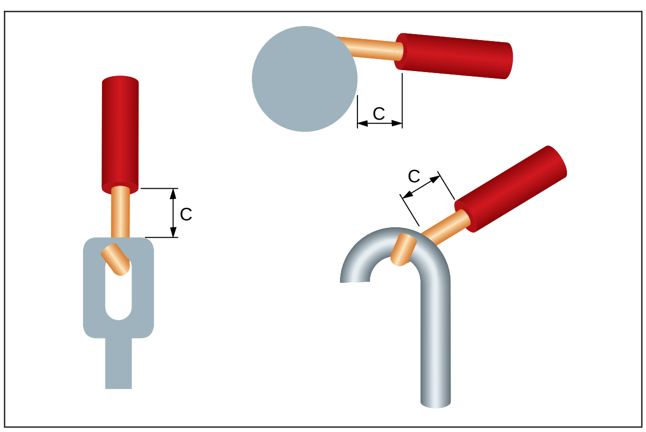


Figure 6-33

6.2.2 Insulation – Clearance (cont.)

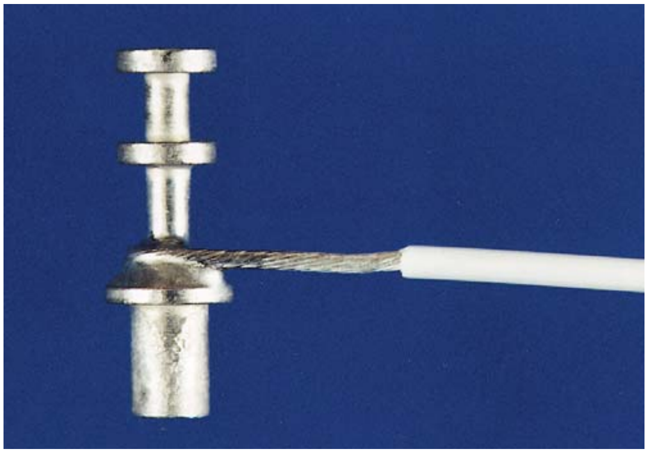


Figure 6-34

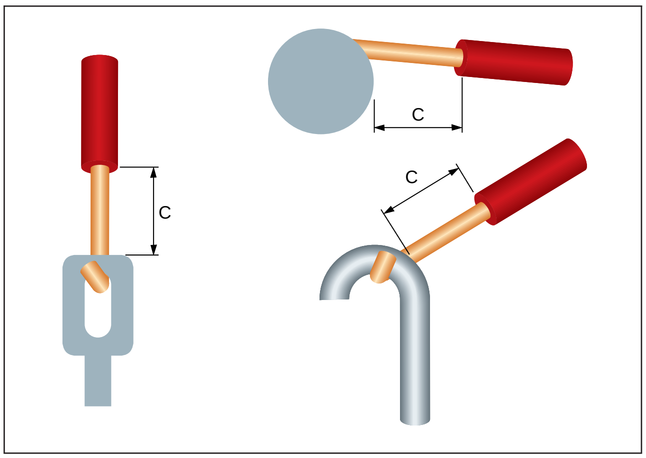


Figure 6-35

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- The insulation clearance (C) is greater than two wire diameters including insulation or 1.5 mm [0.06 in], whichever is greater.

Defect – Class 1,2,3

- Insulation clearance (C) permits violation of minimum electrical clearance to adjacent noncommon conductors.
- Insulation interferes with formation of the solder connection.

Defect – Class 2,3

- Insulation is embedded in or covered with solder (not shown).

6.2.3 Insulation

These criteria are intended for use with shrink sleeving. Criteria for other types of sleeving should be agreed upon between Manufacturer and User.

Cleaning, if required, **shall** be accomplished prior to shrinking of the sleeving.

Heating processes used to shrink sleeve insulation **shall not** damage the connector, wire, sleeving, adjacent components, nor reflow the solder connection.

6.2.3.1 Insulation – Placement

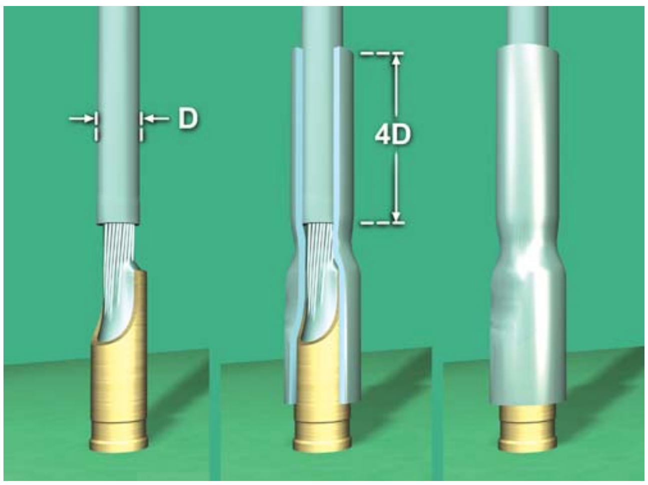


Figure 6-36

Target – Class 1,2,3

- Insulation sleeving overlaps the connector terminal and extends over the wire insulation four wire diameters (D).
- Insulation sleeving is one wire diameter (D) from the point where the connector terminal enters the connector insert.

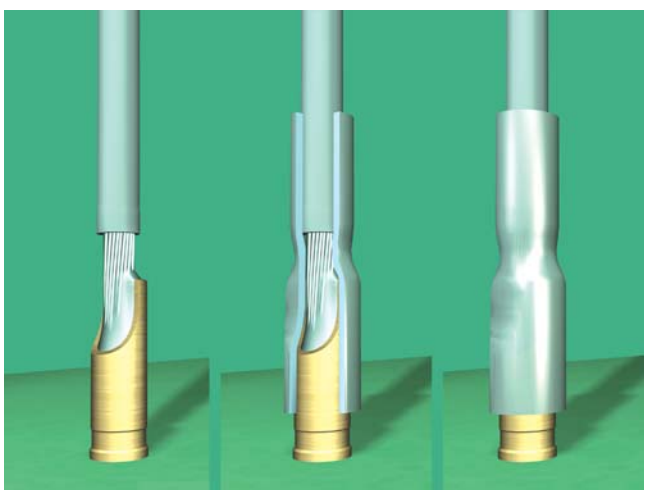


Figure 6-37

Acceptable – Class 1,2,3

- Insulation sleeving overlaps the connector terminal and the wire insulation by a minimum of two wire diameters.
- Insulation sleeving is more than 50% wire diameter and not more than two wire diameters from the point where the connector terminal enters the connector insert.

Acceptable – Class 1

- Sleeving/tubing is tight on terminal, but not tight on wire/cable.

Acceptable – Class 2,3

- Sleeving/tubing is tight on terminal and wire/cable.
- Multiple pieces of sleeving overlap each other by at least three wire/cable diameters.

6.2.3.1 Insulation – Placement (cont.)

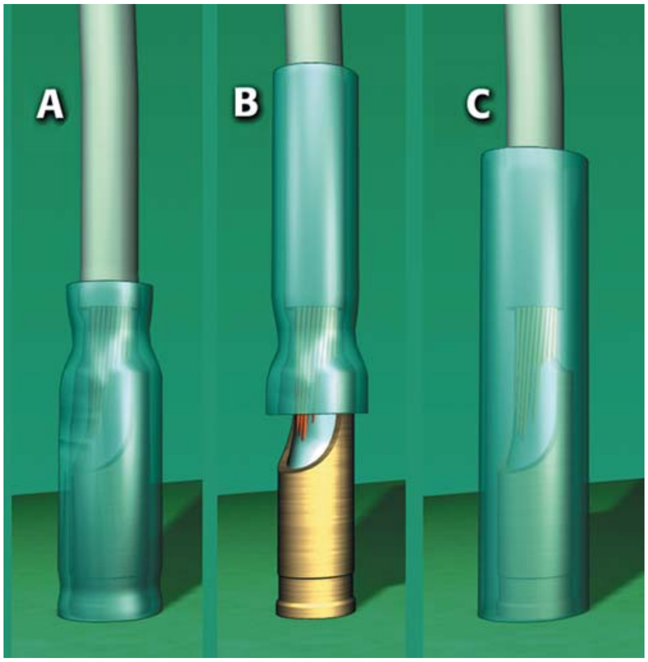


Figure 6-38

Defect – Class 1

- Sleeving/tubing is not tight on terminal.

Defect – Class 2,3

- Sleeving/tubing is not tight on terminal and wire/cable.
- Multiple pieces of sleeving overlap is less than three wire/cable diameters.

Defect – Class 1,2,3

- Insulation sleeving overlaps the wire insulation by less than two wire diameters, see Figure 6-38-A.
- Insulation sleeving is more than two wire diameters from the point where the connector terminal enters the connector insert, see Figure 6-38-B.
- Insulation sleeve is loose on the terminal (could slide or vibrate off, exposing more than the allowed amount of conductor or terminal), see Figure 6-38-C.
- Insulation sleeving prevents movement of floating contact in the insert, when movement is required.

6.2.3.2 Insulation – Damage

Acceptable – Class 1,2,3

- No damage to insulation sleeving, i.e., splits, char, cracks, tears or pinholes.

Figure 6-39

Figure 6-40

Defect – Class 1,2,3

- Insulation sleeving is damaged, i.e., splits, char, cracks, tears or pinholes.

6.3 Conductor

6.3.1 Conductor – Deformation

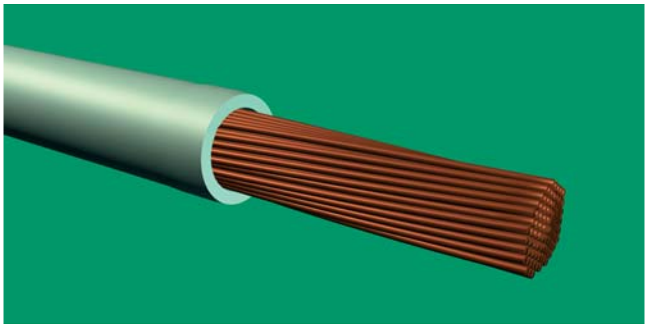


Figure 6-41

Target – Class 1,2,3

- Strands are not flattened, untwisted, buckled, kinked or otherwise deformed.
- Original lay of strands is not disturbed.

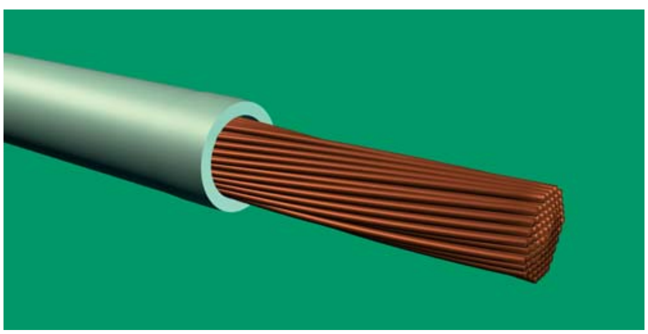


Figure 6-42

Acceptable – Class 1,2,3

- Where strands were straightened during the insulation removal, they have been restored to approximate the original spiral lay of the strands.
- Wire strands are not kinked.

Acceptable – Class 1
Defect – Class 2,3

- The general spiral lay of the strands has not been maintained.

Defect – Class 3

- Wire strand is kinked.

6.3.2 Conductor – Damage

6.3.2.1 Conductor – Damage – Stranded Wire

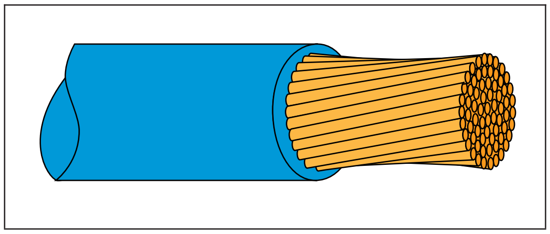


Figure 6-43

Target – Class 1,2,3

- Wire conductor ends are cut perpendicular to the wire longitudinal axis.
- All of the strands of the strand group are the same length.
- Wire strands are not scraped, nicked, cut, flattened, scored, or otherwise damaged.

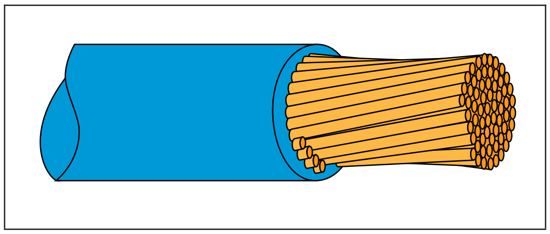


Figure 6-44

Acceptable – Class 1
Process Indicator – Class 2,3

- Strands cut, broken, scraped or severed if the number of damaged or broken strands in a single wire does not exceed the limits in Table 6-2.

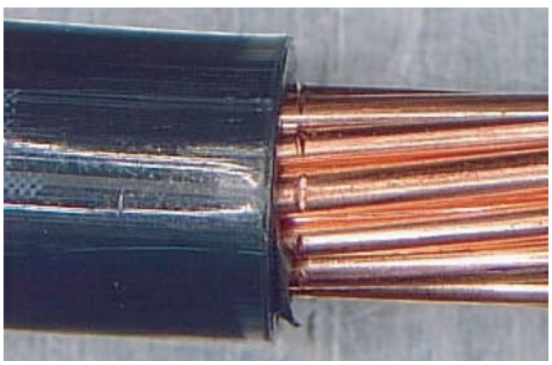


Figure 6-45

Defect – Class 1,2,3

- Damaged strands exceed the limits in Table 6-2.

Table 6-2 Strand Damage[1,2,3]

Number of Strands	Maximum allowable strands scraped, nicked or severed for Class 1,2	Maximum allowable strands scraped, nicked or severed for Class 3 for wires that will not be tinned before installation	Maximum allowable strands scraped, nicked or severed for Class 3 for wires that will be tinned prior to installation
1 (solid conductor)	No damage in excess of 10% of conductor diameter.		
2-6	0	0	0
7-15	1	0	1
16-25	3	0	2
26-40	4	3	3
41-60	5	4	4
61-120	6	5	5
121 or more	6% of strands	5% of strands	5% of strands

Note 1: No damaged strands for wires used at a potential of 6 kV or greater or otherwise designated as high voltage.
Note 2: For plated wires, a visual anomaly that does not expose basis metal is not considered to be strand damage.
Note 3: A strand is considered damaged if nicks or scrapes exceed 10% of strand diameter.

6.3.2.2 Conductor – Damage – Solid Wire

Acceptable – Class 1,2,3

- No nicks or deformation exceeding 10% of the diameter, width or thickness of the conductor. See 5.2.1 for exposed basis metal criteria.

Defect – Class 1,2,3

- Wire is damaged more than 10% of the wire diameter or thickness.
- Wire deformed from repeated bending.

6.3.3 Conductor – Strand Separation (Birdcaging) – Presolder

Wire strands disturbed during insulation removal process should be restored to approximate their original lay.

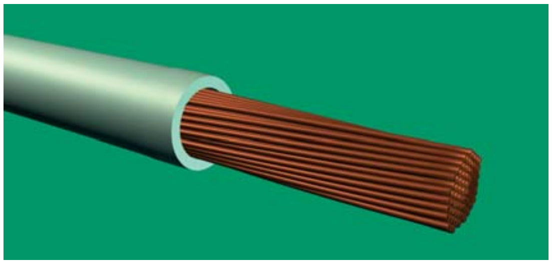


Figure 6-46

Target – Class 1,2,3

- Original lay of strands is not disturbed.

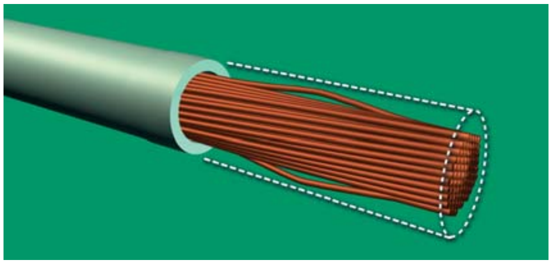


Figure 6-47

Acceptable – Class 1,2,3

- Wire strands have separation (birdcaging) but do not:
  - Exceed one strand diameter.
  - Extend beyond wire insulation outside diameter.

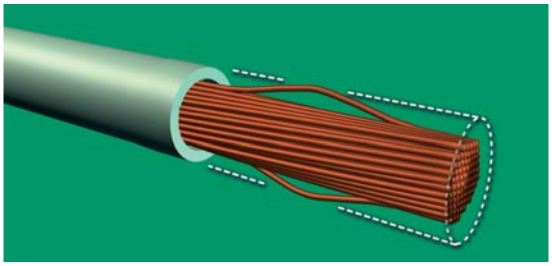


Figure 6-48

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire strands have separation exceeding one strand diameter but do not extend beyond wire insulation outside diameter.

6.3.3 Conductor – Strand Separation (Birdcaging) – Presolder (cont.)

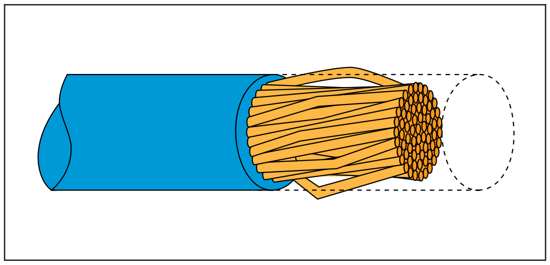


Figure 6-49

Acceptable – Class 1
Defect – Class 2,3

- Wire strands extend beyond wire insulation outside diameter.

6.3.4 Conductor – Strand Separation (Birdcaging) – Post-Solder

Target – Class 1,2,3

- No birdcaging.

Acceptable – Class 1,2,3

- Wire strands have separation (birdcaging), but do not:
  - Exceed one strand diameter.
  - Extend beyond wire insulation outside diameter.

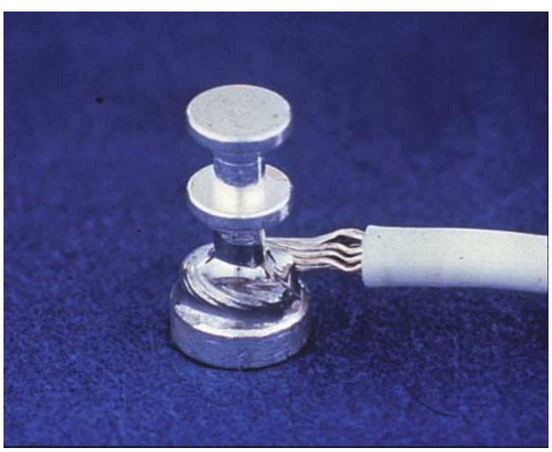


Figure 6-50

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire strands have separation exceeding one strand diameter but do not extend beyond wire insulation outside diameter.

6.3.4 Conductor – Strand Separation (Birdcaging) – Post-Solder (cont.)

Figure 6-51

Acceptable – Class 1
Defect – Class 2,3

- Wire strands are birdcaged beyond wire insulation outside diameter.

6.3.5 Conductor – Tinning

In this document, the term pretinning and tinning have the same meaning, as defined in IPC-T-50: ''The application of molten solder to a basis metal or surface finish in order to increase its solderability.''

Tinning of stranded wire has the added benefit of bonding the individual wire strands together, thereby allowing the wire to be formed to terminals or attachment points without separation of the individual strands (birdcaging).

The following criteria are applicable if tinning is required.

Note: EIA/IPC/JEDEC J-STD-002 provides additional information for assessing this requirement.

Figure 6-52

Target – Class 1,2,3

- Stranded wire is uniformly coated with a thin coat of solder with the individual strands of the wire easily visible.
- Untinned length of strands from end of insulation is not greater than one wire diameter.

Acceptable – Class 1,2,3

- The solder wets the tinned portion of the wire and penetrates to the inner strands of stranded wire.
- Solder wicks up wire provided the solder does not extend to a portion of the wire that is required to remain flexible.
- The tinning leaves a smooth coating of solder and the outline of the strands are discernible.

Process Indicator – Class 2,3

- Strands are not discernible but excess solder does not affect form, fit or function.
- Solder does not penetrate to the inner strands of the wire.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Length of untinned strands from end of insulation is greater than one wire diameter.

6.3.5 Conductor – Tinning (cont.)

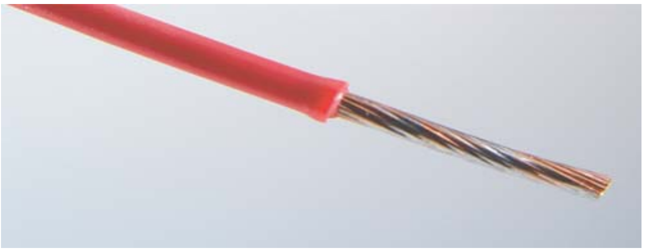


Figure 6-53

Defect – Class 2,3

- Pinholes, voids or dewetting/nonwetting exceeds 5% of the area required to be tinned, see Figure 6-53.
- Solder does not wet the tinned portion of the wire.
- Stranded wire is not tinned prior to attachment to terminals or forming splices (other than mesh).

Figure 6-54

Defect – Class 1,2,3

- Solder wicking extends into the portion of wire that is required to remain flexible after soldering.
- Solder build-up or icicles within the tinned wire area that affect subsequent assembly steps, see Figure 6-54.

6.4 Service Loops

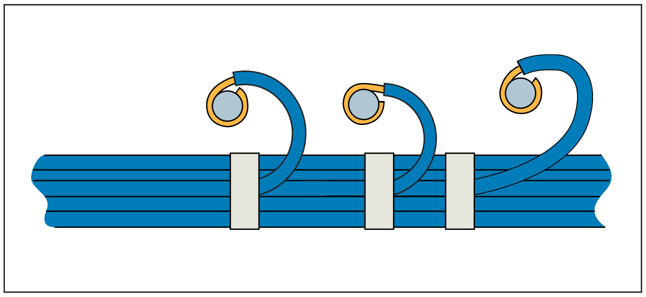


Figure 6-55

Acceptable – Class 1,2,3

- When a service loop is required, wire has sufficient length to allow one field re-termination to be made.

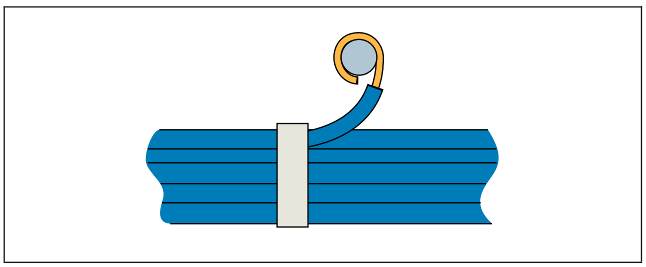


Figure 6-56

Defect – Class 1,2,3

- When a service loop is required, wire does not have sufficient length to allow at least one field re-termination to be made.

6.5 Stress Relief

6.5.1 Stress Relief – Bundle

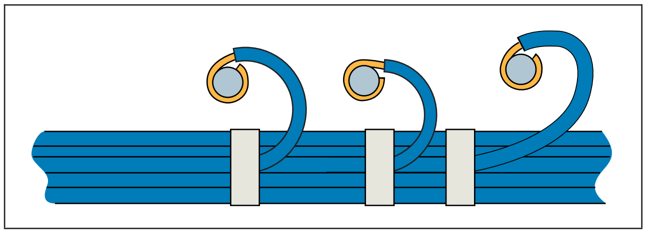


Figure 6-57

Acceptable – Class 1,2,3

- The wire approaches the terminal with a loop or bend sufficient to relieve any tension on the connection during thermal/vibration stress.
- The direction of the stress-relief bend places no strain on the mechanical wrap or the solder connection.
- Bend not touching terminal is in conformance with Table 4-1.

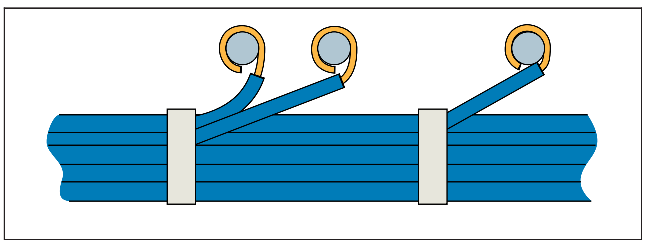


Figure 6-58

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- There is insufficient stress relief, see Figure 6-58.
- The wire is under stress at the wrap, see Figure 6-58.

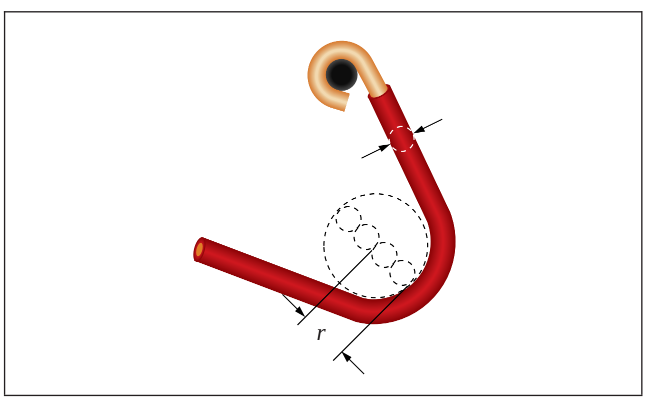


Figure 6-59

Defect – Class 1,2,3

- Does not meet bend radius requirements. See Table 4-1, see Figure 6-59.

6.5.2 Stress Relief – Lead/Wire Bend

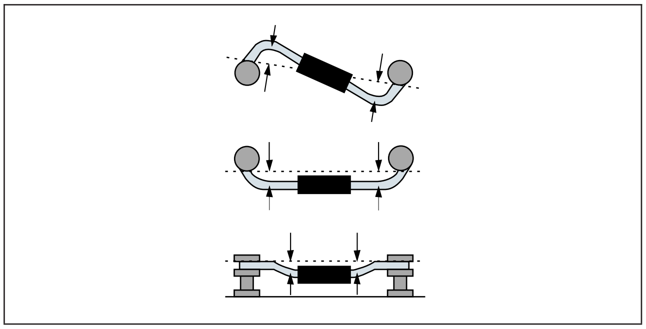


Figure 6-60

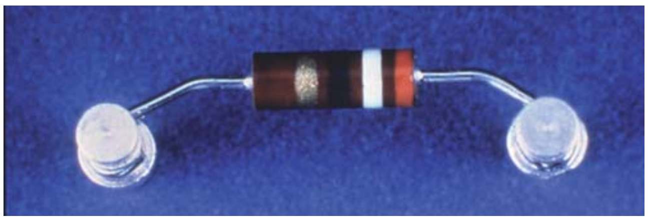


Figure 6-61

Target – Class 1,2,3

- Component body centerline to terminal edge is at least one-half (50%) the component diameter or 1.3 mm [0.05 in], whichever is greater.
- Clip and adhesive mounted component leads have stress relief.

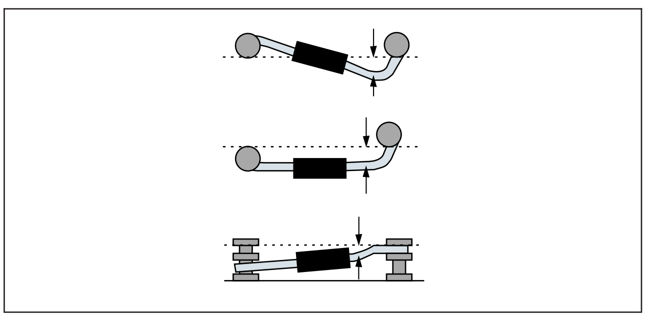


Figure 6-62

Acceptable – Class 1,2,3

- One lead has stress relief, provided the component is not clip or adhesive mounted, or otherwise constrained.
- Each lead has stress relief when the component is clipped or adhesive mounted or otherwise constrained.

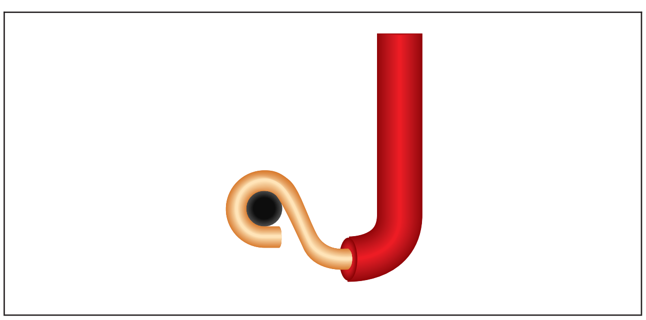


Figure 6-63

Acceptable – Class 1
Defect – Class 2,3

- The wire is formed around the terminal opposite to the feed-in direction.

6.5.2 Stress Relief – Lead/Wire Bend (cont.)

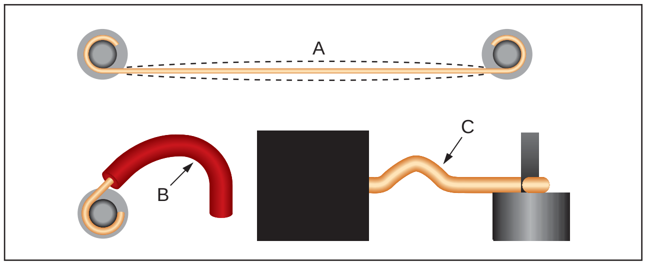


Figure 6-64

Acceptable – Class 1,2,3

- The wire is straight between the connections with no loop or bend, but wire is not taut, see Figure 6-64-A.
- Wire is not kinked, see Figure 6-64-B, C.

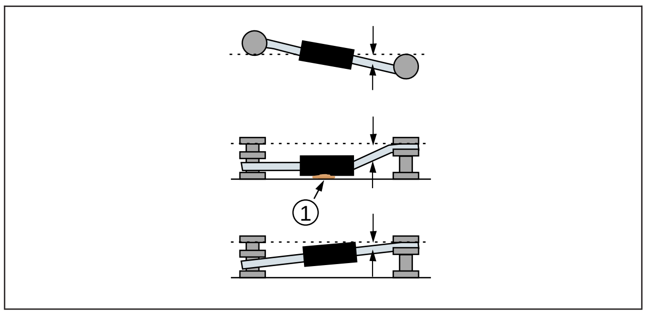


Figure 6-65
1. Adhesive

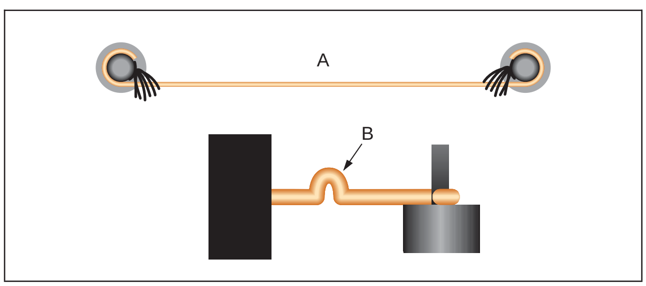


Figure 6-66

Defect – Class 1,2,3

- No stress relief.
- Stress relief not present in all leads of a constrained component, see Figure 6-65.
- Wire is stretched taut between the terminals, see Figure 6-66-A.
- Lead/wire is kinked, see Figure 6-66-B.

6.6 Lead/Wire Placement – General Requirements

The criteria associated with each terminal type or connection are in clauses 6.8 through 6.15.

Unless otherwise specified the wire or lead should be in contact with base of the terminal or a previously installed wire. The lead and wire ends should not extend beyond the terminal greater than one lead diameter.

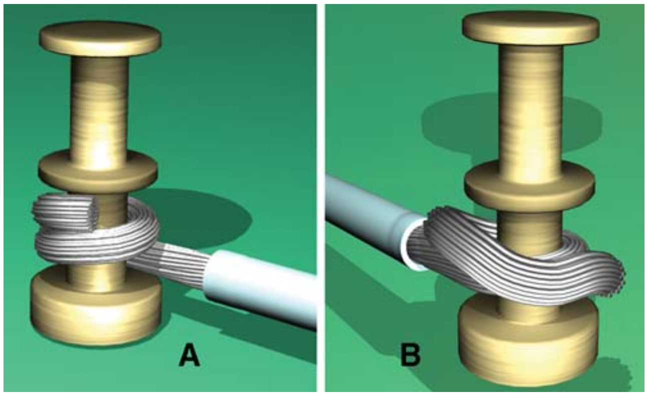


Figure 6-67

Wire Overwrap – When a wire/lead that is wrapped more than 360° and remains in contact with the terminal post, see Figure 6-67-A.

Wire Overlap – When a wire/lead that is wrapped more than 360° and crosses over itself, i.e., does not remain in contact with the terminal post, see Figure 6-67-B.

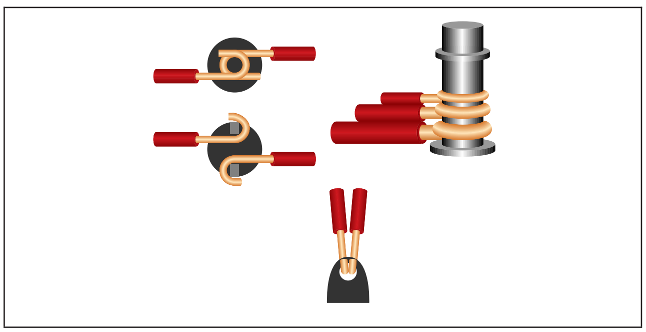


Figure 6-68

Target – Class 1,2,3

- Wires placed in ascending order with the largest on the bottom.
- Wraps to a terminal are parallel with the terminal base and each other.
- Wires are mounted as close to the terminal base as allowed by the insulation.

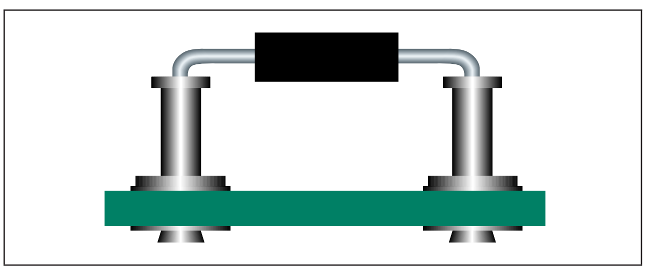


Figure 6-69

Acceptable – Class 1,2,3

- Wrapped conductors do not cross over or overlap each other on terminal.
- Strand separation (birdcaging) meets the requirements of 6.3.3 and 6.3.4.
- Calibration parts may be mounted to the tops of hollow terminals, see Figure 6-69.

Acceptable – Class 1
Defect – Class 2,3

- Terminal altered to accept oversized wire or wire group.
- Wrapped conductors cross over or overlap each other on terminal, see Figure 6-67-B.
- Strand separation (birdcaging) does not meet the requirements of 6.3.3 and 6.3.4.
- The lead or wire interferes with the wrapping of other leads or wires on the terminal.

6.7 Solder – General Requirements

Unless otherwise stated for a specific terminal type, the following are general requirements for all terminals.

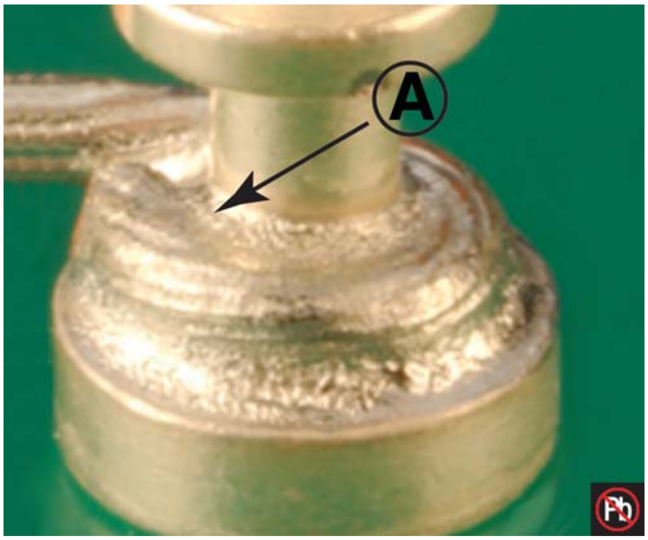


Figure 6-70

Figure 6-71

Target – Class 1,2,3

- 100% solder fillet around wire/lead and terminal interface (full extent of wrap).
- Solder wets the wire/lead and terminal and forms a discernible fillet feathering out to a smooth edge.
- Wire/lead is clearly discernible in the solder connection.

Acceptable – Class 1,2

- Depression of solder between the terminal and the wrap of the wire is less than or equal to 50% of the wire/lead radius (R), see Figures 6-70-A and 6-72-2.

Acceptable – Class 3

- Depression of solder between the terminal and the wrap of the wire is less than or equal to 25% of the wire/lead radius (R), see Figures 6-70-A and 6-72-2.

Acceptable – Class 1,2,3

- Solder fillet at least 75% of the circumference of the wire/lead and terminal interface.
- For leads/wires with a wrap greater than or equal to 180°, solder fillet is at least 75% of the wire/lead and terminal interface in the minimum required wrap area.
- When acceptable wire wrap is less than 180°, solder fillet is 100% of the circumference of the wire/lead and terminal interface.

Acceptable – Class 1
Process Indicator – Class 2,3

- Wire/lead not discernible in solder connection.

6.7 Solder – General Requirements (cont.)

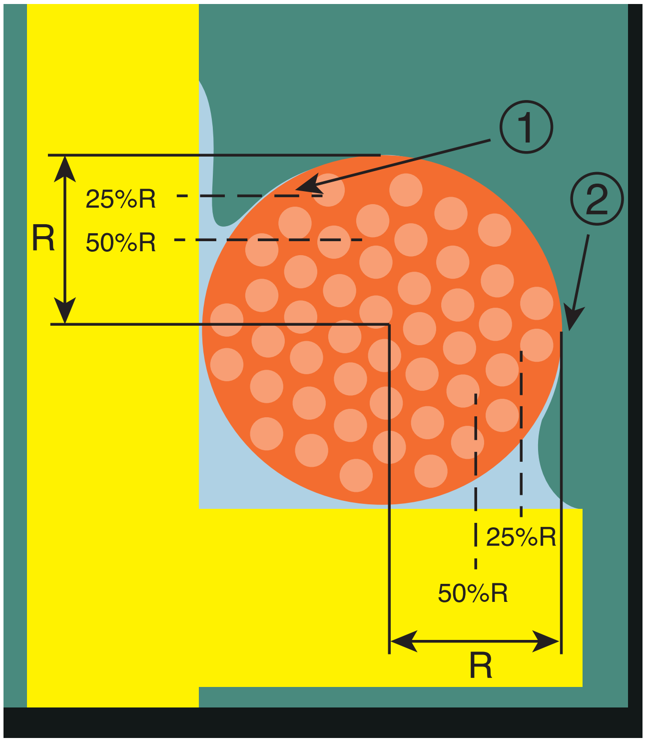


Figure 6-72 Solder Depression

1. As shown, solder depression is a defect for Class 3.
2. As shown, solder depression is acceptable for all three Classes.

Defect – Class 1,2

- Depression of solder between the terminal and the wrap of the wire is greater than 50% of wire/lead radius (R), see Figure 6-72.

Defect – Class 3

- Depression of solder between the terminal and the wrap of the wire is greater than 25% of wire/lead radius (R).

Defect – Class 1,2,3

- For terminals with a required minimum wrap of less than 180°, solder is wetted less than 100% of the required minimum wrap area.
- For terminals with a required minimum wrap of more than 180°, solder is wetted less than 75% of the required minimum wrap area.

6.8 Turrets and Straight Pins

6.8.1 Turrets and Straight Pins – Lead/Wire Placement

Table 6-3 is applicable to leads and wires attached to turret and straight pin terminals.

Table 6-3 Turret or Straight Pin Terminal Lead/Wire Placement[2]

Criteria	Class 1	Class 2	Class 3
< 90° contact between the lead/wire and terminal post	Defect		
90° to < 180° contact between the lead/wire and terminal post	Acceptable	Process Indicator	Defect
≥ 180° contact between lead/wire and post	Acceptable		
Wire overlaps itself, Note 1	Acceptable	Defect	
Wire violates minimum electrical clearance	Defect		

Note 1: See 6.6.
Note 2: See 6.14 for criteria AWG 30 and smaller wires.

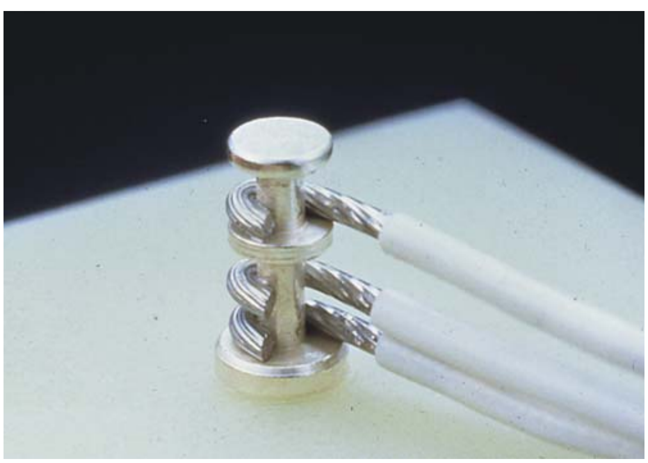


Figure 6-73

Target – Class 1,2,3

- Wraps parallel to each other and to the base.
- Wire mounted against terminal base or previously installed wire.
- On straight pins, the top wire on terminal is one wire diameter below the top of the terminal.
- Wraps are a minimum of 180° and a maximum of 270°.
- Wires and leads mechanically secure to terminals before soldering.

6.8.1 Turrets and Straight Pins – Lead/Wire Placement (cont.)

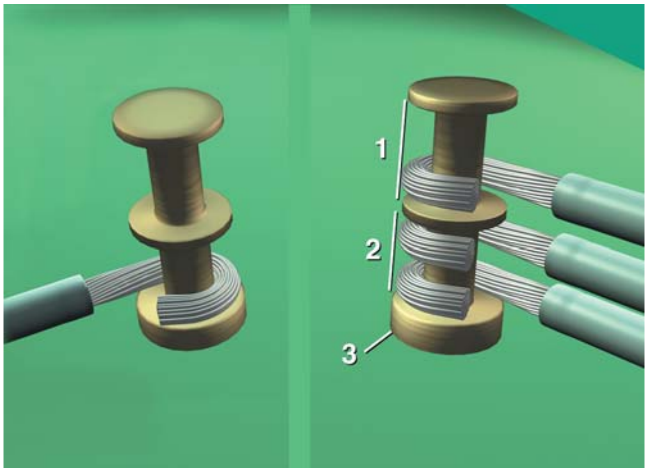


Figure 6-74
1. **Upper guide slot**
2. **Lower guide slot**
3. **Base**

Acceptable – Class 1,2,3

• Wires and leads wrapped a minimum of 180° and do not overlap.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

• On straight pins, the top wire on terminal is less than one wire diameter below the top of the terminal.

Acceptable – Class 1
Defect – Class 2,3

• Wire overlaps itself.

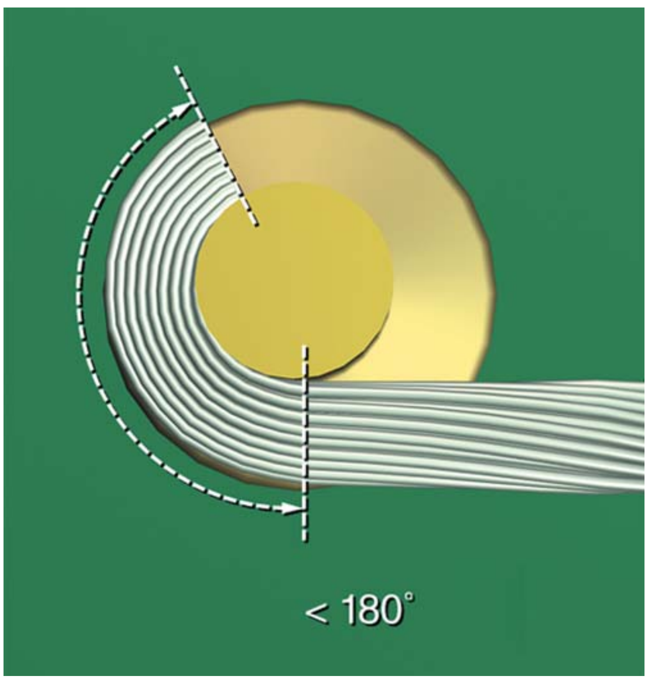


Figure 6-75

Process Indicator – Class 2

• Wrap for round posts 90° to less than 180° of contact between the wires and the terminal.

Defect – Class 1,2

• Wrap for round posts has less than 90° of contact between the wires and the terminal.

Defect – Class 1,2,3

• Long wire end violates minimum electrical clearance.

Defect – Class 3

• Wrap for round posts has less than 180° of contact between the wires and the terminal.

6.8.2 Turrets and Straight Pins – Solder

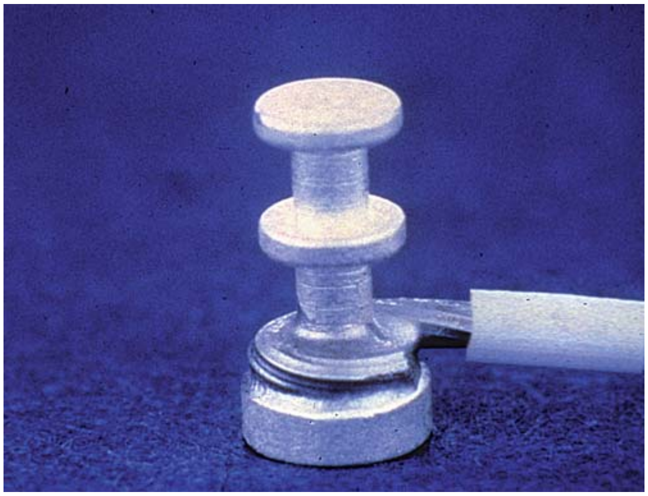


Figure 6-76

Figure 6-77

Target – Class 1,2,3

- Lead outline is discernible, smooth flow of solder on wire and terminal.
- Solder fillets at all points of wire/lead and terminal interface.

Acceptable – Class 1,2,3

- Solder is wetted to at least 75% of the contact area between the wire/lead and terminal interface for leads wrapped equal to or more than 180°.

Acceptable – Class 1,2

- Solder is wetted to 100% of contact areas between the wire/lead and terminal interface for leads wrapped between 90° and 180°.

Acceptable – Class 1
Process Indicator – Class 2,3

- Wire/lead not discernible in solder connection.

Figure 6-78

Defect – Class 1,2

- Solder is wetted less than 100% of the lead to terminal contact area when the wrap is more than 90° and less than 180°.

Defect – Class 1,2,3

- Less than 75% fillet of the lead to terminal contact when the wrap is equal to or more than 180°.

6.9 Bifurcated

6.9.1 Bifurcated – Lead/Wire Placement – Side Route Attachments

Table 6-4 is applicable to leads and wires attached to side-route bifurcated terminals.

Table 6-4 Bifurcated Terminal Lead/Wire Placement – Side Route

Criteria	Class 1	Class 2	Class 3
< 90° wrap	Defect		
≥ 90° wrap	Acceptable		
Wire overlaps itself, Note 1	Acceptable	Defect	
Violates minimum electrical clearance	Defect		

Note 1: See 6.6.

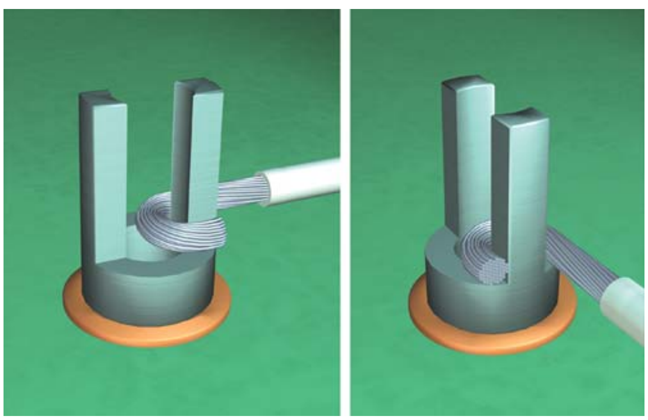


Figure 6-79

Target – Class 1,2,3

- The wire or lead contacts two parallel faces (180° bend) of the terminal post.
- No overlapping of wraps.
- Wires placed in ascending order with largest on the bottom.
- Multiple wire attachments alternate terminal posts.

6.9.1 Bifurcated – Lead/Wire Placement – Side Route Attachments (cont.)

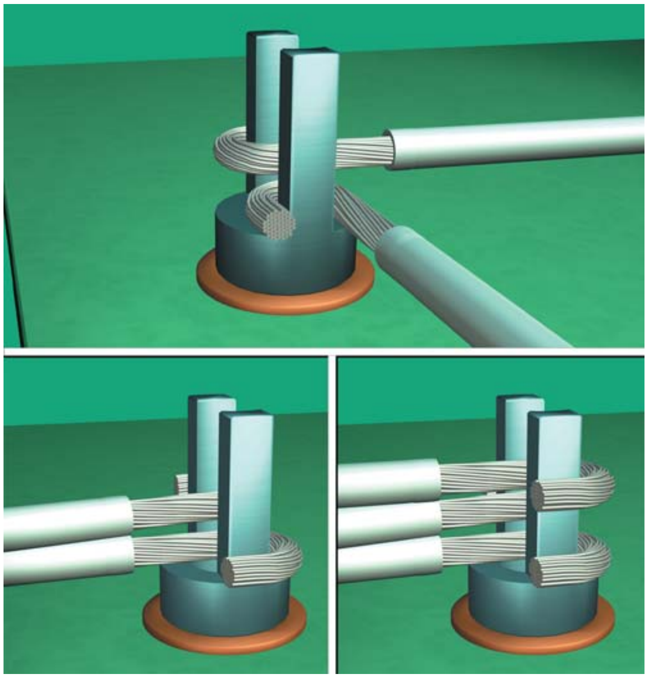


Figure 6-80

Acceptable – Class 1,2,3

- Wire end extends beyond the base of the terminal provided minimum electrical spacing is maintained.
- Wire passes through the slot and makes positive contact with at least one corner of the post.
- No portion of the wrap extends beyond the top of the terminal post.
- If required, wire wrap is at least 90°.

Acceptable – Class 1,2

- Wires/leads 0.75 mm [0.03 in] or larger in diameter are routed straight through the posts.

Note: 0.75 mm [0.03 in] is approximately equal to 22 AWG stranded wire.

Acceptable – Class 3

- Wires/leads 0.75 mm [0.03 in] or larger in diameter are routed straight through the posts and staked, see 6.9.2.

6.9.1 Bifurcated – Lead/Wire Placement – Side Route Attachments (cont.)

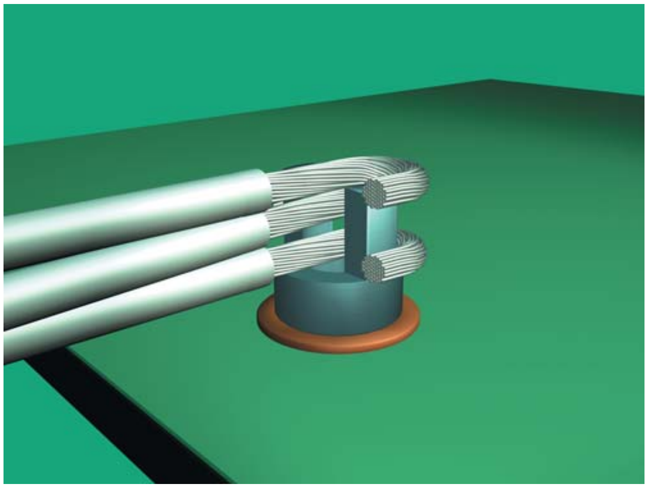


Figure 6-81

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Any portion of the wrap extends beyond the top of terminal post.
- Wire does not have positive contact with at least one corner of the post.

Acceptable – Class 1
Defect – Class 2,3

- Wire overlaps itself.

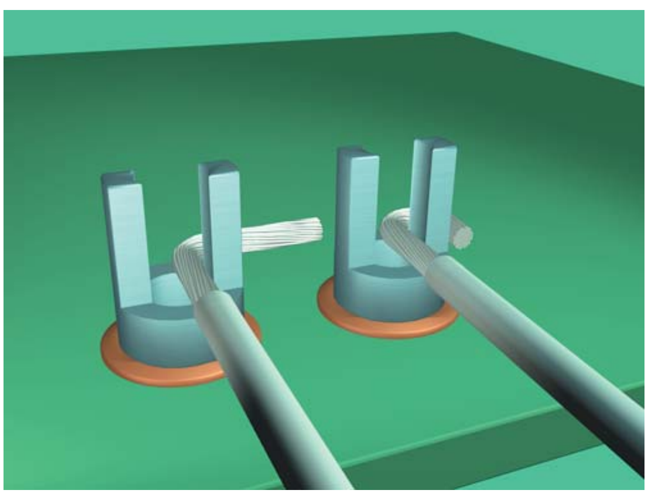


Figure 6-82

Defect – Class 3

- Wire/lead equal to or greater than 0.75 mm [0.03 in] in diameter is wrapped less than 90° and is not staked, see 6.9.2.
- Straight through conductor is not in contact with the base of the terminal or the previously installed conductor, with allowance given for insulation thickness.

Defect – Class 1,2,3

- Wire does not pass through slot.
- Wire end violates minimum electrical clearance, see Figure 6-82.
- Wire/lead less than 0.75 mm [0.03 in] in diameter is wrapped around a post less than 90° and is not staked, see 6.9.2.

6.9.2 Bifurcated – Lead/Wire Placement – Staked Wires

As an alternative to wrap requirements of 6.9.1 or 6.11, the following criteria (summarized in Table 6-5) apply to wires/leads/components that are staked, bonded or otherwise constrained to provide support for the solder connection.

Table 6-5 Staking Requirements of Side Route Straight Through Connections – Bifurcated Terminals

Conductor Diameter	Class 1	Class 2	Class 3
< 0.75 mm [0.03 in][1]		Defect if not staked	
≥ 0.75 mm [0.03 in][2]	Acceptable if not staked	Process Indicator if not staked	Defect if not staked

Note 1: AWG-22 and smaller
Note 2: AWG-20 and larger

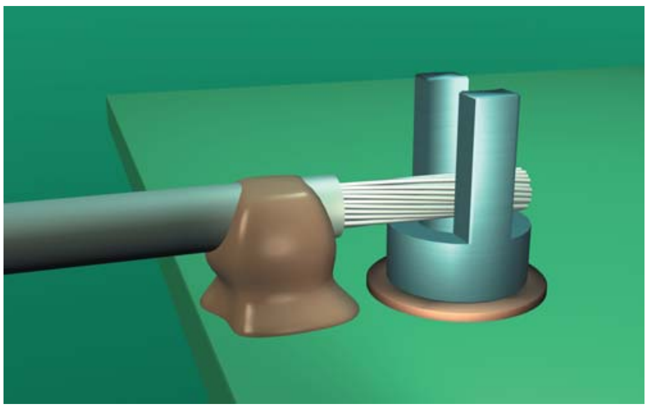


Figure 6-83

Target – Class 1,2,3

- Wire is permanently staked or constrained by a permanent mounting device.
- Wire contacts base of terminal or the previous wire.
- Wire extends through posts of bifurcated terminal.

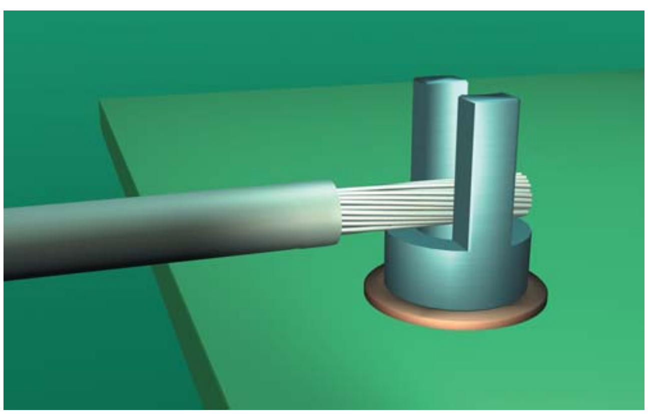


Figure 6-84

Acceptable – Class 1
Process Indicator – Class 2

- Wires or leads equal to or greater than 0.75 mm [0.03 in] and wrapped less than 90° are not staked.

Defect – Class 1,2

- Wires or leads less than 0.75 mm [0.03 in] and wrapped less than 90° are not staked.

Defect – Class 3

- Any straight through wire is not staked.

6.9.3 Bifurcated – Lead/Wire Placement – Bottom and Top Route Attachments

Table 6-6 is applicable to leads and wires attached to bottom-route bifurcated terminals.

Table 6-6 Bifurcated Terminal Lead/Wire Placement – Bottom Route

Criteria	Class 1	Class 2	Class 3
< 90° wrap	Acceptable	Process Indicator	Defect
90° to 180° wrap	Acceptable		

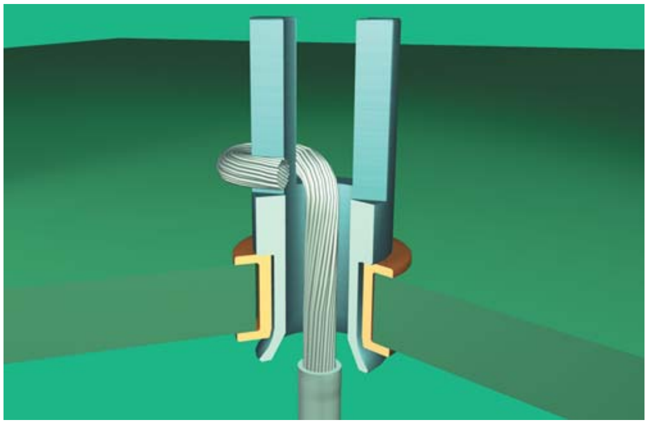


Figure 6-85

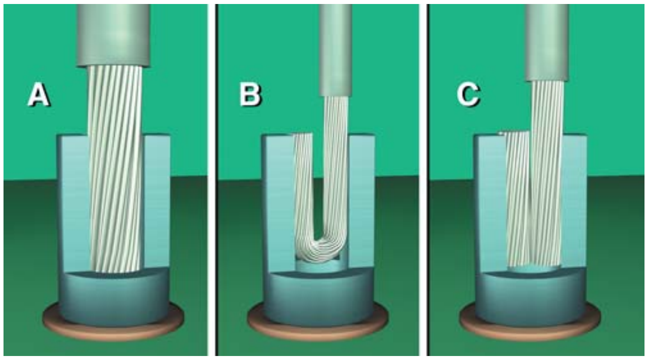


Figure 6-86

Target – Class 1,2,3

- Wire insulation does not enter shank of terminal.
- Bottom route wire wrap contacts two parallel sides of post (180°).
- Wire is against base of terminal.
- Top route wire has space between posts filled by using separate filler or bending the wire double, see Figure 6-86-B, C.

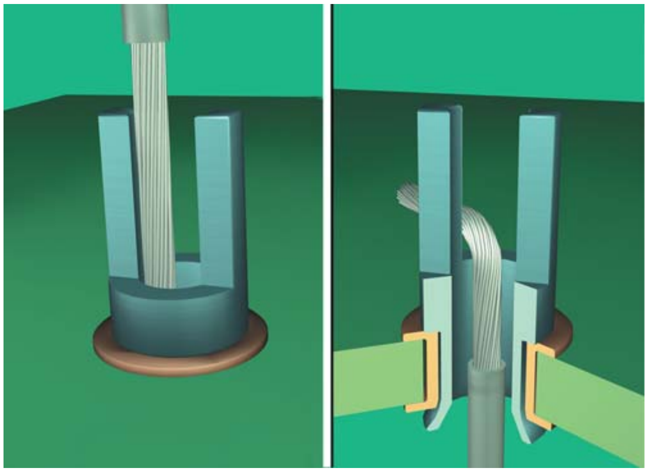


Figure 6-87

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire insulation enters base or posts of terminal.
- Top route wire is not supported with filler.
- Bottom route wire not wrapped to terminal base or post with a minimum 90° bend.

6.9.4 Bifurcated – Solder

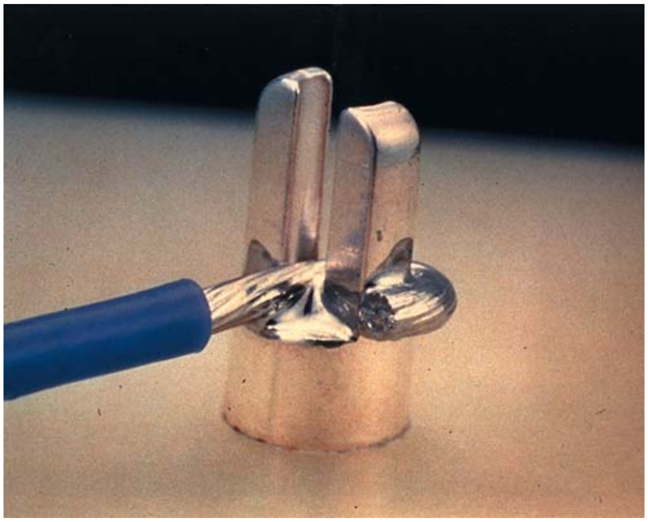


Figure 6-88

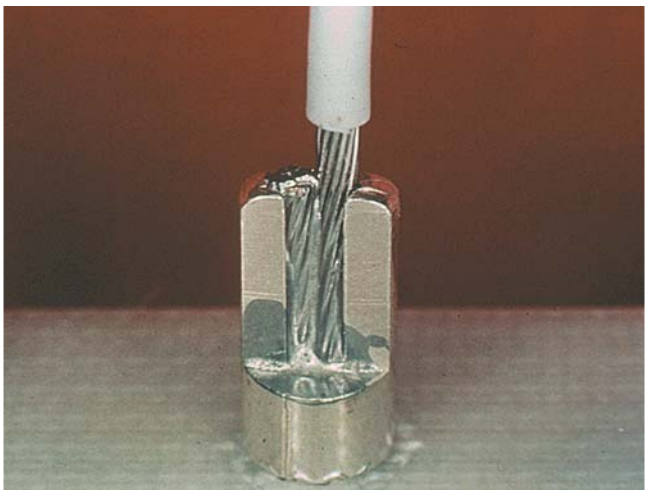


Figure 6-89

Target – Class 1,2,3

- Lead outline is discernible; smooth flow of solder on wire and terminal.
- Solder fillets at all points of wire/lead and terminal interface.

6.9.4 Bifurcated – Solder (cont.)

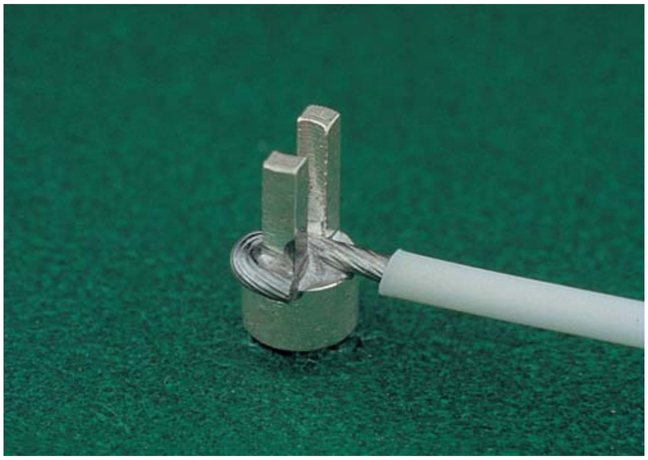


Figure 6-90

Figure 6-91

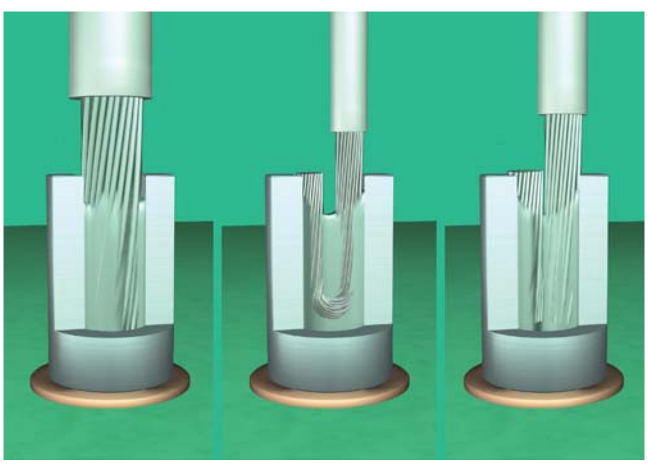


Figure 6-92

Acceptable – Class 1,2,3

- Solder is wetted to at least 75% of the contact area between the wire/lead and terminal interface for leads wrapped equal to or more than 180°.
- Solder is wetted to 100% of the contact area between the wire/lead and terminal interface for leads wrapped less than 180°.
- Solder is 75% of the height of the terminal post for top-route wires.

6.9.4 Bifurcated – Solder (cont.)

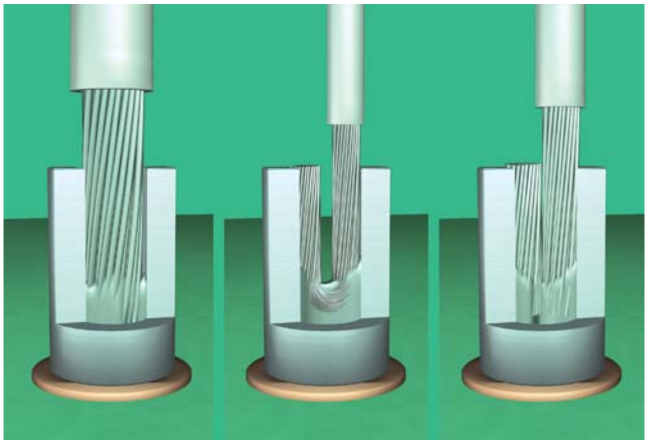


Figure 6-93

Defect – Class 1,2,3

- Solder is less than 75% of the height of the terminal post for top-route wires.
- Less than 100% fillet of the lead to terminal contact when the wrap is less than 180° (not shown).
- Less than 75% fillet of the lead to terminal contact when the wrap is equal to or more than 180° (not shown).

6.10 Slotted

6.10.1 Slotted – Lead/Wire Placement

Figure 6-94

Target – Class 1,2,3

- Lead or wire extends completely through and beyond the exit side of the slot.
- Wire is in contact with base of terminal area or previously installed wire.

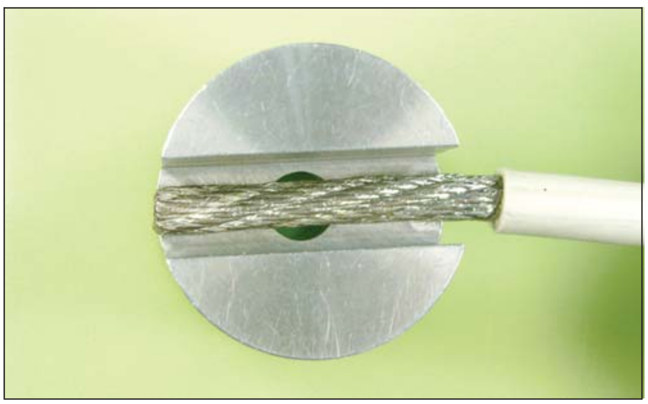


Figure 6-95

Acceptable – Class 1,2,3

- Lead or wire end is discernible on the exit side of terminal.
- No portion of the wire termination extends above the top of the terminal post.

Note: Wrap is not required on a slotted terminal.

Figure 6-96

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire extends above the top of the terminal post.

Defect – Class 1,2,3

- Lead end is not flush or does not extend beyond the exit side of terminal.
- Wire end violates minimum electrical clearance.

6.10.2 Slotted – Solder

Solder should form a fillet with that portion of the lead or wire that is in contact with the terminal. Solder may completely fill the slot but should not be built up on top of the terminal. The lead or wire should be discernible in the terminal.

Figure 6-97

Target – Class 1,2,3

- Solder forms a fillet with that portion of the lead or wire that is in contact with the terminal.
- There is visible insulation clearance.

Figure 6-98

Acceptable – Class 1,2,3

- Solder fills terminal slot.
- Lead or wire end is discernible in the solder on the exit side of terminal.

Figure 6-99

Defect – Class 1,2,3

- Wire or lead end is not discernible on the exit side of the terminal.
- Fillet not formed with 100% of the portion of the wire that is in contact with the terminal (not shown).

6.11 Pierced/Perforated

6.11.1 Pierced/Perforated – Lead/Wire Placement

Table 6-7 is applicable to leads and wires attached to pierced or perforated terminals.

Table 6-7 Pierced or Perforated Terminal Lead/Wire Placement

Criteria	Class 1	Class 2	Class 3
Wire overlaps itself, Note 1	Acceptable	Defect	
Wire does not pass through the eye.	Acceptable	Defect	
Wire does not contact at least two surfaces of the terminal.	Acceptable	Defect	
Wire end violates minimum electrical clearance.	Defect		

Note 1: See 6.6.

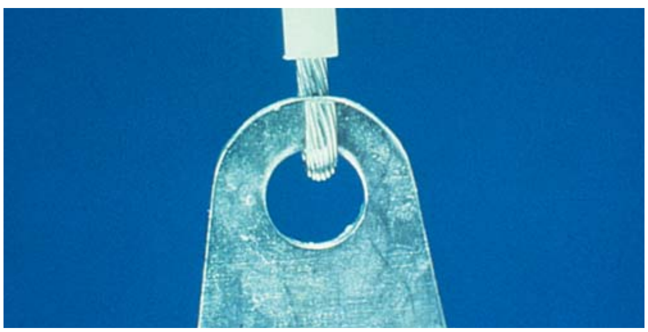


Figure 6-100

Target – Class 1,2,3

- Wire passes through the eye of the terminal.
- Wire wrapped to contact two nonadjacent sides of the terminal.

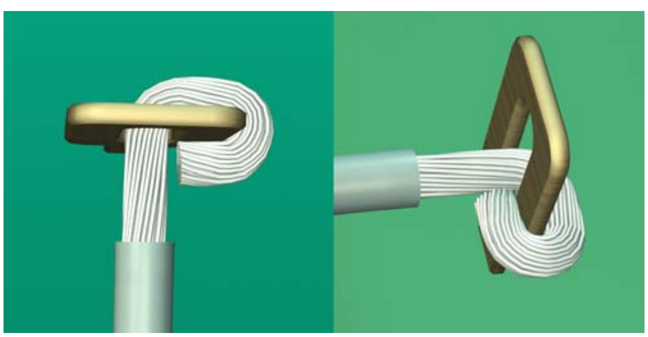


Figure 6-101

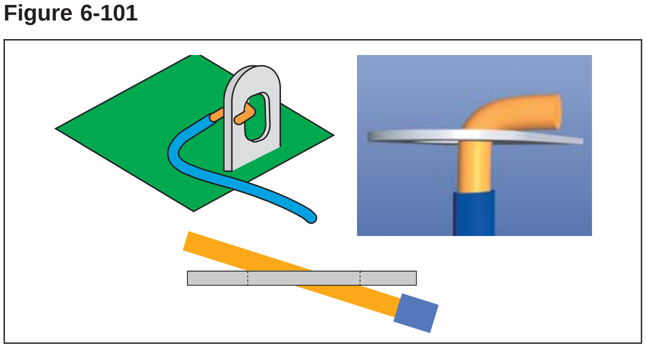


Figure 6-102

6.11.1 Pierced/Perforated – Lead/Wire Placement (cont.)

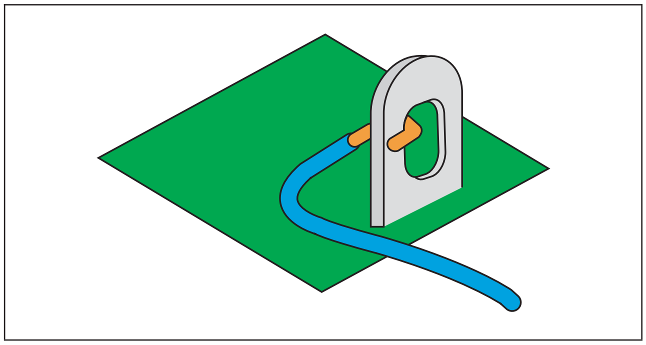


Figure 6-103

Acceptable – Class 2,3

- Wire contacts at least two surfaces of the terminal.

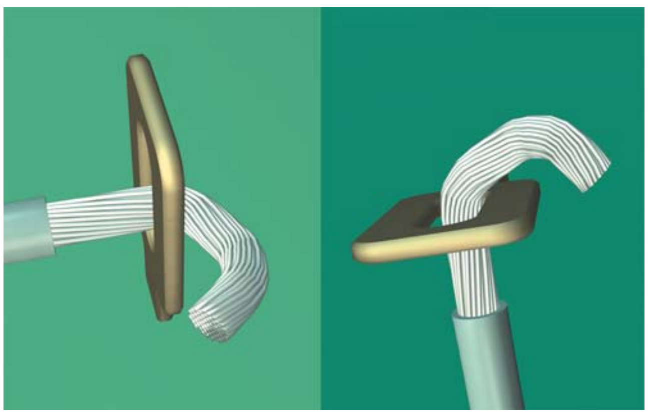


Figure 6-104

Acceptable – Class 1
Defect – Class 2,3

- Wire does not contact at least two surfaces of the terminal.
- Wire does not pass through the eye of the terminal.
- Wire overlaps itself.

Defect – Class 2,3

- Terminal altered to accept oversize wire or wire group.

Defect – Class 1,2,3

- Wire end violates minimum electrical clearance to noncommon conductor (not shown).

6.11.2 Pierced/Perforated – Solder

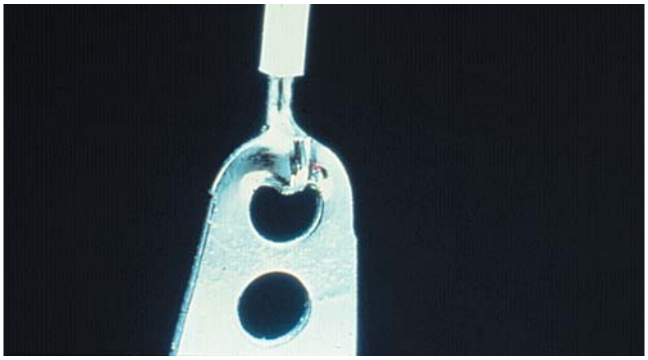


Figure 6-105

Target – Class 1,2,3

- Lead outline is discernible; smooth flow of solder on wire and terminal.
- Solder fillets at all points of wire/lead and terminal interface.

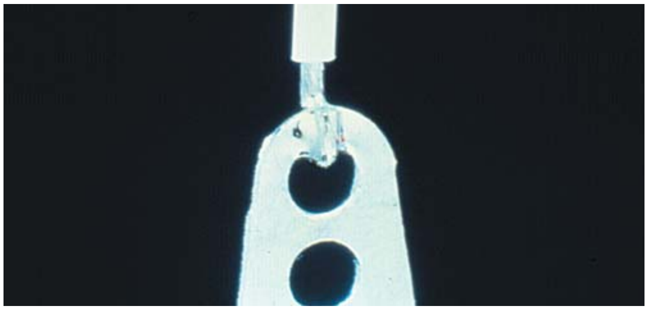


Figure 6-106

Acceptable – Class 1,2,3

- Solder fillet joins the wire to the terminal for at least 75% of the wire and terminal interface for wraps of equal to or more than 180°.
- Solder fillet joins the wire to the terminal for 100% of the wire and terminal interface for wraps less than 180°.

Acceptable – Class 1
Process Indicator – Class 2,3

- Wire/lead not discernible in solder connection.

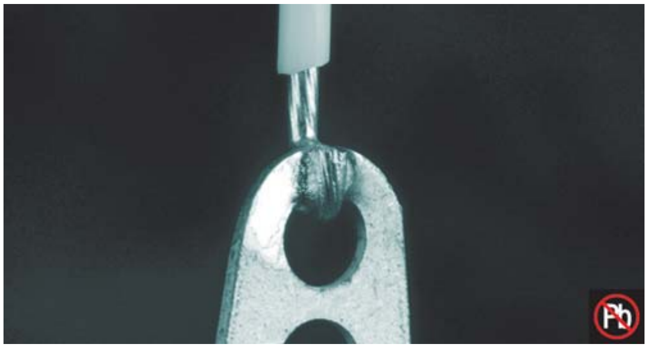


Figure 6-107

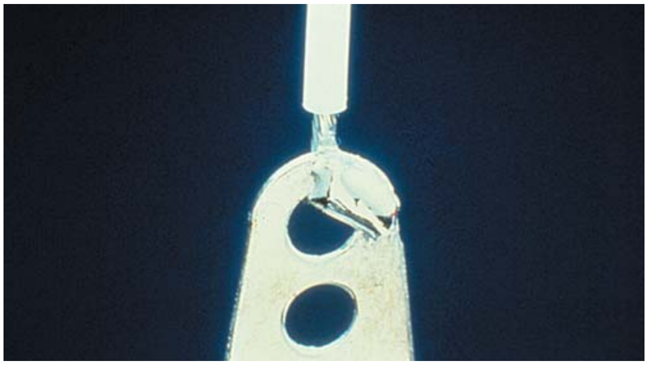


Figure 6-108

Defect – Class 1,2,3

- Less than 100% fillet of the lead to terminal contact when the wrap is less than 180°.
- Less than 75% fillet of the lead to terminal contact when the wrap is equal to or more than 180°.

6.12 Hook

6.12.1 Hook – Lead/Wire Placement

Table 6-8 is applicable to leads and wires attached to hook terminals.

Table 6-8 Hook Terminal Lead/Wire Placement

Criteria	Class 1	Class 2	Class 3
< 90° contact between the lead/wire and terminal post.	Defect		
90° to < 180° contact between the lead/wire and terminal post.	Acceptable	Process Indicator	Defect
≥ 180° contact between the lead/wire and terminal post.	Acceptable		
Wire overlaps itself, Note 1	Acceptable	Defect	
Less than one lead/wire diameter space from end of hook to closest wire.	Acceptable	Process Indicator	Defect
Wire less than two lead/wire diameters or 1 mm [0.04 in], whichever is greater, from the terminal base.	Acceptable	Process Indicator	Defect
Wire violates minimum electrical clearance.	Defect		

Note 1: See 6.6.

Figure 6-109

Target – Class 1,2,3

- The wire is attached at the center of the 180° arc of the hook.

6.12.1 Hook – Lead/Wire Placement (cont.)

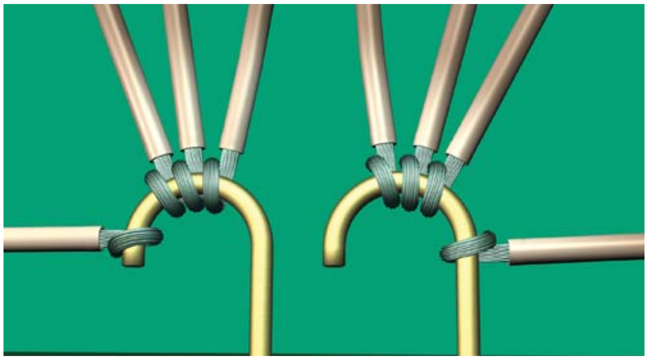


Figure 6-110

Acceptable – Class 1,2,3

- Wire contacts and wraps terminal at least 180°.
- Minimum of one wire diameter space from end of hook to the closest wire.
- Wires do not overlap.

Figure 6-111

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire is wrapped less than one wire diameter from end of hook.
- Wire is less than two wire diameters or 1 mm [0.04 in], whichever is greater, from the base of the terminal.
- Wire wrap is less than 180°.

Defect – Class 1,2

- Wire wrap is less than 90°.

Acceptable – Class 1
Defect – Class 2,3

- Wire overlaps itself.

Defect – Class 1,2,3

- Wire end violates minimum electrical clearance to noncommon conductor.

6.12.2 Hook – Solder

Figure 6-112

Target – Class 1,2,3

- Wire/lead outline is discernible; smooth flow of solder on wire and terminal.
- Solder fillets at all points of wire/lead and terminal interface.

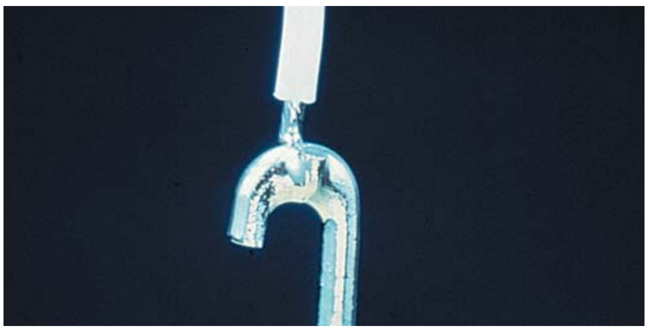


Figure 6-113

Acceptable – Class 1,2

- Solder is wetted to 100% of the contact area between the wire/lead and terminal interface for leads wrapped less than 180°.

Acceptable – Class 1,2,3

- Solder is wetted to at least 75% of the contact area between the wire/lead and terminal interface for leads wrapped equal to or more than 180°.

Acceptable – Class 1
Process Indicator – Class 2,3

- Wire/lead not discernible in solder connection.

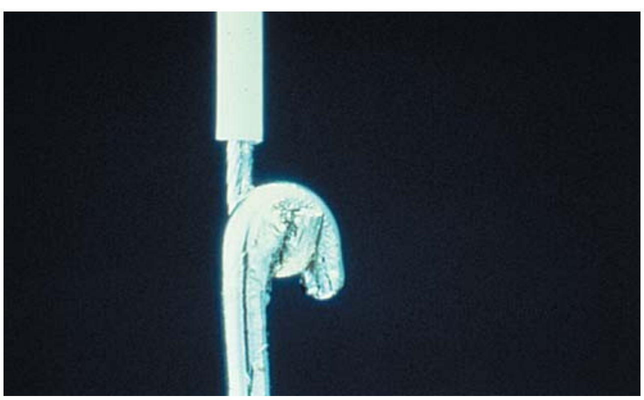


Figure 6-114

Defect – Class 1,2

- Less than 100% fillet of the lead to terminal contact when the wrap is less than 180°.

Defect – Class 1,2,3

- Less than 75% fillet of the lead to terminal contact when the wrap is equal to or more than 180°.

6.13 Solder Cups

6.13.1 Solder Cups – Lead/Wire Placement

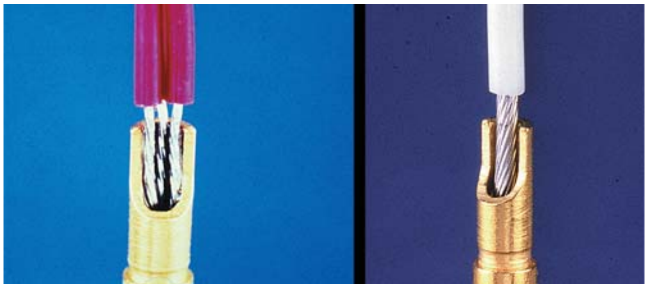


Figure 6-115

Target – Class 1,2,3

- Solder cups have the wire(s) inserted straight in and contact the back wall or other inserted wires for the full depth of the cup.

6.13.1 Solder Cups – Lead/Wire Placement (cont.)

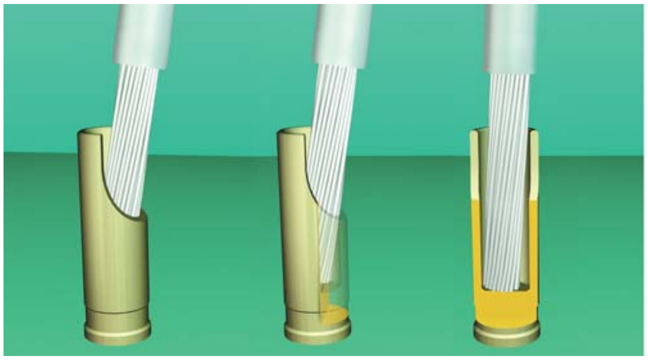


Figure 6-116

Acceptable – Class 1,2,3

- Wire does not interfere with subsequent assembly operations.
- Conductor strands not cut or modified to fit into the terminal.
- Multiple conductors are not twisted together.

Acceptable – Class 1
Process Indicator – Class 2,3

- Wire does not contact the back wall or other wires.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire(s) not inserted for full depth of cup.

Acceptable – Class 1
Defect – Class 2,3

- Solder cup altered to accept oversized wire or wire group.

Defect – Class 1,2,3

- Strands not in conformance with 6.3.2.
- Wire strands outside of the cup.
- Wire placement interferes with subsequent assembly steps.
- Multiple conductors are twisted together.

6.13.2 Solder Cups – Solder

These criteria are applicable to either solid or stranded wire, single or multiple wires.

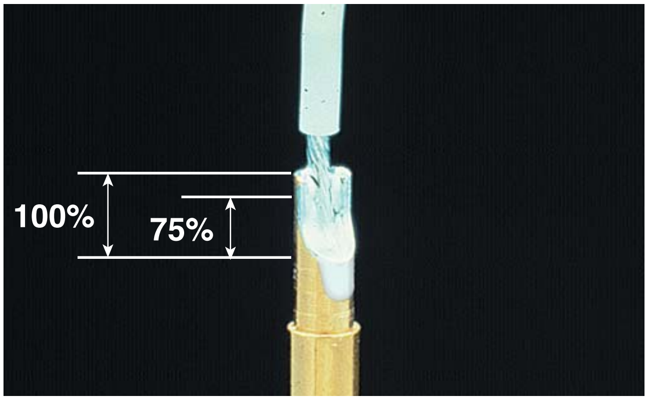


Figure 6-117

Target – Class 1,2,3

- Solder wets the entire inside of the cup.
- Solder fill is 100%.

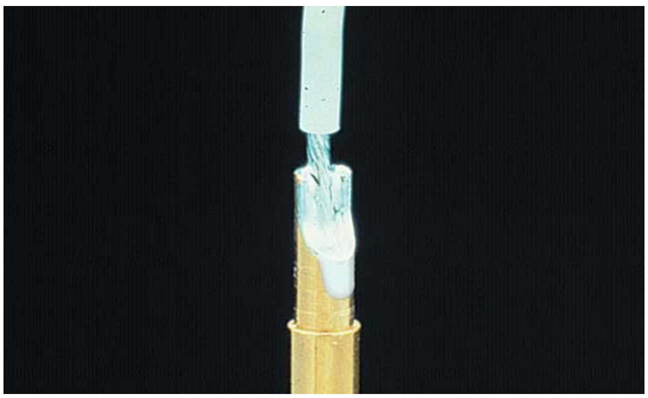


Figure 6-118

Figure 6-119

Acceptable – Class 1,2,3

- Thin film of solder on the outside of the cup.
- Solder fill 75% or more of visible portion above the cup lip.
- Solder buildup on the outside of the cup, as long as it does not affect form, fit or function.
- Solder visible in or slightly protrudes from the inspection hole (if one is provided).

6.13.2 Solder Cups – Solder (cont.)

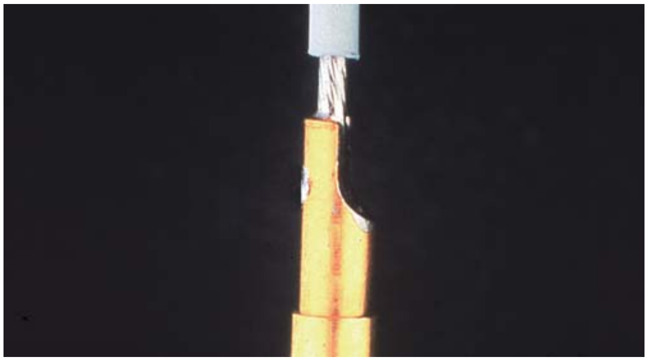


Figure 6-120

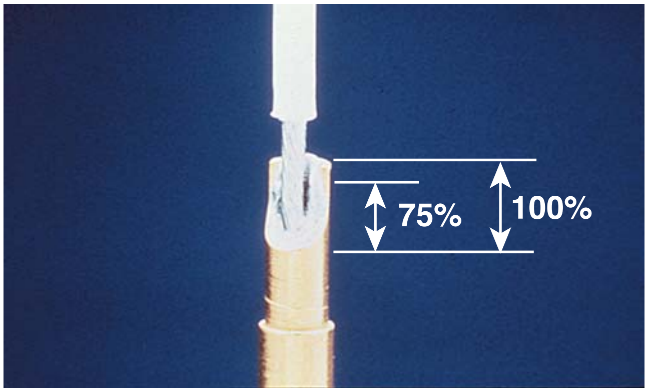


Figure 6-121

Defect – Class 1,2,3

- Solder does not fill the inside of the cup.
- Vertical fill of solder in the visible portion of the cup is less than 75%.
- Solder buildup on outside of the cup negatively affects form, fit or function.
- Solder not visible in the inspection hole (if one is provided).

6.14 AWG 30 and Smaller Diameter Wires – Lead/Wire Placement

Table 6-9 is applicable to AWG 30 and smaller diameter wires. These criteria do not apply to jumper wires.

Table 6-9 AWG 30 and Smaller Wire Wrap Requirements

Criteria	Class 1	Class 2	Class 3
< 90°	Defect		
90° to < 180°	Acceptable	Defect	
180° to < 360°	Acceptable	Process Indicator	Defect
≥ 360°	Acceptable		

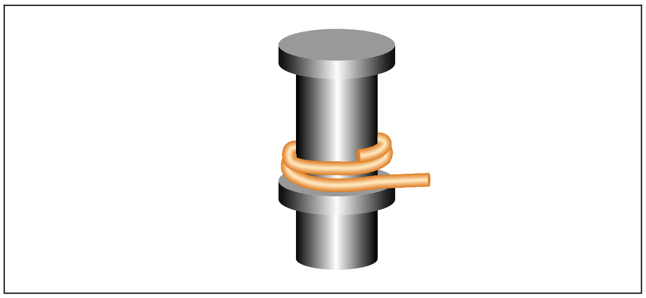


Figure 6-122

Target – Class 1,2,3

- Wire has two wraps (720°) around terminal post.
- Wire does not overlap or cross over itself or other wires terminated on the terminal.

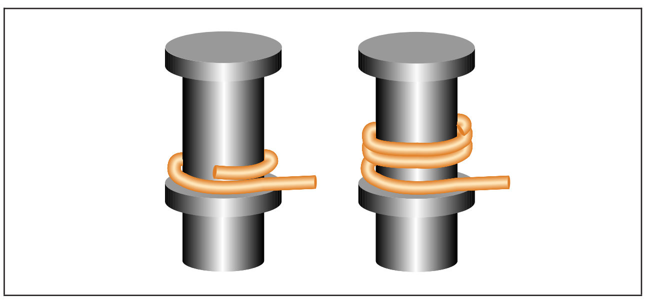


Figure 6-123

Acceptable – Class 1,2,3

- Wire has more than one wrap (360°) but less than three.

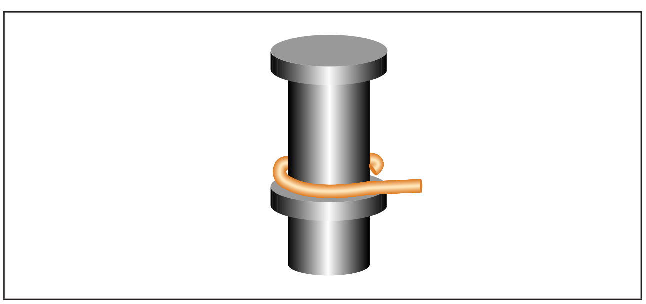


Figure 6-124

Acceptable – Class 1
Defect – Class 2

- Wire has less than 180° wrap.

Process Indicator – Class 2
Defect – Class 3

- Wire has less than one 360° wrap.

6.15 Series Connected

These criteria apply when three or more terminals are connected by a common bus wire.

Figure 6-125

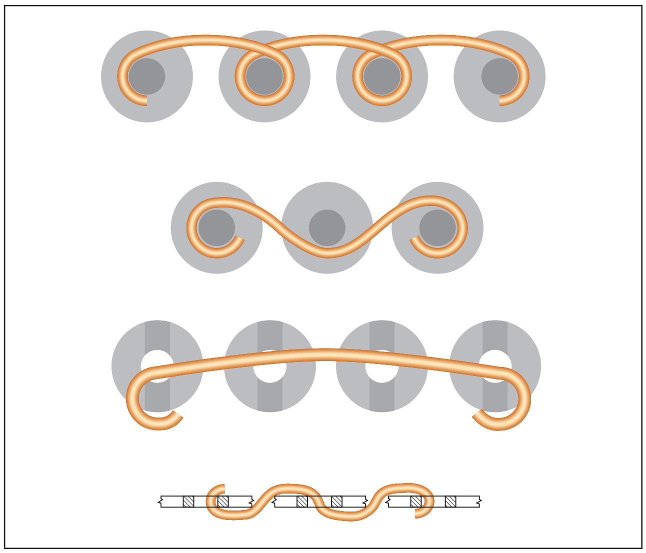


Figure 6-126

Target – Class 1,2,3

- Stress relief radii between each terminal.
- Turrets – Wire contacts base of terminal or a previously installed wire, and wraps around or interweaves each terminal.
- Hooks – Wire wraps 360° around each terminal.
- Bifurcated – Wire passes between posts and contacts base of terminal or previously installed wire.
- Pierced/Perforated – Wire contacts two nonadjacent sides of each terminal.
- The connection to the first and last terminals meets the required wrap for individual terminals.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Turrets – Wire does not wrap 360° around each intermediate terminal or is not interwoven between terminals.
- Hooks – Wire wraps less than 360° around intermediate terminal.
- Bifurcated – Wire does not pass between the posts or is not in contact with the terminal base or a previously installed wire.
- Pierced/Perforated – Wire does not contact two nonadjacent sides of each inner terminal.

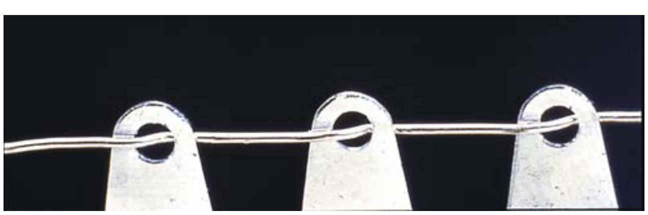


Figure 6-127

Defect – Class 1,2,3

- No stress relief between any two terminals.
- The connection to the first and last terminals does not meet the required wrap for individual terminals.

6.16 Edge Clip – Position

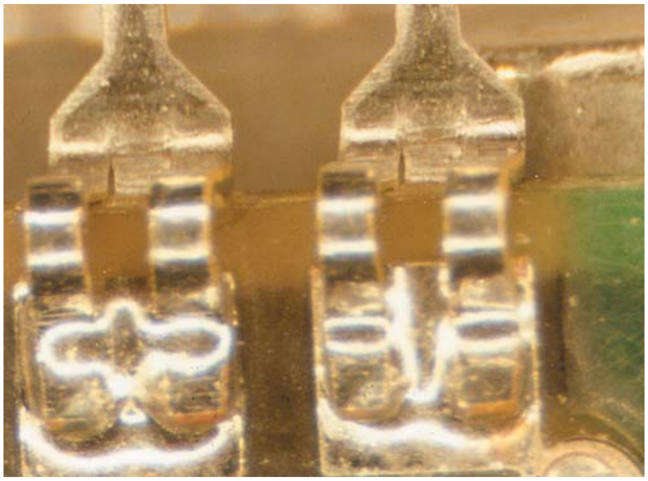


Figure 6-128

Target – Class 1,2,3

- Clip is centered on land with no side overhang.

Figure 6-129

Acceptable – Class 1,2,3

- Clip has 25% maximum overhang off land.
- Overhang does not reduce spacing below minimum electrical clearance.

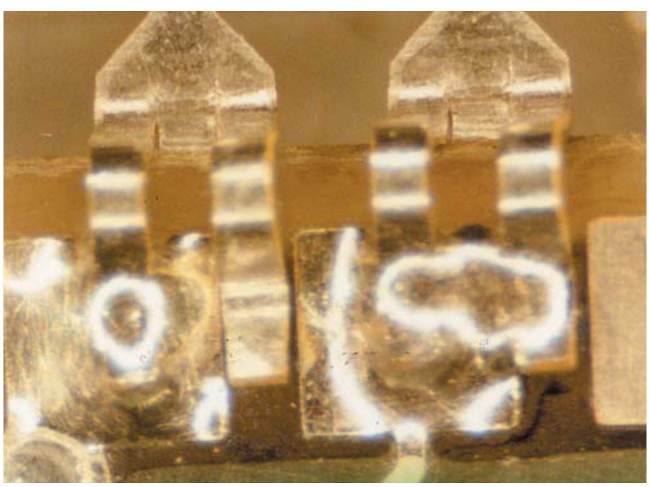


Figure 6-130

Defect – Class 1,2,3

- Clip exceeds 25% overhang off land.
- Clip overhangs land, reducing the spacing below minimum electrical clearance.

7 Through-Hole Technology

This section includes hardware, adhesive, forming, mounting, termination and soldering criteria for through-hole installation.

The placement of any component on the electronic assembly does not prevent the insertion or removal of any hardware (tool clearance included) used to mount the assembly.

Minimum spacing between installed hardware and the conducting land, component leads or uninsulated components depends on specified voltage and is not less than the specified minimum electrical clearance, see 1.8.4.

Bonding material is sufficient to hold the part but does not encapsulate and cover component identification.

Visual inspection includes part identification and polarity, assembly sequence, and damage to hardware, component, or board.

In addition to the criteria in this section the criteria of Section 5 are applicable.

The following topics are addressed in this section:

7.1 Component Mounting

7.1.1 Component Mounting – Orientation

This section covers acceptability requirements for the installation, location, and orientation of components and wires mounted onto printed boards.

Criteria are given for only the actual mounting or placement of components or wires on electronic assemblies and to standoff spacers. Solder is mentioned where it is an integral part of the placement dimensions, but only as related to those dimensions.

Inspection usually starts with a general overall view of the electronic assembly, then follows each component/wire to its connection, concentrating on the lead into the connection, the connection and the tail end of the lead/wire leaving the connection. The wire/lead protrusion step for all lands should be saved for last so that the board can be flipped over and all connections checked together.

7.1.1.1 Component Mounting – Orientation – Horizontal

Additional criteria for horizontal mounting of axial leaded components are provided in clauses 7.3.1 (supported holes) and 7.4.1 (unsupported holes).

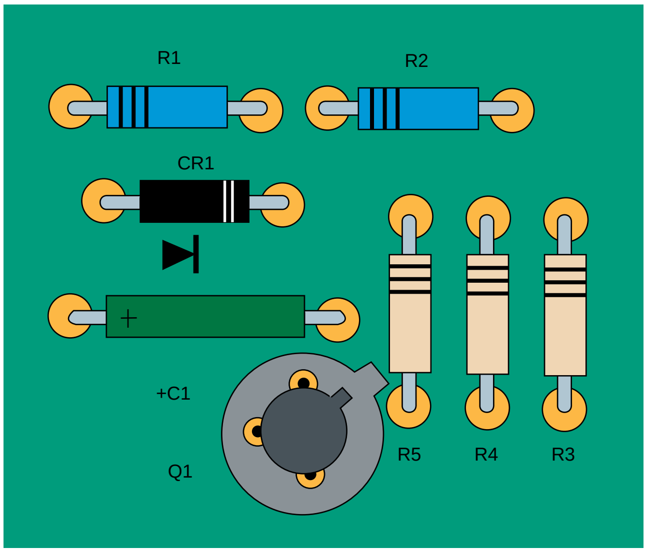


Figure 7-1

Target – Class 1,2,3

- Components are centered between their lands.
- Component markings are discernible.
- Nonpolarized components are oriented so that markings all read the same way (left-to-right or top-to-bottom).

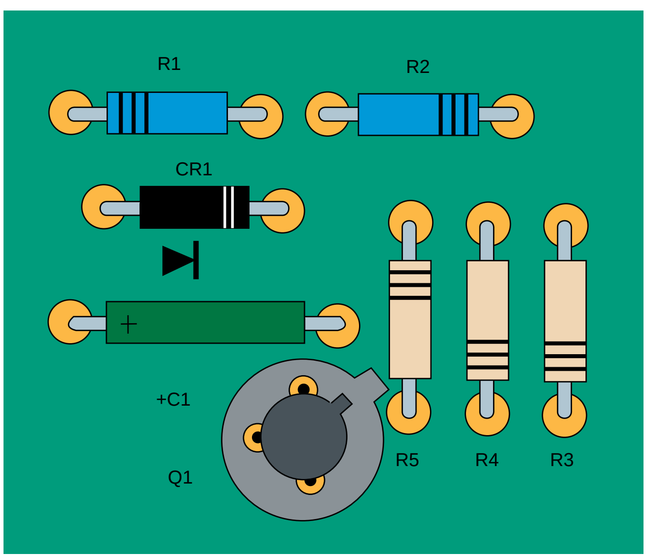


Figure 7-2

Acceptable – Class 1,2,3

- Polarized and multilead components are oriented correctly.
- When hand formed and hand-inserted, polarization symbols are discernible.
- All components are as specified and terminate to correct lands.
- Nonpolarized components are not oriented so that markings all read the same way (left-to-right or top-to-bottom).

7.1.1.1 Component Mounting – Orientation – Horizontal (cont.)

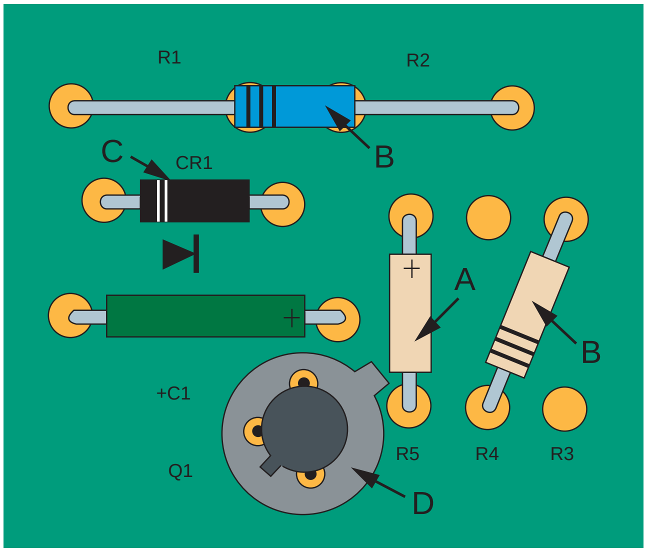


Figure 7-3

Defect – Class 1,2,3

- Component is not as specified (wrong part), see Figure 7-3-A.
- Component not mounted in correct holes, see Figure 7-3-B.
- Polarized component mounted backwards, see Figure 7-3-C.
- Multileaded component not oriented correctly, see Figure 7-3-D.

7.1.1.2 Component Mounting – Orientation – Vertical

Additional criteria for vertical mounting of axial leaded components are provided in clauses 7.3.2 (supported holes) and 7.4.2 (unsupported holes).

In the examples in Figures 7-4 through 7-6, the arrows printed on the black capacitor casing are pointing to the negative end of the component.

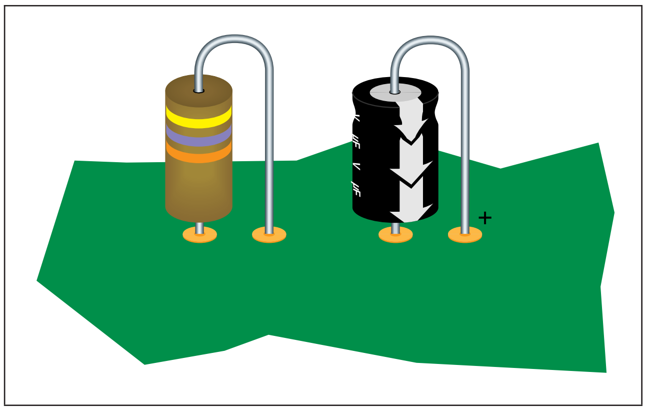


Figure 7-4

Target – Class 1,2,3

- Nonpolarized component markings read from the top down.
- Polarized markings are located on top.

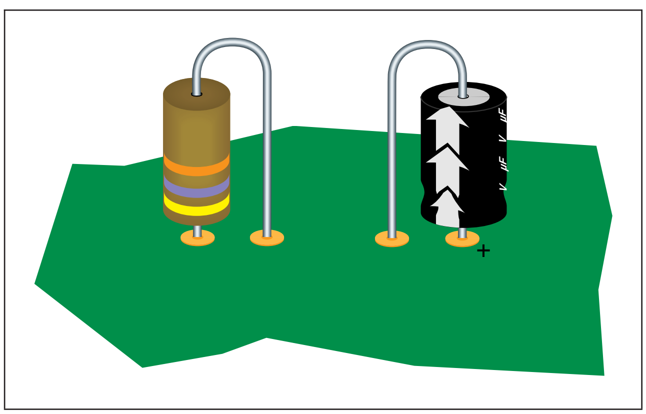


Figure 7-5

Acceptable – Class 1,2,3

- Polarized part is mounted with a long ground lead.
- Polarized marking hidden.
- Nonpolarized component markings read from bottom to top.

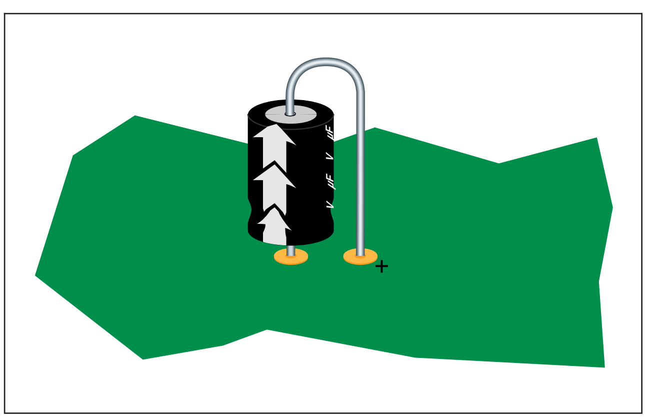


Figure 7-6

Defect – Class 1,2,3

- Polarized component is mounted backwards.

7.1.2 Component Mounting – Lead Forming

7.1.2.1 Component Mounting – Lead Forming – Bend Radius

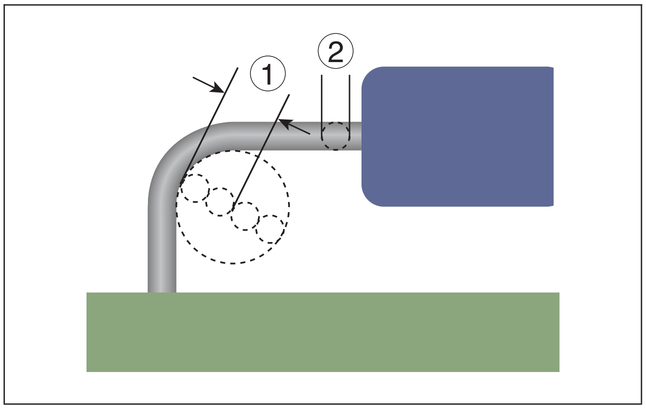


Figure 7-7
1. Radius (R)
2. Diameter (D)

Acceptable – Class 1,2,3

- The inside bend radius of component leads meets requirements of Table 7-1.

Table 7-1 Lead Bend Radius

Lead Diameter (D) or Thickness (T)	Minimum Inside Bend Radius (R)
< 0.8 mm [0.03 in]	1 (D) or (T)
0.8 mm [0.03 in] to 1.2 mm [0.05 in]	1.5 (D) or (T)
> 1.2 mm [0.05 in]	2 (D) or (T)

Note: Rectangular leads use thickness (T).

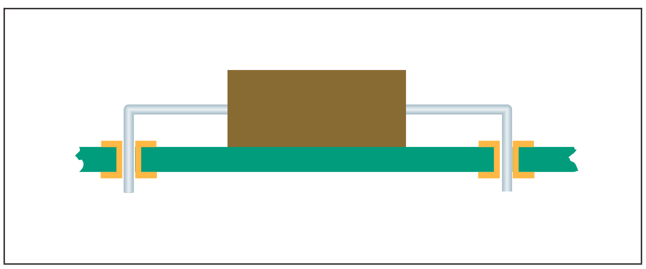


Figure 7-8

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Inside bend radius does not meet requirements of Table 7-1.

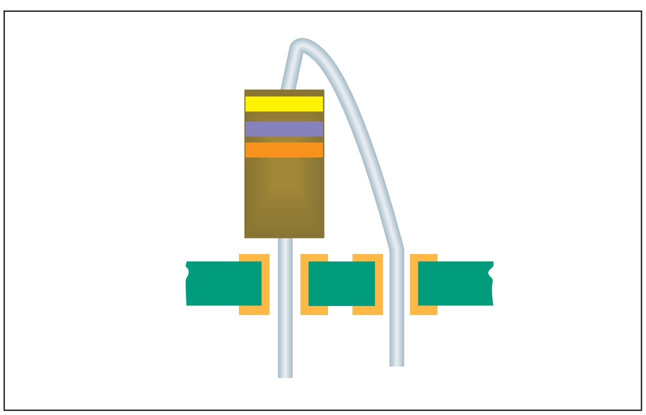


Figure 7-9

Defect – Class 1,2,3

- Lead is kinked.

7.1.2.2 Component Mounting – Lead Forming – Space between Seal/Weld and Bend

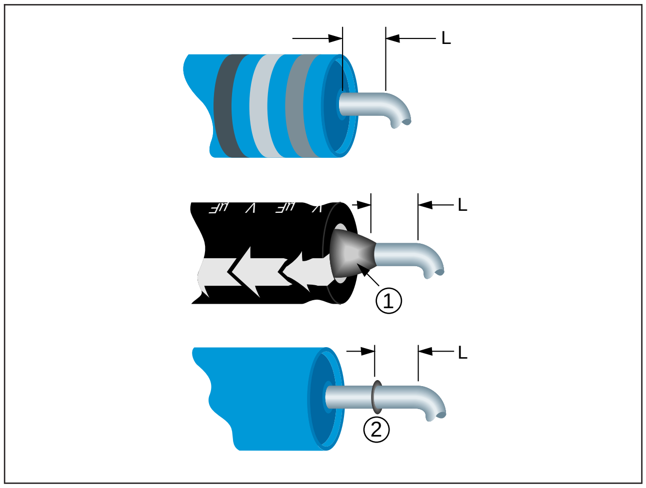


Figure 7-10
1. Solder bead
2. Weld

Acceptable – Class 1,2,3

- Leads of through-hole mounted component extend at least one lead diameter or thickness but not less than 0.8 mm [0.03 in] from the body, solder bead, or lead weld.

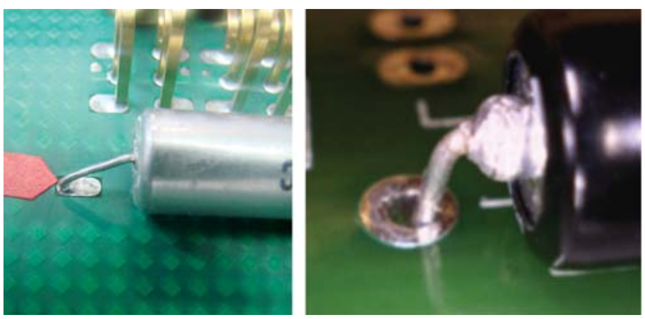


Figure 7-11

Figure 7-12

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Lead bend of through-hole mounted component is less than one lead diameter/thickness or less than 0.8 mm [0.03 in], from the component body, solder bead or component body lead seal.

Defect – Class 1,2,3

- Fractured lead weld, solder bead, or component body lead seal.
- Lead damage exceeds limits of 7.1.2.4.

7.1.2.3 Component Mounting – Lead Forming – Stress Relief

Components are mounted in any one or a combination of the following configurations:

- In a conventional manner utilizing 90° (nominal) lead bends directly to the mounting hole.
- With camel hump bends. Configuration incorporating a single camel hump may have the body positioned off-center.
- Other configurations may be used with agreement of the customer or where design constraints exist.

Loop bends may be used if the location of the mounting holes prevents the use of a standard bend and if there is no possibility of shorting the lead to any adjacent component lead or conductor. Use of loop bends may impact circuit impedance, etc., and **shall** be approved by design engineering.

Prepped components with stress bends as shown in Figure 7-14 usually cannot meet the maximum clearance requirements of a straight-legged vertical - radial leaded component, see 7.1.6. Maximum clearance between component and board surface is determined by design limitations and product use environments. The component preparation equipment and manufacturer's suggested component lead bend specifications and capabilities determine limitation. This may require change in tooling to meet requirements for end use.

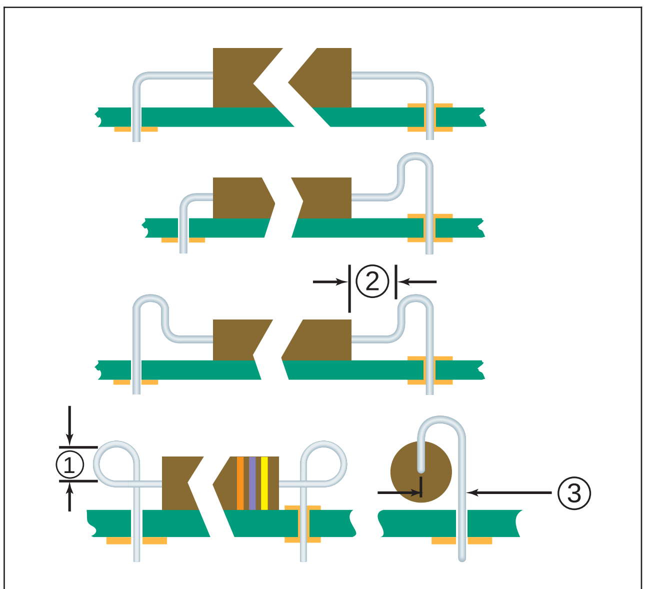


Figure 7-13
1. Typically four - eight wire diameters
2. One wire diameter minimum
3. Two wire diameter minimum

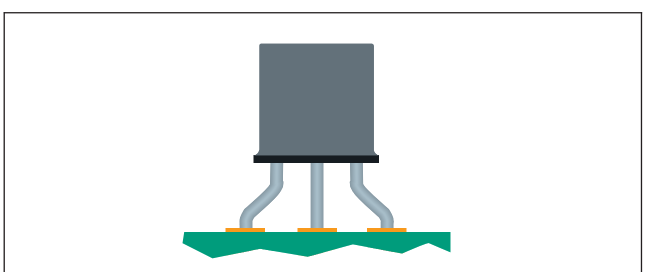


Figure 7-14

Acceptable – Class 1,2,3

- Leads are formed to provide stress relief.
- Component lead exiting component body is approximately parallel to major body axis.
- Component lead entering hole is approximately perpendicular to board surface.
- Component centering may be offset as a result of the type of stress relief bend.

7.1.2.3 Component Mounting – Lead Forming – Stress Relief (cont.)

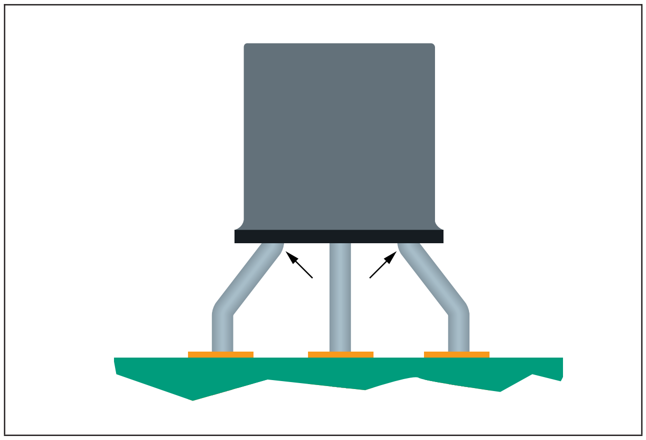


Figure 7-15

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Lead bends less than one lead diameter or thickness but not less than 0.8 mm [0.03 in] away from body seal.

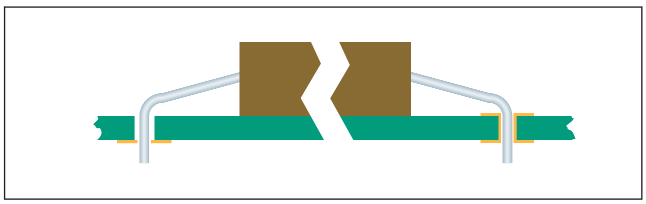


Figure 7-16

Defect – Class 1,2,3

- Damage or fracture of component body-to-lead seal.
- No stress relief.

7.1.2.4 Component Mounting – Lead Forming – Damage

These criteria are applicable whether leads are formed manually or by machine or die.

Figure 7-17

Acceptable – Class 1,2,3

- No nicks or deformation exceeding 10% of the diameter, width or thickness of the lead. See 5.2.1 for exposed basis metal criteria.

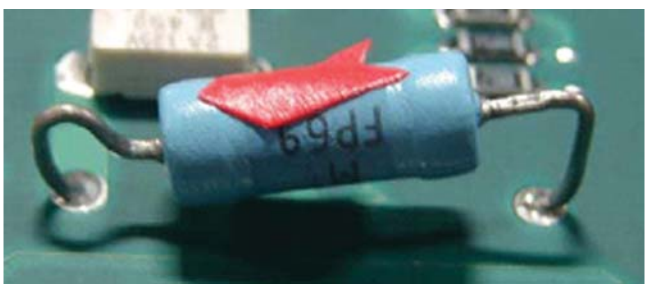


Figure 7-18

Defect – Class 1,2,3

- Lead is damaged more than 10% of the lead diameter or thickness.
- Lead deformed from repeated or careless bending.

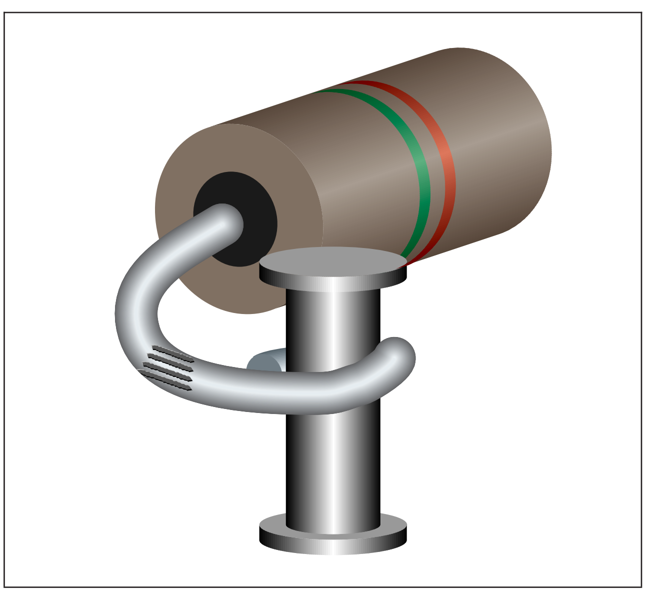


Figure 7-19

Defect – Class 1,2,3

- Heavy indentations such as serrated pliers mark.
- Lead diameter is reduced more than 10%.

7.1.3 Component Mounting – Leads Crossing Conductors

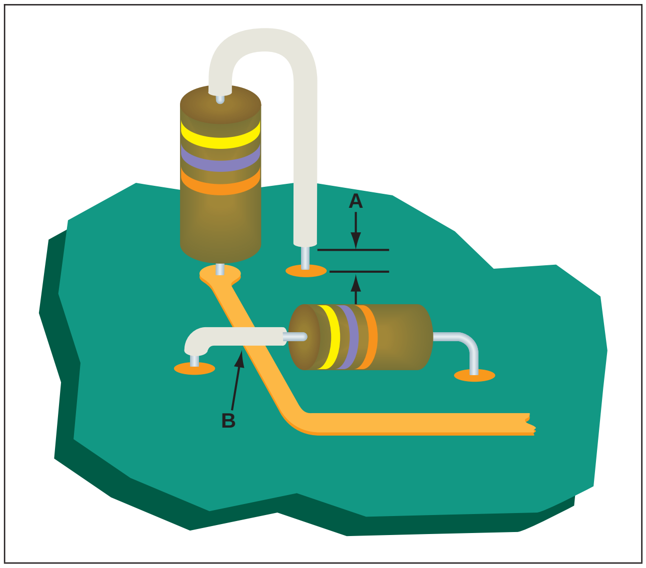


Figure 7-20

Acceptable – Class 1,2,3

- Sleeve does not interfere with formation of the required solder connection, see Figure 7-20-A.
- Sleeve covers area of protection designated, see Figure 7-20-B.

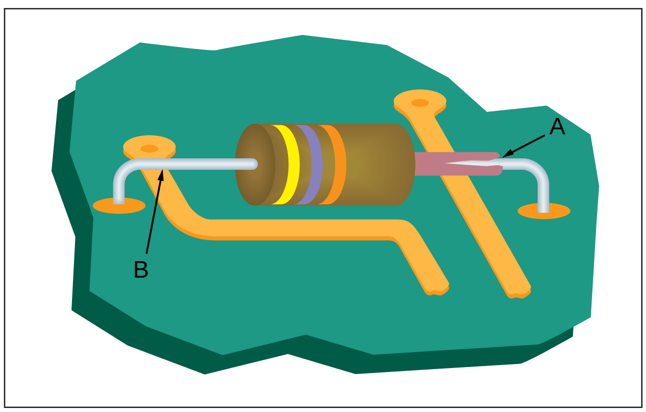


Figure 7-21

Not Established – Class 1
Defect – Class 2,3

- Splitting and/or unraveling of sleeving, see Figure 7-21-A.

Defect – Class 1,2,3

- Component leads and wires required to have sleeving are not sleeved, see Figure 7-21-B.
- Damaged/insufficient sleeving does not provide protection from shorting.
- Sleeving interferes with formation of the required solder connection.
- A component lead crossing an electrically noncommon conductor violates minimum electrical clearance, see Figure 7-21-B.

7.1.4 Component Mounting – Hole Obstruction

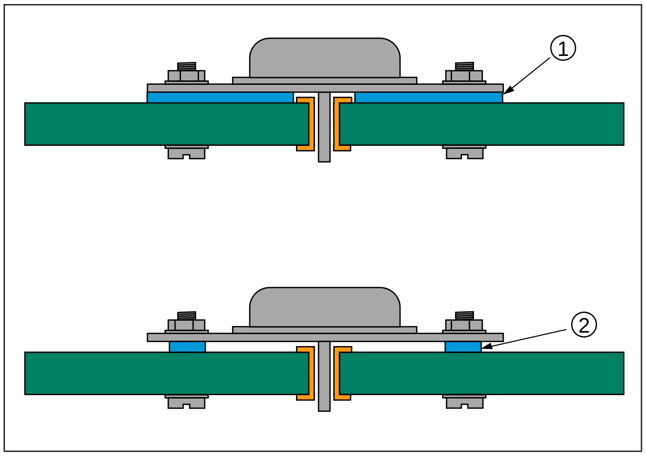


Figure 7-22
1. Insulating washer
2. Spacer

Acceptable – Class 1,2,3

- Parts and components are mounted such that they do not obstruct solder flow onto the primary side (solder destination side) lands of plated through-holes required to be soldered.

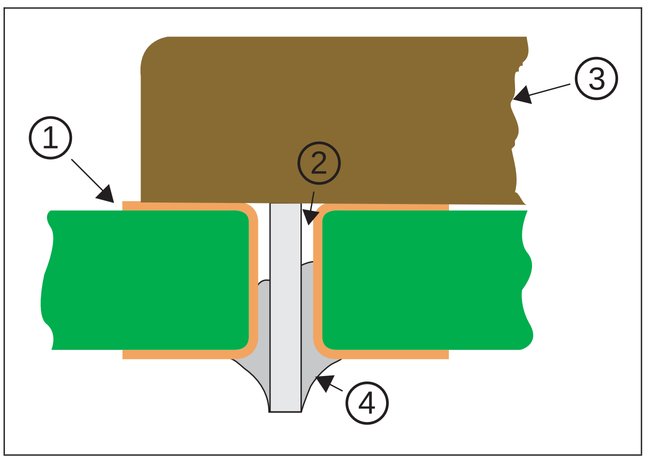


Figure 7-23
1. Component body contacts land and obstructs solder flow.
2. Air
3. Component body
4. Solder

Process Indicator – Class 2
Defect – Class 3

- Parts and components obstruct solder flow onto the primary side (solder destination side) lands of plated through-holes required to be soldered.

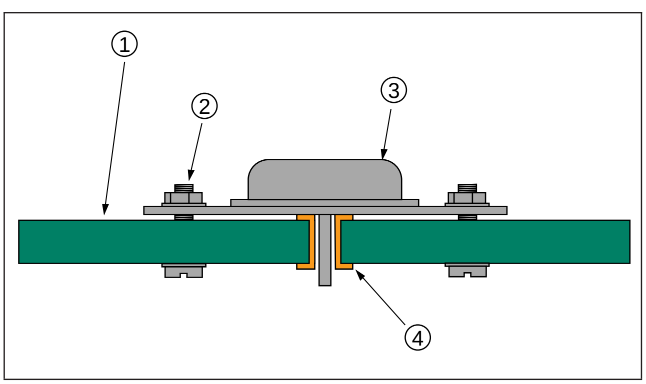


Figure 7-24
1. Nonmetal
2. Mounting hardware
3. Component case
4. Conductive pattern

Defect – Class 1,2,3

- Parts and components are mounted such that they violate minimum electrical clearance.

7.1.5 Component Mounting – DIP/SIP Devices and Sockets

These criteria are applicable to Dual-in-Line Packages (DIP), Single-in-Line Packages (SIP) and sockets.

Note: In some cases a heat sink may be located between the component and the printed board; in these cases other criteria may be specified.

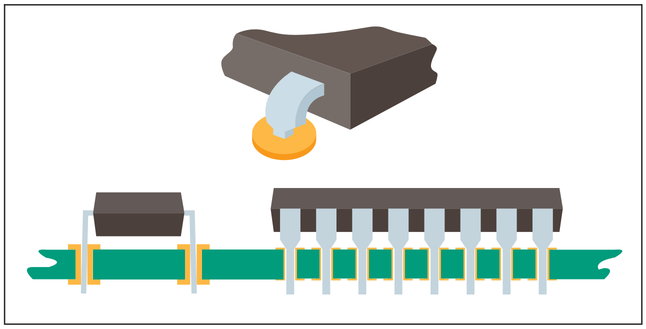


Figure 7-25

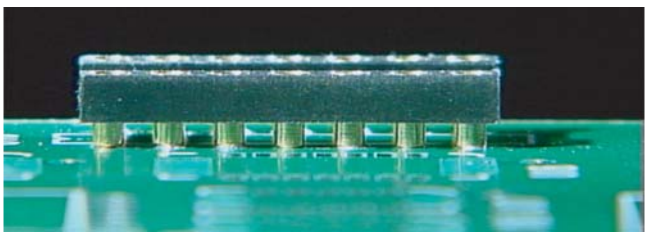


Figure 7-26

Target – Class 1,2,3

- Standoff step on all leads rests on the land.
- Lead protrusion meets requirements, see 7.3.3 and 7.4.3.

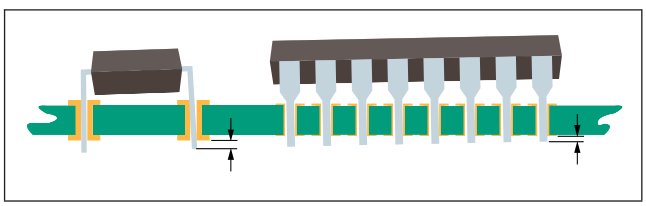


Figure 7-27

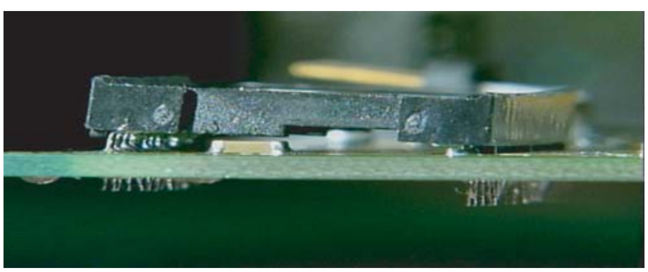


Figure 7-28

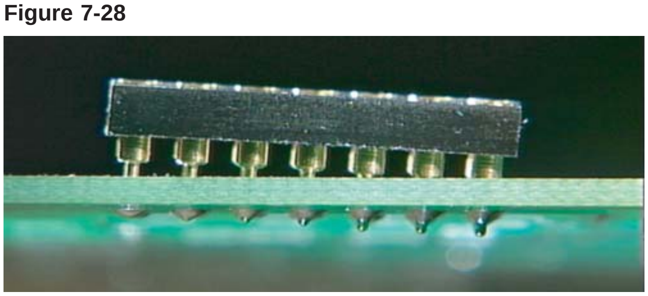


Figure 7-29

Acceptable – Class 1,2,3

- Amount of tilt is limited by minimum lead protrusion and height requirements.

7.1.5 Component Mounting – DIP/SIP Devices and Sockets (cont.)

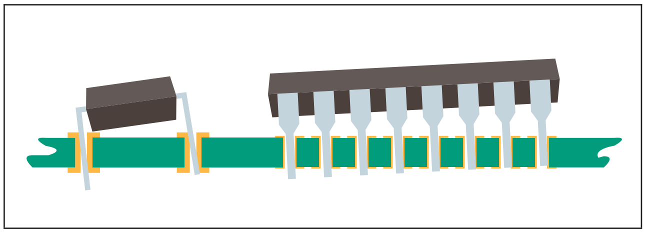


Figure 7-30

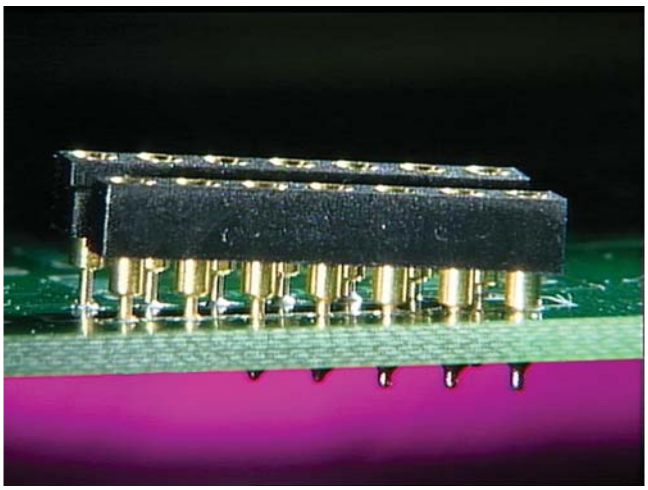


Figure 7-31

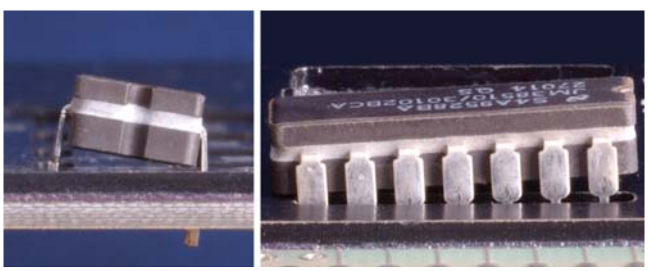


Figure 7-32

Defect – Class 1,2,3

- Tilt of the component exceeds maximum component height limits.
- Lead protrusion does not meet acceptance requirements due to tilt of component.

7.1.6 Component Mounting – Radial Leads – Vertical

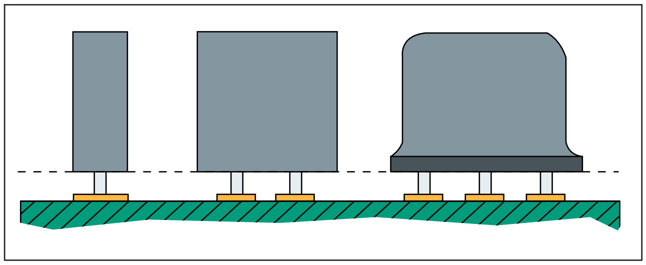


Figure 7-33

Target – Class 1,2,3

• Component is perpendicular and base is parallel to board.

• Clearance between base of component and board surface/ land is between 0.3 mm [0.01 in] and 2 mm [0.08 in].

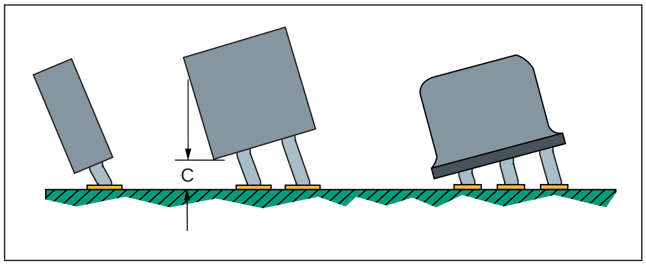


Figure 7-34

Acceptable – Class 1,2,3

• Component tilt does not violate minimum electrical clearance, see Figure 7-34-C.

Acceptable – Class 1
Process Indicator – Class 2,3

• Space between component base and board surface/land is less than 0.3 mm [0.01 in] or more than 2 mm [0.08 in], see 7.1.4.

Defect – Class 1,2,3

• Violates minimum electrical clearance.

Note: Some components cannot be tilted due to mating requirements with enclosures or panels, for example toggle switches, potentiometers, LCDs, and LEDs.

7.1.6.1 Component Mounting – Radial Leads – Vertical – Spacers

Spacers used for mechanical support or to compensate for component weight need to be in full contact with both component and board surface.

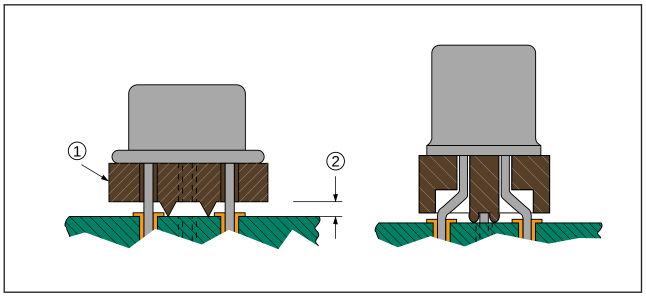


Figure 7-35
1. Spacer
2. Contact

Target – Class 1,2,3

- Spacer is in full contact with both component and board.
- Lead is properly formed.

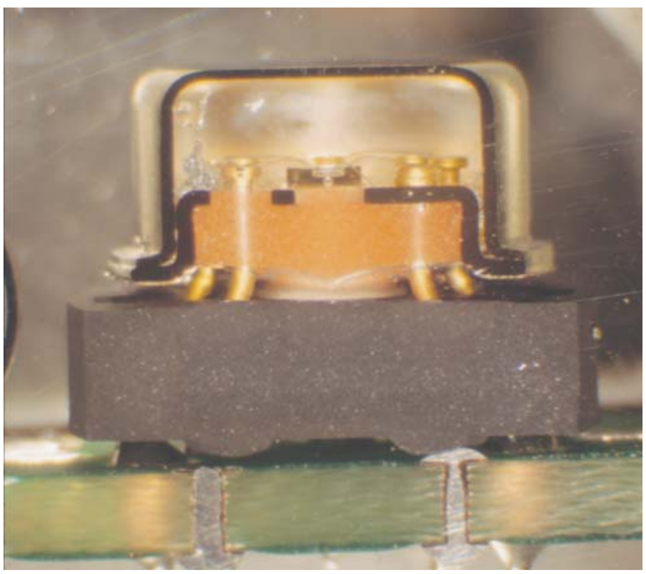


Figure 7-36

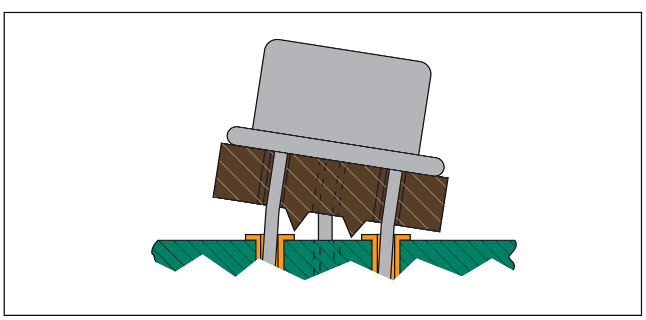


Figure 7-37

Acceptable (Supported Holes) – Class 1,2
Process Indicator (Supported Holes) – Class 3
Defect (Unsupported Holes) – Class 1,2,3

- Spacer is not in full contact with component and board.

7.1.6.1 Component Mounting – Radial Leads – Vertical – Spacers (cont.)

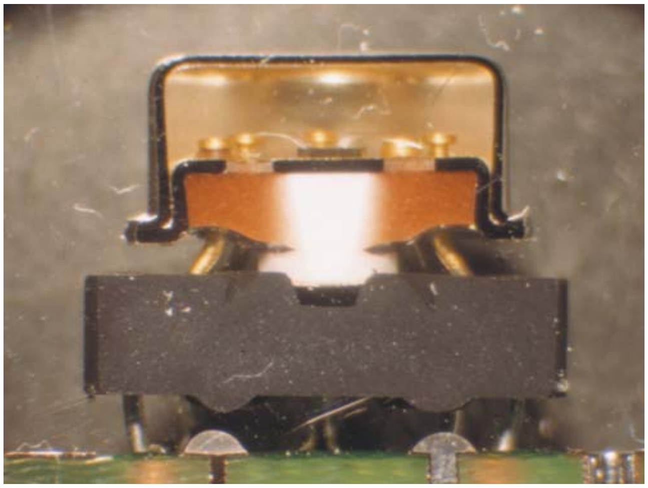


Figure 7-38

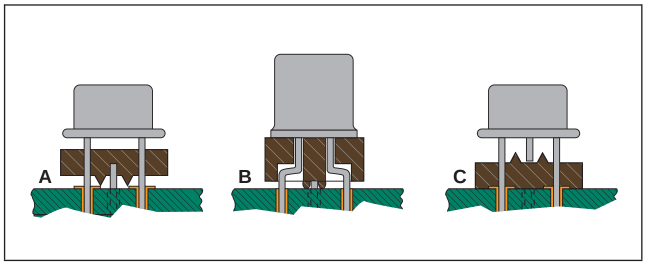


Figure 7-39

Acceptable (Supported Holes) – Class 1
Process Indicator (Supported Holes) – Class 2
Defect (Supported Holes) – Class 3
Defect (Unsupported Holes) – Class 1,2,3

- Spacer is not in contact with component and board, see Figure 7-39-A.
- Lead is improperly formed, see Figure 7-39-B.

Not Established – Class 1
Defect – Class 2,3

- Spacer is inverted, see Figure 7-39-C.

7.1.7 Component Mounting – Radial Leads – Horizontal

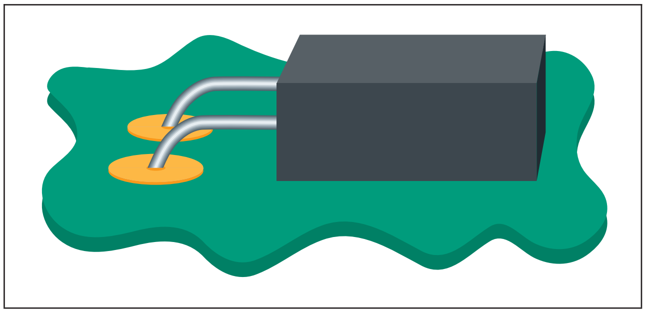


Figure 7-40

Target – Class 1,2,3

- The component body is flat and in full contact with the board's surface.
- Bonding material is present, if required, see 7.2.2.

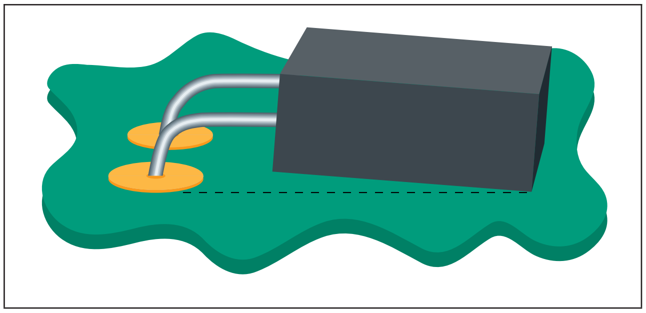


Figure 7-41

Acceptable – Class 1,2,3

- Component in contact with board on at least one side and/or surface.

Note: When documented on an approved assembly drawing, a component may be either side mounted or end mounted. The body may need to be bonded or otherwise secured to the board to prevent damage when vibration and shock forces are applied.

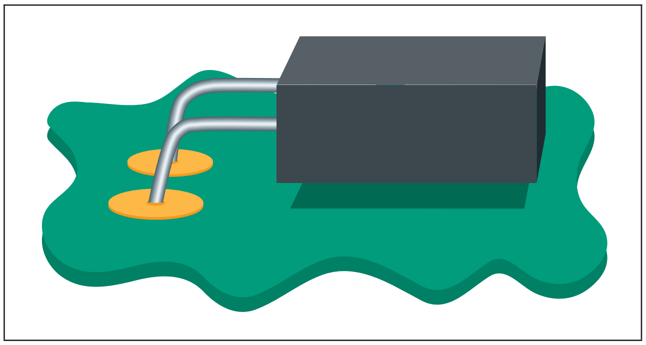


Figure 7-42

Defect – Class 1,2,3

- Unbonded component body not in contact with mounting surface.
- Bonding material not present if required.

7.1.8 Component Mounting – Connectors

These criteria apply to soldered connectors. For connector pin criteria see 4.3. For connector damage criteria see 9.5.

Connector module/pin misalignment, defined in this section, is to be measured at the connector lead-in area/hole (for receptacles) or at the pin tip (for pin headers).

In cases where an assembly connector is composed of two or more identical connector modules, modules manufactured by different suppliers **shall not** be mixed.

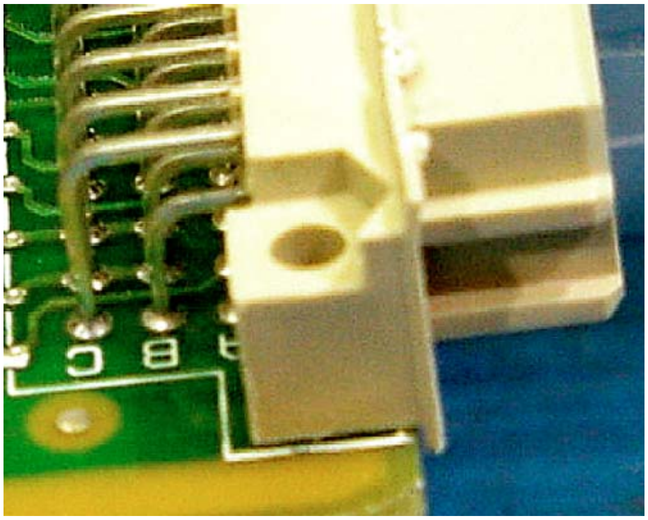


Figure 7-43

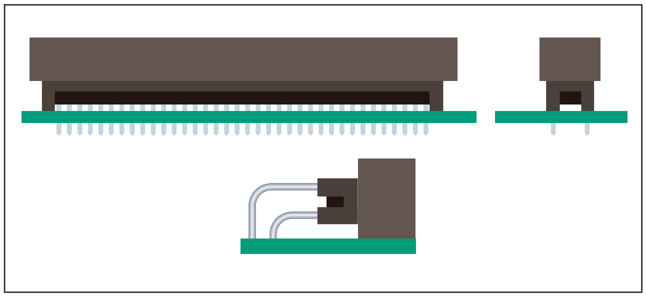


Figure 7-44

Target – Class 1,2,3

- Connector is flush with board.
- Lead protrusion meets requirements.
- Board lock (if equipped) is fully inserted/snapped into the board.

7.1.8 Component Mounting – Connectors (cont.)

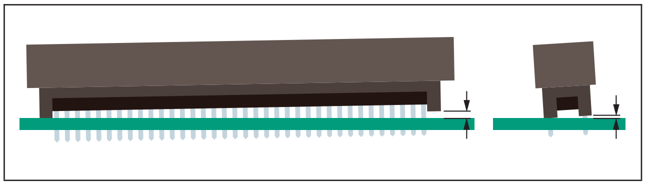


Figure 7-45

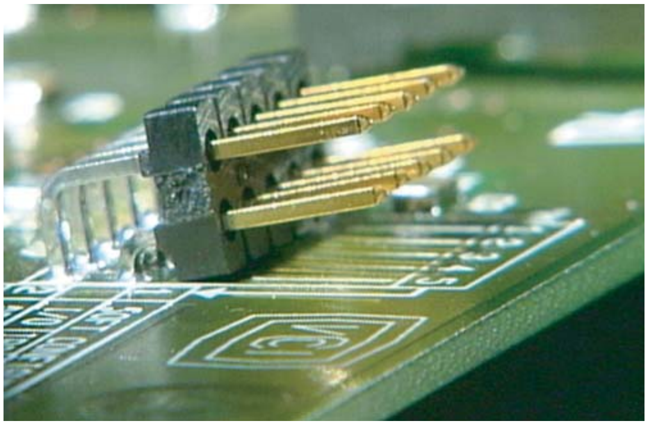


Figure 7-46

Acceptable – Class 1,2,3

- Board lock is fully inserted/snapped through the board.
- Any tilt or misalignment, provided:
  - – Minimum lead protrusion is met.
  - – Maximum height requirements are not exceeded.
  - – Mates correctly.

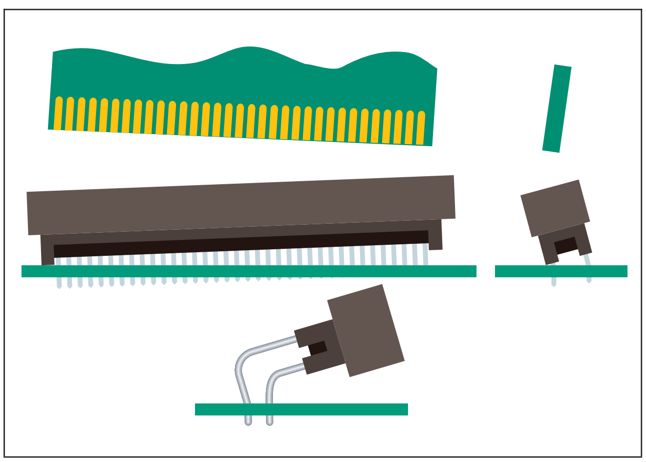


Figure 7-47

Defect – Class 1,2,3

- Will not mate when used in application due to angle or misalignment.
- Component violates height requirements.
- Board lock is not fully inserted/snapped into board.
- Lead protrusion does not meet acceptance requirements.

Note: A trial mating of connector to connector or to assembly may be required to assure the connectors meet form, fit and function requirement.

7.1.8.1 Component Mounting – Connectors – Right Angle

These criteria are applicable to right angle soldered connectors with pin spacing greater than or equal to 2.5 mm [0.1 in].

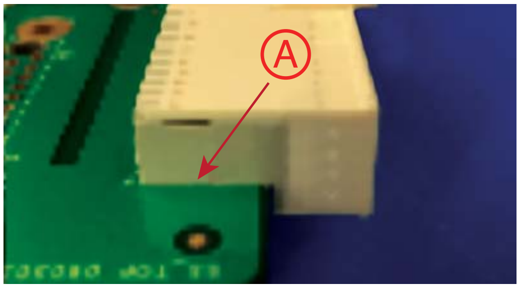


Figure 7-48

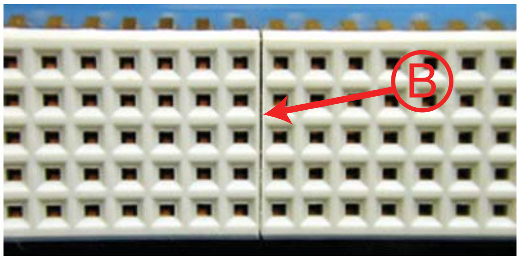


Figure 7-49

Target – Class 1,2,3

- Connector is mounted flush with the surface of the board, see Figure 7-48-A.
- All modules of a multi-part connector are aligned and are mounted flush to adjoining modules, see Figure 7-49-B.

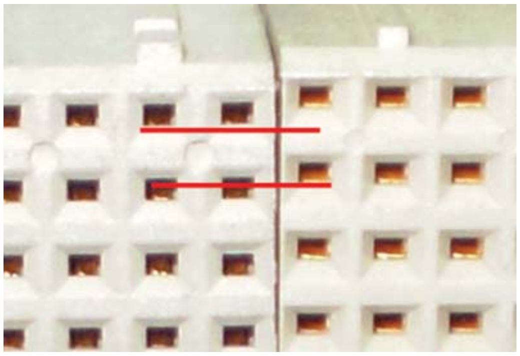


Figure 7-50

Acceptable – Class 1

- Connector spacing does not affect mating of connector with assembling requirements, e.g., face plates, bracket, mating connector, etc.

Acceptable – Class 2,3

- Connector-to-board spacing is equal to or less than 0.13 mm [0.005 in] (not shown).
- Maximum misalignment is less than 0.25 mm [0.01 in] across the contact openings of all connectors in the connector lineup, see Figure 7-50.

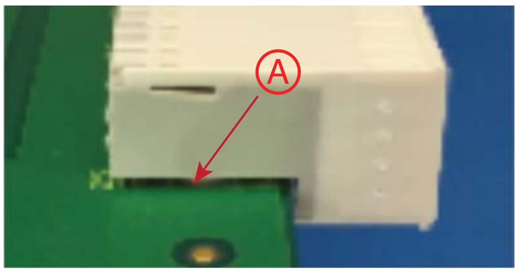


Figure 7-51

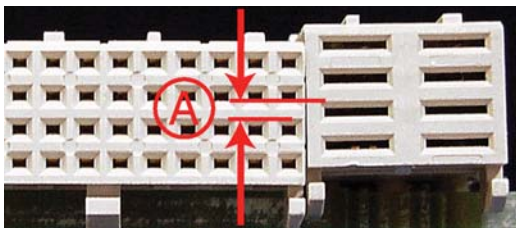


Figure 7-52

Defect – Class 1,2,3

- Connector spacing affects mating of connector with assembling requirements, e.g., face plates, bracket, mating connector, etc.

Defect – Class 2,3

- Connector-to-board spacing is greater than 0.13 mm [0.005 in], see Figure 7-51-A.
- Maximum misalignment is greater than 0.25 mm [0.01 in] across the faces (contact openings) of all modules (connectors) in the connector lineup, see Figure 7-52-A.

7.1.8.2 Component Mounting – Connectors – Vertical Shrouded Pin Headers and Vertical Receptacle Connectors

These criteria are applicable to vertical shrouded pin headers and vertical receptacle connectors that are 2 mm - 2.54 mm [0.08 - 0.1 in] pin spacing.

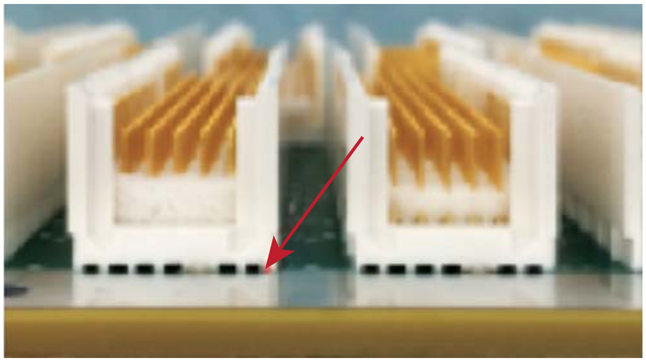


Figure 7-53

Target – Class 1,2,3

- Connector is mounted flush with the surface of the board, see Figure 7-53.
- All modules of a multi-part connector are aligned and are mounted flush to adjoining modules (not shown).

Acceptable – Class 1

- Connector spacing does not affect mating of connector with assembling requirements, e.g., face plates, bracket, mating connector, etc.

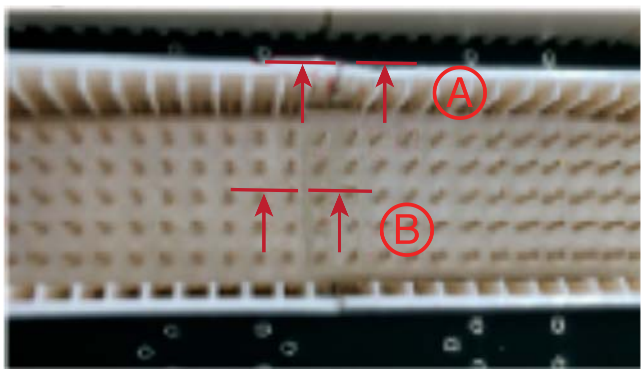


Figure 7-54

Acceptable – Class 2,3

- Connector-to-board spacing is equal to or less than 0.13 mm [0.005 in] (not shown).
- The misalignment of individual connector/modules contact openings, requiring alignment, are equal to, or less than, 0.25 mm [0.01 in], with adjacent modules, see Figure 7-54-A.
- Maximum misalignment between any two modules/pins in the connector lineup is less than 0.25 mm [0.01 in], see Figure 7-54-B.

Defect – Class 1,2,3

- Connector spacing affects mating of connector with assembling requirements, e.g., face plates, bracket, mating connector, etc.

Defect – Class 2,3

- Connector-to-board spacing is greater than 0.13 mm [0.005 in], (not shown).
- The misalignment of individual connector/modules contact openings, requiring alignment, is greater than 0.25 mm [0.01 in], with adjacent modules (not shown).
- Maximum misalignment between any two modules/pins in the connector lineup is greater than 0.25 mm [0.01 in] (not shown).

7.1.9 Component Mounting – Conductive Cases

Where a potential for shorting (violation of minimum electrical clearance) exists between conductive component bodies, at least one of the bodies **shall** be protected by an insulator.

7.2 Component Securing

7.2.1 Component Securing – Mounting Clips

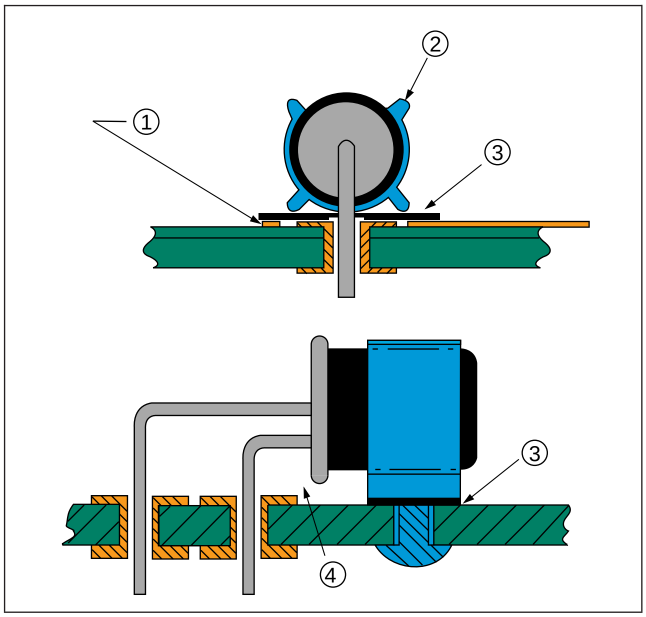


Figure 7-55

1. Conductive patterns
2. Metallic mounting clip
3. Insulation material
4. Clearance

Target – Class 1,2,3

- Uninsulated metallic component insulated from underlying circuitry with insulating material.
- Uninsulated metallic clips and holding devices used to secure components insulated from underlying circuitry with insulating material.

7.2.1 Component Securing – Mounting Clips (cont.)

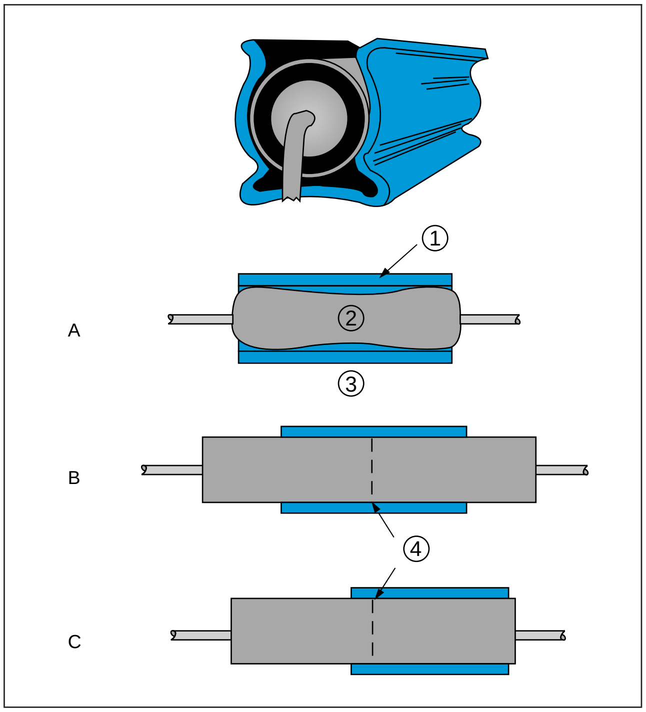


Figure 7-56

1. **Clip**
2. **Nonsymmetrical body**
3. **Top view**
4. **Center of gravity**

Acceptable – Class 1,2,3

- The clip makes contact to both sides of the component, see Figure 7-56-A.
- The component is mounted with the center of gravity within the confines of the clip, see Figure 7-56-B,C.
- The end of the component is flush with or extends beyond the end of the clip, see Figure 7-56-C.
- Spacing between land and uninsulated component body does not violate minimum electrical clearance.

7.2.1 Component Securing – Mounting Clips (cont.)

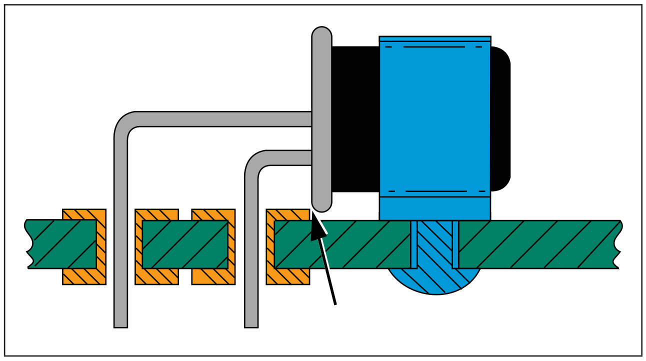


Figure 7-57

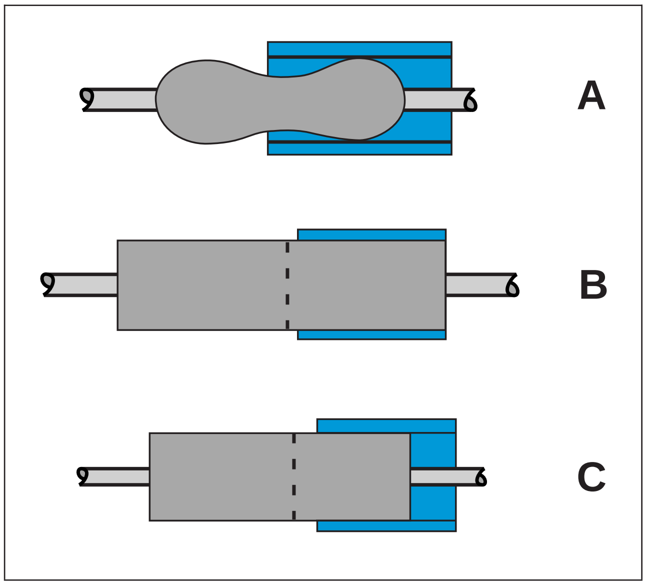


Figure 7-58

Defect – Class 1,2,3

- Spacing between land and uninsulated component body is less than minimum electrical clearance, see Figure 7-57.
- Uninsulated metallic clip or holding device is not insulated from underlying circuitry.
- Clip does not restrain component, see Figure 7-58-A.
- Component center or center of gravity not within the confines of the clip, see Figure 7-58-C.

7.2.2 Component Securing – Adhesive Bonding

The criteria below **shall** be used when staking is required and criteria are not provided on the drawing. These criteria do not apply to SMT components (see 8.1).

Visual inspection of staking may be performed without magnification. Magnification from 1.75X to 4X may be used for referee purposes.

Refer to adhesive manufacturer's guidelines for curing requirements.

7.2.2.1 Component Securing – Adhesive Bonding – Nonelevated Components

These criteria are the same for sleeved or unsleeved components, see exception below for glass bodied components.

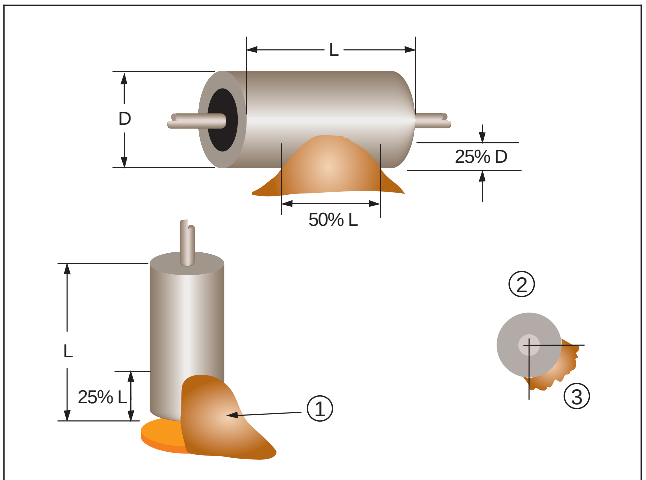


Figure 7-59
1. Adhesive
2. Top view
3. 25% Circumference

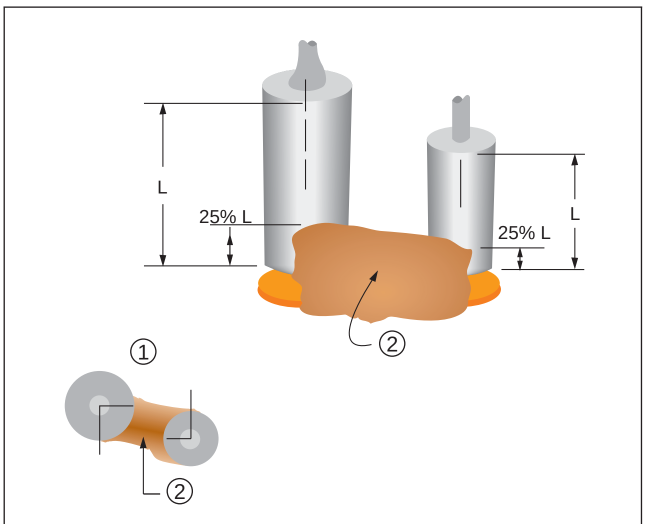


Figure 7-60
1. Top view
2. Adhesive

Acceptable – Class 1,2,3

- Continuous adhesion fillet to the mounting surface and component body.
- Adhesive is cured.
- No gap/separation/crack between staking and attachment surfaces.
- Staking material does not contact component body seals.
- On a horizontally mounted component the staking material:
  - Adheres to component for at least 50% of its length (L).
  - Maximum fillet height allows for the top of the component to be visible for the entire length of the component body.
  - Minimum fillet height of 25% component diameter (D).
- On a vertically mounted component:
  - The staking material bead(s) are continuous for least 25% of the component length (L) (height) with slight flow of staking material under the component body with no contact to the component body seal, see Figure 7-59-1.
  - The staking material adheres to the component:
    - For at least three beads spaced approximately evenly around the circumference adding up to minimum 25% OR
    - A single bead for a minimum of at least 25% of the component circumference.
- On glass bodied components:
  - The component bodies are sleeved, when required, prior to staking material attachment.
  - Adhesives, e.g., staking, bonding, do not contact an unsleeved area of a sleeved glass body component.
- Multiple vertically mounted components:
  - Staking material adheres to each component for at least 25% of its length (L), and the adhesion is continuous between components, see Figure 7-60-2.
  - The staking material adheres to each component for a minimum 25% of its circumference, see Figure 7-60-1.
- Sleeved axial component (except glass body) have staking material in contact with one or both end faces of the component.

Acceptable – Class 3

- On a horizontally mounted component (sleeved or unsleeved) the staking material is applied to both sides of the component.

7.2.2.1 Component Securing – Adhesive Bonding – Nonelevated Components (cont.)

Not Established – Class 1,2
Defect – Class 3

- On a horizontally mounted component (sleeved or unsleeved) the staking material is less than 25% of the component's diameter (D) on both sides.

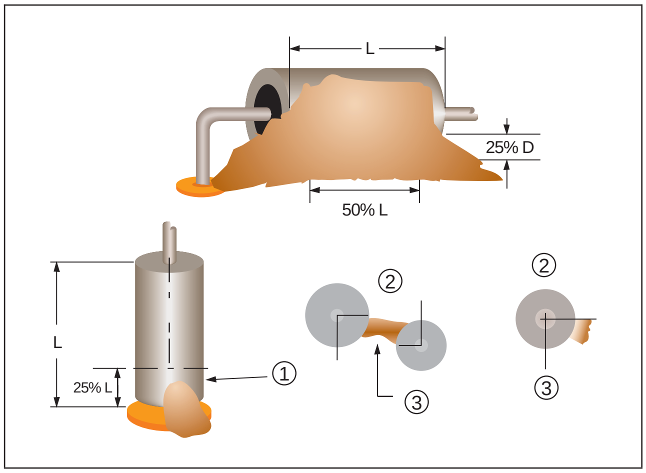


Figure 7-61
1. < 50% length (L)
2. Top view
3. < 25% circumference

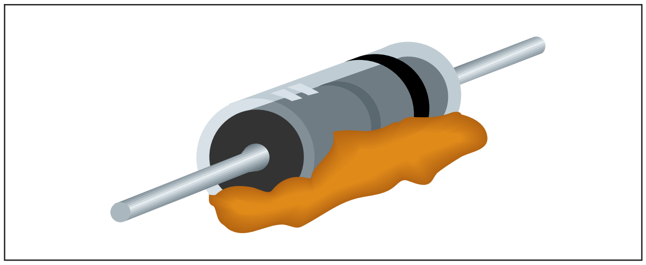


Figure 7-62

Not Established – Class 1
Process Indicator – Class 2
Defect – Class 3

- For horizontally mounted components (sleeved or unsleeved), the top of the component is not visible for the entire length of the component body due to excess staking material.

Not Established – Class 1,2
Defect – Class 3

- On a horizontally mounted component (sleeved or unsleeved) the staking material is not applied to both sides of the component.

Not Established – Class 1
Defect – Class 2,3

- Horizontally mounted axial leaded components having staking material contacting component body seals.
- Vertically mounted component:
  - There are less than three beads of staking material adhering to the component OR
  - One bead of adhesive adhering to less than 25% of component circumference.
  - Adhesive is less than 25% of the component length (height).

7.2.2.1 Component Securing – Adhesive Bonding – Nonelevated Components (cont.)

Defect – Class 1,2,3

- There is not a continuous adhesion fillet to the mounting surface and component body.
- Uninsulated metallic case components bonded over conductive patterns.
- Staking material on areas to be soldered preventing compliance to Table 7-4.
- Rigid adhesives, e.g., staking, bonding, contact an unsleeved area of a sleeved glass body component, see Figure 7-62.
- Staking material is not cured.
- Horizontally mounted component the staking material adheres to:
  - Component and mounting surface less than 50% of the component length (L).
  - Less than 25% of the component's diameter (D), on one side.
- Multiple vertically mounted components:
  - The staking material adheres to each component for less than 25% of its length (L).
  - The staking material adheres for less than 25% of each component circumference.
  - The adhesion is not continuous between components.

7.2.2.2 Component Securing – Adhesive Bonding – Elevated Components

This applies in particular to encapsulated or potted transformers and/or coils that are not mounted flush to the board.

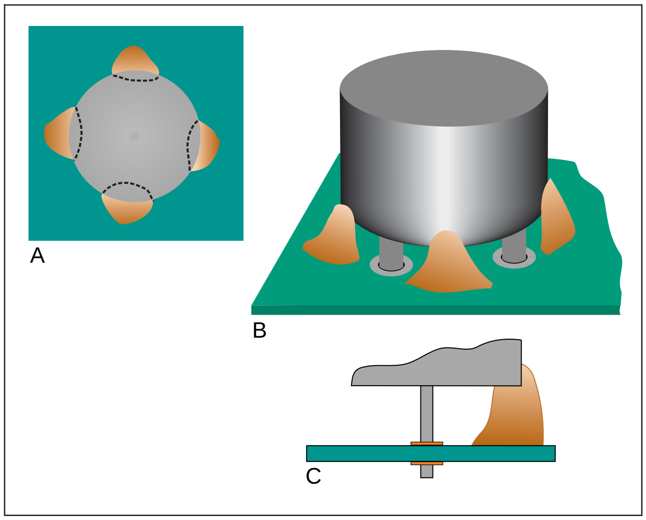


Figure 7-63

Acceptable – Class 1,2,3

- Bonding requirements should be specified in engineering documents, but as a minimum, components are bonded to mounting surface in at least four places evenly spaced around component when no mechanical support is used, see Figure 7-63-A.
- At least 20% of the total periphery of the component is bonded, see Figure 7-63-B.
- Bonding material firmly adheres to both the bottom and sides of the component and to the printed wiring board, see Figure 7-63-C.
- Adhesive material does not interfere with formation of required solder connection.

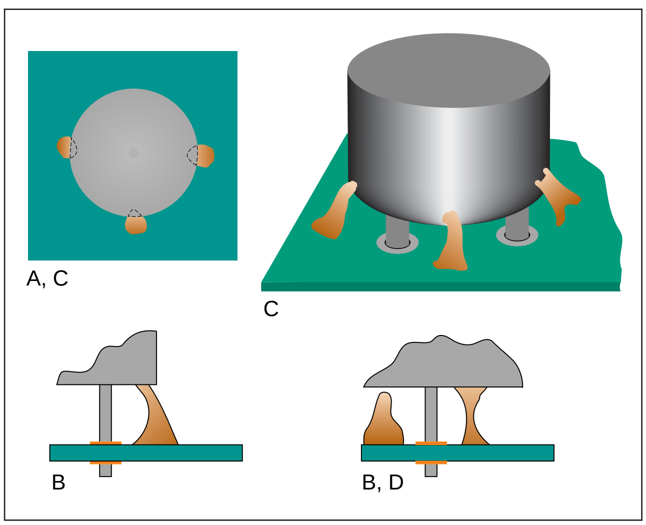


Figure 7-64

Defect – Class 1,2,3

- Bonding requirements are less than the specified requirements.
- Any bonding spots failing to wet and show evidence of adhesion to both the bottom and side of the component and the mounting surface, see Figure 7-64-B.
- Less than 20% of the total periphery of the component is bonded, see Figure 7-64-C.
- The bonding material forms too thin a column to provide good support, see Figure 7-64-D.
- Adhesive material interferes with formation of required solder connection.

7.2.3 Component Securing – Other Devices

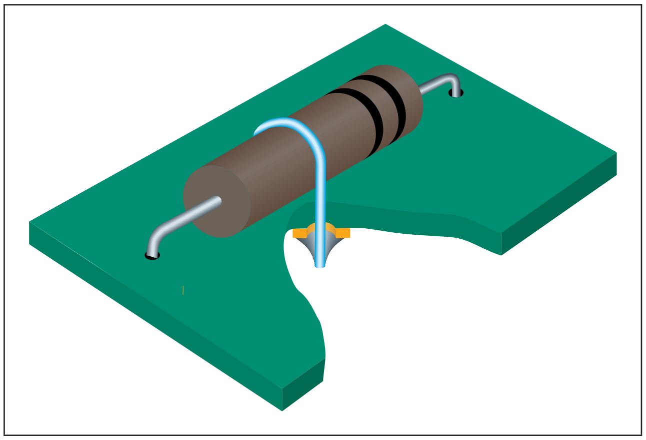


Figure 7-65

Acceptable – Class 1,2,3

- Component is held firmly against the mounting surface.
- There is no damage to the component body or insulation from the securing device.
- Conductive securing device does not violate minimum electrical clearance.

7.3 Supported Holes

7.3.1 Supported Holes – Axial Leaded – Horizontal

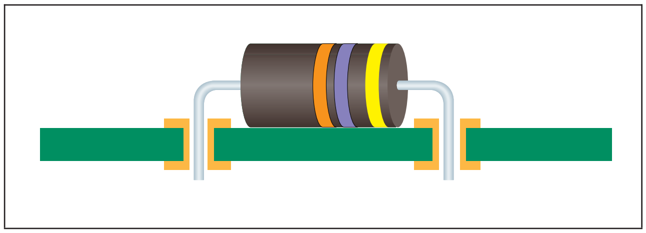


Figure 7-66

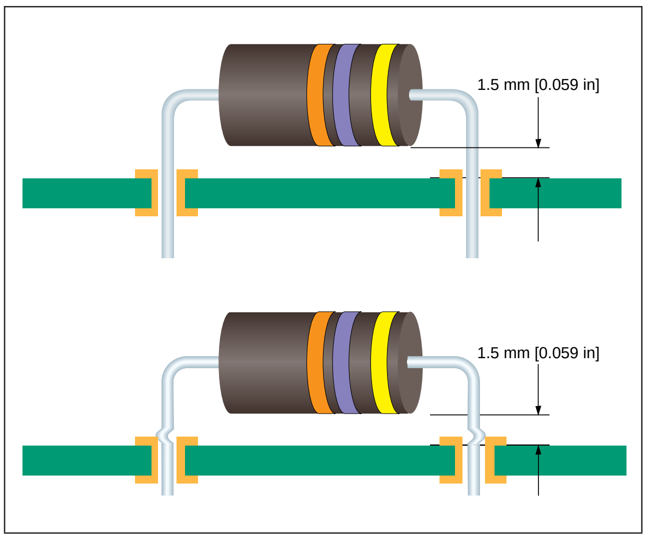


Figure 7-67

Target – Class 1,2,3

- The entire body length of the component is in contact with the board surface.
- Components required to be mounted off the board are at least 1.5 mm [0.06 in] from the board surface, e.g., high heat dissipating.

7.3.1 Supported Holes – Axial Leaded – Horizontal (cont.)

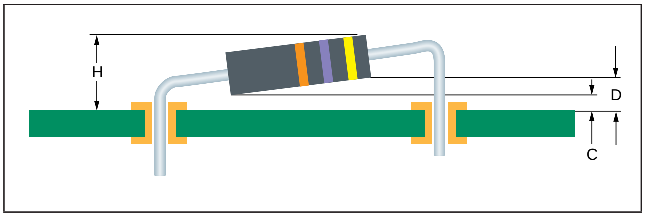


Figure 7-68

Acceptable – Class 1,2

- The maximum clearance (D) between the component and the board surface does not violate the requirements for lead protrusion, see 7.3.3, or component height (H). (H) is a user-determined dimension.

Acceptable – Class 3

- Clearance (C) between the component body and the board does not exceed 0.7 mm [0.03 in].

Process Indicator – Class 3

- The farthest distance (D) between the component body and the board is larger than 0.7 mm [0.03 in].

Defect – Class 3

- The distance (D) between the component body and the board is larger than 1.5 mm [0.06 in].

Defect – Class 1,2,3

- Component height exceeds user-determined dimension (H).
- Components required to be mounted above the board surface are less than 1.5 mm [0.06 in] (C) from the board surface.

7.3.2 Supported Holes – Axial Leaded – Vertical

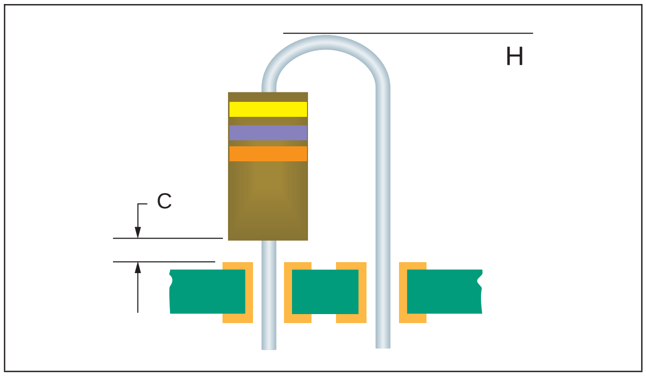


Figure 7-69

Target – Class 1,2,3

- The clearance (C) of the component body or weld bead above the land is 1 mm [0.04 in].
- The component body is perpendicular to the board.
- The overall height does not exceed maximum design height requirements (H).

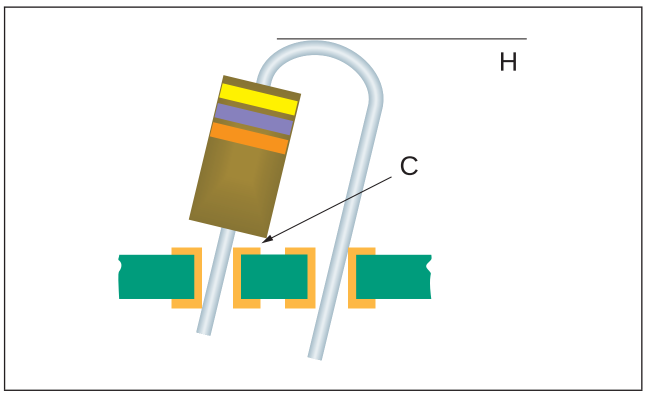


Figure 7-70

Acceptable – Class 1,2,3

- The component or weld bead clearance (C) above the land meets the requirements of Table 7-2.
- The angle of the component lead does not cause a violation of minimum electrical clearance.

Table 7-2 Component to Land Clearance

	Class 1	Class 2	Class 3
(C) Min.	0.1 mm [0.004 in]	0.4 mm [0.016 in]	0.8 mm [0.03 in]
(C) Max.	6 mm [0.2 in]	3 mm [0.1 in]	1.5 mm [0.06 in]

7.3.2 Supported Holes – Axial Leaded – Vertical (cont.)

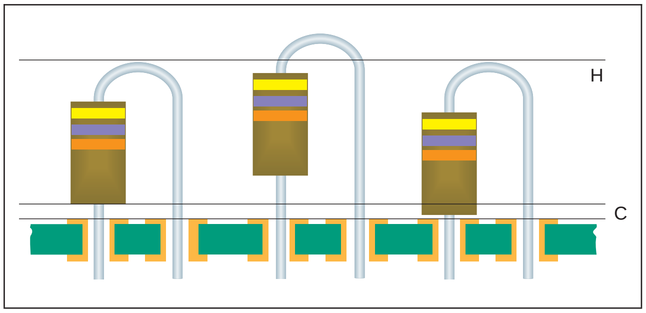


Figure 7-71

Defect – Class 1,2,3

- The component or weld bead clearance (C) is less than the minimum given in Table 7-2, see Figure 7-71.
- The component or weld bead clearance (C) is greater than the maximum given in Table 7-2, see Figure 7-71.
- Components violate minimum electrical clearance.
- Component height does not meet form, fit or function.
- Component height exceeds user-determined dimension, see Figure 7-71-H.

7.3.3 Supported Holes – Wire/Lead Protrusion

Lead protrusion **shall** be in accordance with Table 7-3.

Note: High frequency applications may require more precise control of lead extensions to prevent violation of functional design considerations.

Table 7-3 Protrusion of Wires/Leads in Supported Holes

	Class 1	Class 2	Class 3
(L) Min.	End is discernible in the solder, Notes 1, 3		
(L) Max., Note 2	No danger of shorts	2.5 mm [0.1 in]	1.5 mm [0.06 in]

Note 1. For components having pre-established lead lengths that are less than board thickness, and the components or lead shoulders are flush to the board surface, the lead end is not required to be visible in the subsequent solder connection.

Note 2: Connector leads, relay leads, tempered leads and leads greater than 1.3 mm [0.05 in] diameter are exempt from the maximum length requirement provided that they do not violate minimum electrical spacing.

Note 3: As an exception to discernible minimum lead length, see 7.3.5.

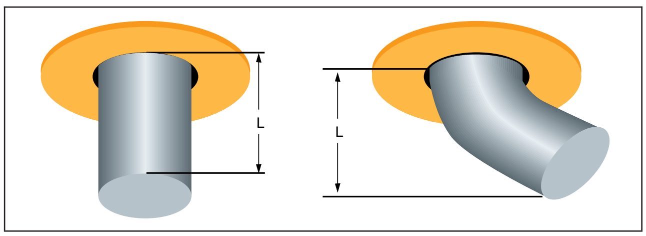


Figure 7-72

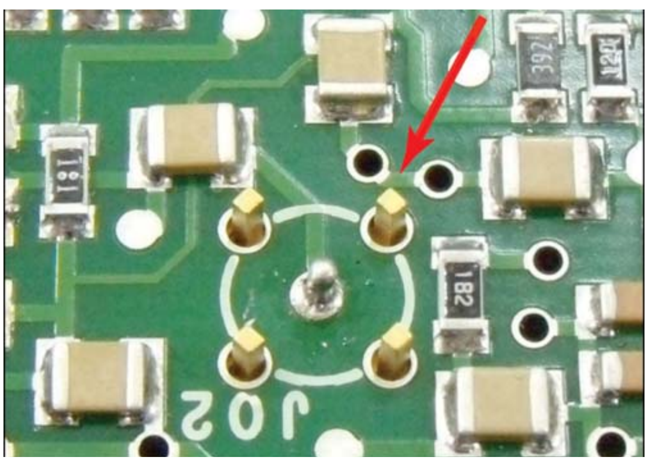


Figure 7-73

Acceptable – Class 1,2,3

- The leads protrude beyond the land within the specified minimum and maximum (L) of Table 7-3, provided there is no danger of violating minimum electrical clearance.
- The leads meet the design length (L) requirements when specified.

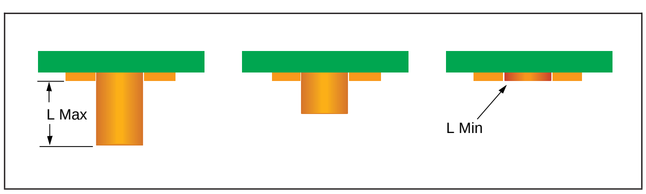


Figure 7-74

Defect – Class 1,2,3

- Lead protrusion does not meet the requirements of Table 7-3.
- Lead protrusion violates minimum electrical clearance.
- Lead protrusion exceeds maximum design height requirements.

7.3.4 Supported Holes – Wire/Lead Clinches

Component leads in through-hole connections may be terminated using a straight through, partially clinched or clinched configuration. The clinch should be sufficient to provide mechanical restraint during the soldering process. The orientation of the clinch relative to any conductor is optional. DIP leads should have at least two diagonally opposing leads partially bent outward. Leads greater than 1.3 mm [0.050 in] thick or diameter should not be bent nor formed for mounting purposes. Tempered leads **shall not** be terminated with a full clinched configuration.

The lead meets the protrusion requirements of Table 7-3 when measured vertically from the land surface and does not violate minimum electrical clearance requirements.

This section applies to terminations with a clinching requirement. Other requirements may be specified on relevant specifications or drawings. Partially clinched leads for part retention are considered as unclinched leads and **shall** meet protrusion requirements.

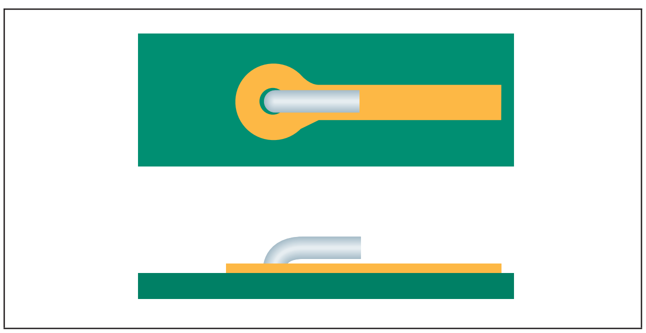


Figure 7-75

Target – Class 1,2,3

- Lead end is parallel to the board and direction of the clinch is along the connecting conductor.

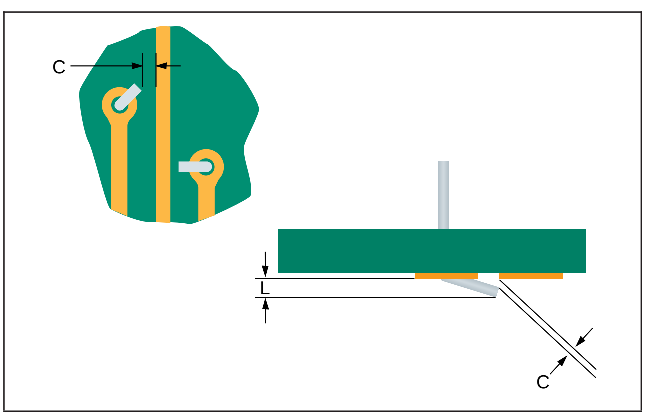


Figure 7-76

Acceptable – Class 1,2,3

- The clinched lead does not violate the minimum electrical clearance (C) between noncommon conductors.
- The protrusion (L) beyond the land is not greater than the similar length allowed for straight-through leads, see Figure 7-76 and Table 7-3.

7.3.4 Supported Holes – Wire/Lead Clinches (cont.)

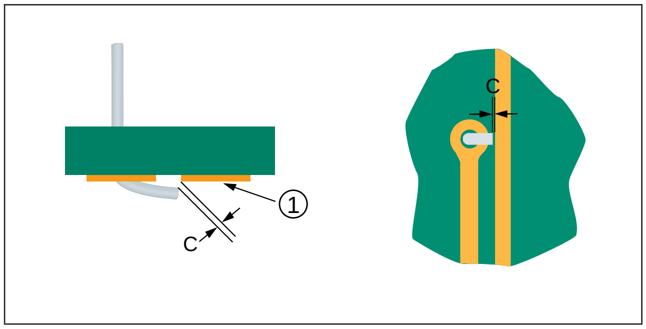


Figure 7-77

1. Noncommon conductor

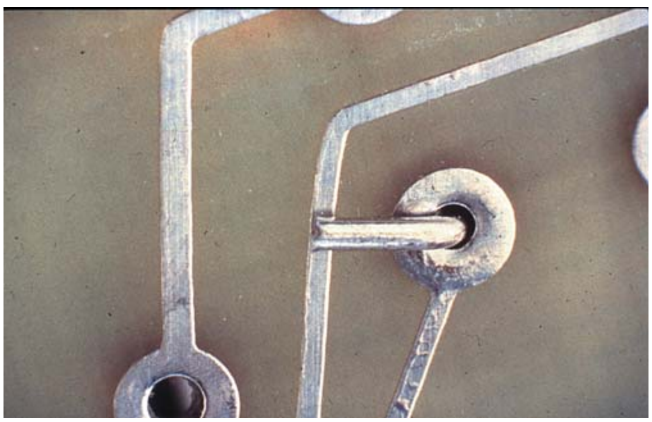


Figure 7-78

Defect – Class 1,2,3

- The lead is clinched toward an electrically noncommon conductor and violates minimum electrical clearance (C).

7.3.5 Supported Holes – Solder

Criteria for soldered supported holes are provided in 7.3.5.1 through 7.3.5.12. These criteria are applicable regardless of the soldering process, e.g., hand soldering, wave soldering, intrusive soldering, etc.

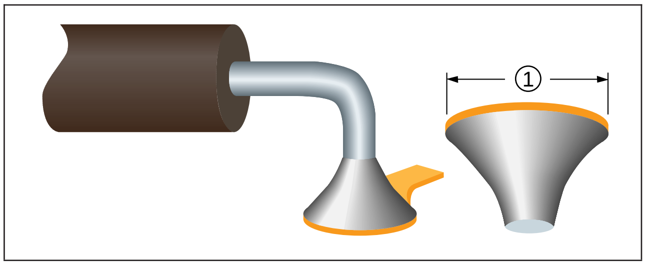


Figure 7-79
1. Land area

Target – Class 1,2,3

- No void areas or surface imperfections.
- Lead and land are well wetted.
- Lead is discernible.
- 100% solder fillet around lead.
- Solder covers lead and feathers out to a thin edge on land/conductor.

Figure 7-80

Figure 7-81

Acceptable – Class 1,2,3

- Lead is discernible in the solder.

7.3.5 Supported Holes – Solder (cont.)

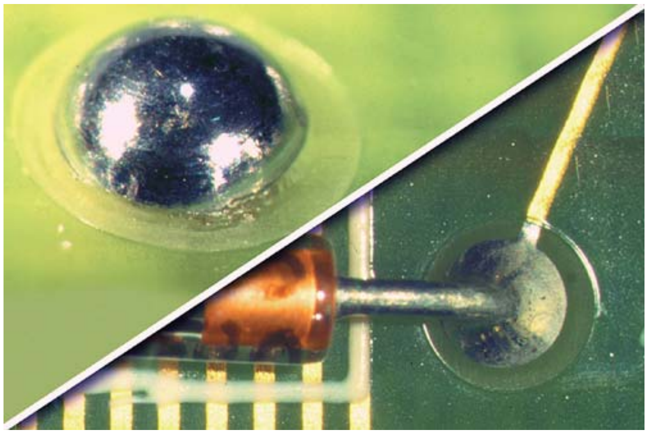


Figure 7-82

Acceptable – Class 1
Process Indicator – Class 2,3

- Fillet convex, and as an exception to Tables 7-3 and 7-4, lead not discernible due to excess solder, providing visual evidence of the lead in the hole can be determined on the primary side.

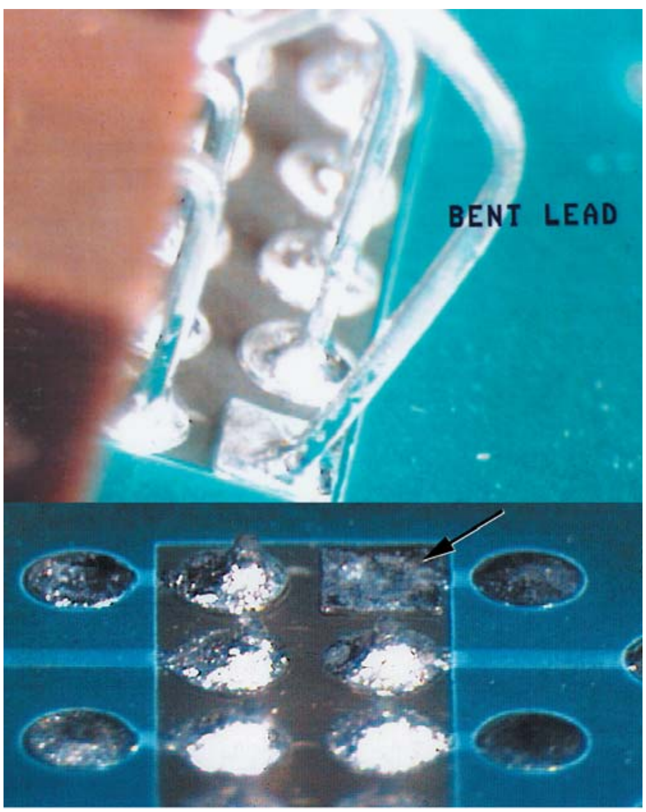


Figure 7-83

Defect – Class 1,2,3

- Lead not discernible due to bent lead.
- Solder not wetted to lead or land.
- Solder coverage does not comply with Table 7-4.

7.3.5 Supported Holes – Solder (cont.)

Table 7-4 Plated Through-Holes with Component Leads – Minimum Acceptable Solder Conditions[1]

<table>
<tr><th colspan="2">Criteria</th><th>Class 1</th><th>Class 2</th><th>Class 3</th></tr>
<tr><td rowspan="3">A.</td><td>Vertical solder fill for components with less than 14 leads not connected to an internal thermal plane, Notes 2 and 3 (see 7.3.5.1).</td><td rowspan="3">Not Specified</td><td>75%</td><td rowspan="3">75%</td></tr>
<tr><td>Vertical solder fill for each lead that is connected to a thermal plane, on components with less than 14 leads, Notes 2, 3 and 4 (see 7.3.5.1).</td><td rowspan="2">50% or 1.2 mm [0.05 in], whichever is less</td></tr>
<tr><td>Vertical solder fill for components with 14 leads or more, Notes 2 and 3 (see 7.3.5.1).</td></tr>
<tr><td>B.</td><td>Circumferential wetting of lead and barrel on solder destination side (see 7.3.5.2).</td><td>Not Specified</td><td>180°</td><td>270°</td></tr>
<tr><td>C.</td><td>Percentage of land area covered with wetted solder on solder destination side (see 7.3.5.3).</td><td colspan="3">0%</td></tr>
<tr><td>D.</td><td>Circumferential wetting of lead and barrel on solder source side (see 7.3.5.4).</td><td colspan="2">270°</td><td>330°</td></tr>
<tr><td>E.</td><td>Percentage of land area covered with wetted solder on solder source side (see 7.3.5.5).</td><td colspan="3">75%</td></tr>
</table>

Note 1. Wetted solder refers to solder applied by the solder process. For intrusive soldering there may not be an external fillet between the lead and the land.
Note 2. The unfilled height includes both source and destination side depressions.
Note 3. Less than 100% solder fill may not be acceptable in some applications, e.g., thermal shock, electrical performance. The User is responsible for identifying these situations to the Manufacturer.
Note 4. For Class 2 vertical solder fill, 50% or 1.2 mm [0.05 in], whichever is less, is allowed provided there is 360° wetting to the PTH lead and barrel wall on the solder source side.

Defect – Class 1,2,3

- Solder connections are not in compliance with Table 7-4.

7.3.5.1 Supported Holes – Solder – Vertical Fill (A)

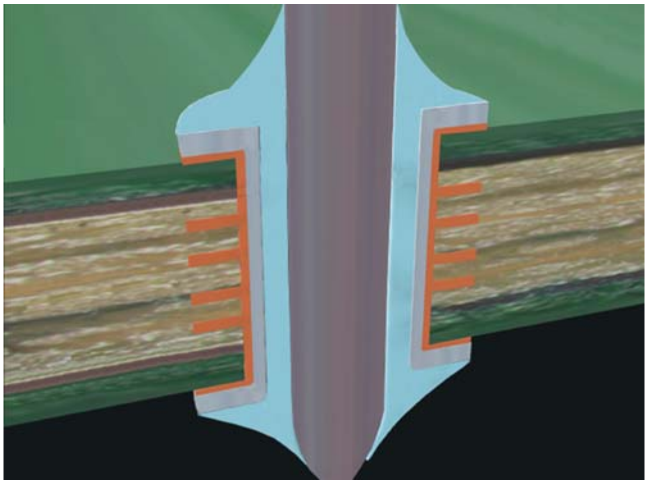


Figure 7-84

Target – Class 1,2,3

- There is 100% fill.

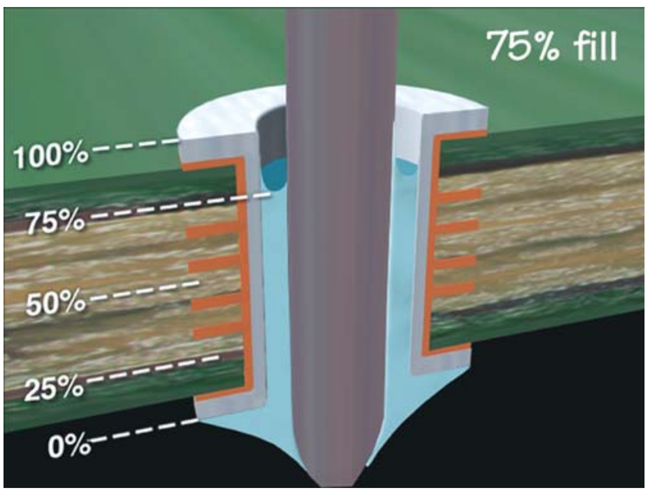


Figure 7-85

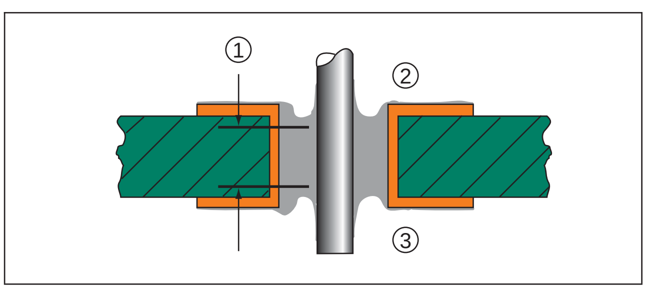


Figure 7-86
1. Vertical fill meets requirements of Table 7-4
2. Solder destination side
3. Solder source side

Acceptable – Class 2

- Minimum vertical fill of 50% or 1.2 mm [0.05 in], whichever is less, for components with 14 or more leads (not shown).
- Component lead is discernible in the solder source side of the solder connection.
- Minimum vertical fill of hole is more than 50% or 1.2 mm [0.05 in], whichever is less, for components with less than 14 leads and having an internal thermal plane providing the solder fillet of Side B of Figure 7-87 has wetted 360° of the PTH barrel wall and 360° of the lead and the surrounding PTHs meet requirements of Table 7-4.

Acceptable – Class 2,3

- Minimum 75% fill. A maximum of 25% total depression, including both solder source and solder destination sides is permitted.

Note: For Class 2, this criteria is specific to components with less than 14 leads and not having an internal thermal plane.

7.3.5.1 Supported Holes – Solder – Vertical Fill (A) (cont.)

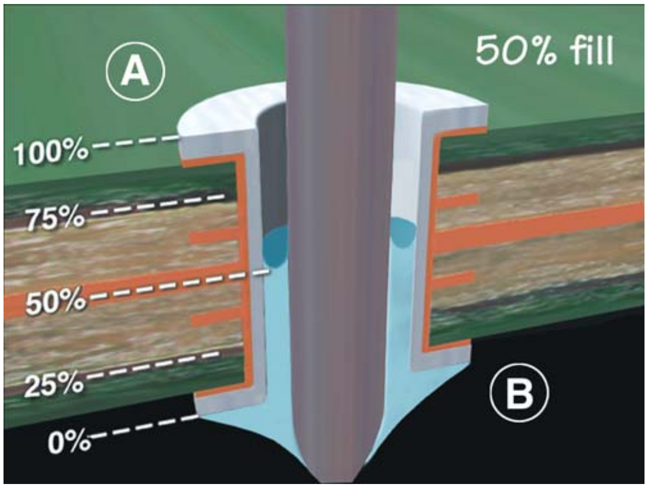


Figure 7-87

Defect – Class 2

- Vertical fill of hole is less than 75% for component with less than 14 leads and not having an internal thermal plane.
- Vertical fill of hole is less than 75%, and greater than 50% or 1.2 mm [0.05 in], whichever is less, for components with less than 14 leads and having an internal thermal plane and the solder fillet on Side B of Figure 7-87 has wetted less than 360° of the PTH barrel wall and less than 360° of the lead.
- Vertical fill of hole is less than 50% or 1.2 mm [0.05 in], whichever is less, for component with 14 leads or more.

Defect – Class 3

- Vertical fill of hole is less than 75%.

Note: Less than 100% solder fill may not be acceptable in some applications, e.g., thermal shock, electrical performance. The User is responsible for identifying these situations to the Manufacturer.

7.3.5.2 Supported Holes – Solder – Solder Destination Side – Lead to Barrel (B)

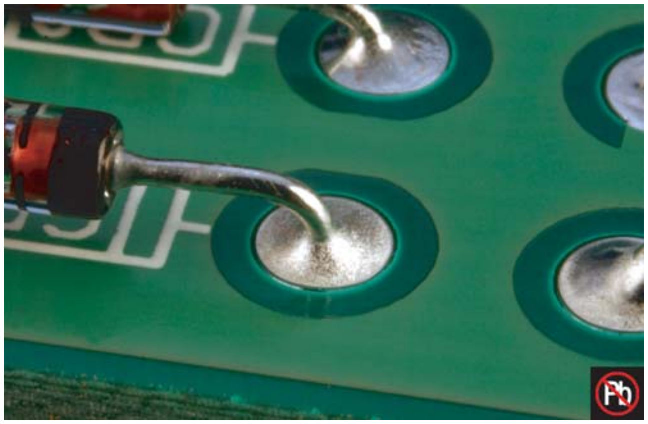


Figure 7-88

Target – Class 1,2,3

• 360° wetting present on lead and barrel.

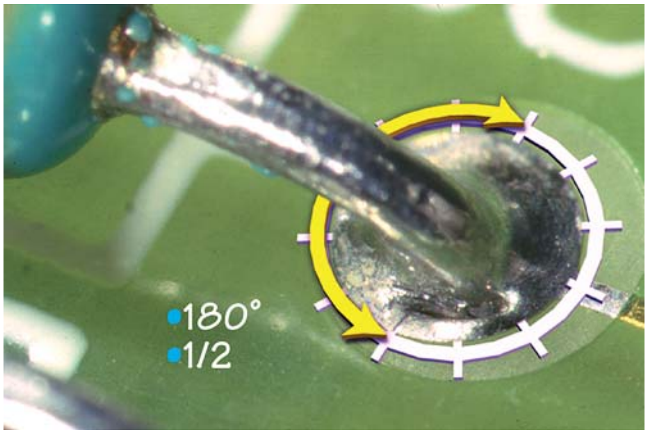


Figure 7-89

Not Established – Class 1
Acceptable – Class 2

• Minimum 180° wetting present on lead and barrel, see Figure 7-89.

Acceptable – Class 3

• Minimum 270° wetting present on lead and barrel, see Figure 7-90.

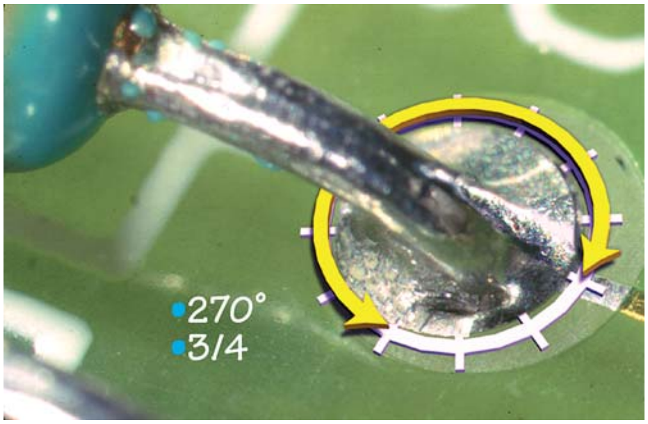


Figure 7-90

7.3.5.2 Supported Holes – Solder – Solder Destination Side – Lead to Barrel (B) (cont.)

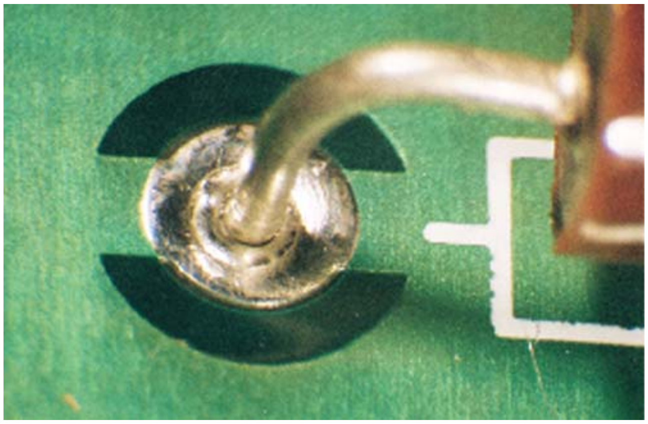


Figure 7-91

Figure 7-92

Defect – Class 2

- Less than 180° wetting on lead or barrel.

Defect – Class 3

- Less than 270° wetting on lead or barrel.

7.3.5.3 Supported Holes – Solder – Solder Destination Side – Land Area Coverage (C)

Figure 7-93

Acceptable – Class 1,2,3

- The land area does not need to be wetted with solder on the solder destination side.

7.3.5.4 Supported Holes – Solder – Solder Source Side – Lead to Barrel (D)

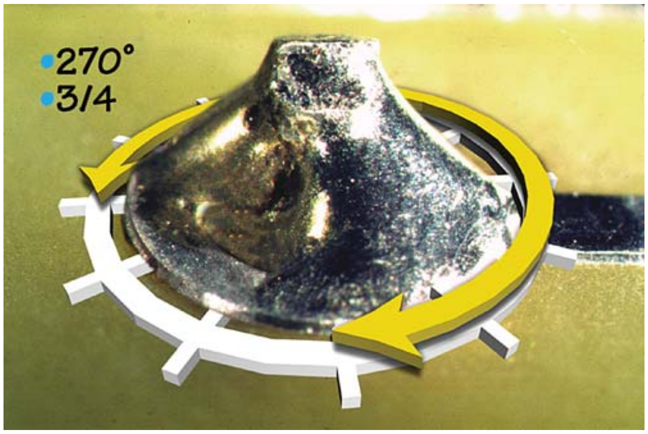


Figure 7-94

Acceptable – Class 1,2

- Minimum 270° fillet and wetting (lead, barrel and termination area).

Acceptable – Class 3

- Minimum 330° fillet and wetting (lead, barrel and termination area), not shown.

Figure 7-95

Defect – Class 1,2,3

- Does not meet requirements of Table 7-4.

7.3.5.5 Supported Holes – Solder – Solder Source Side – Land Area Coverage (E)

Figure 7-96

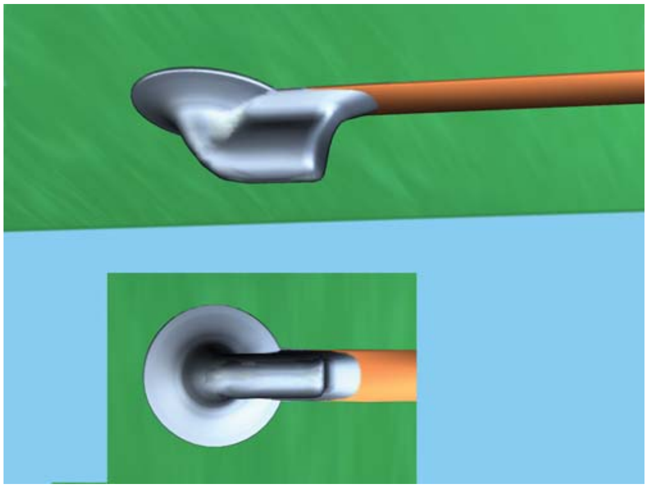


Figure 7-97

Target – Class 1,2,3

- Land area completely covered on the solder source side.

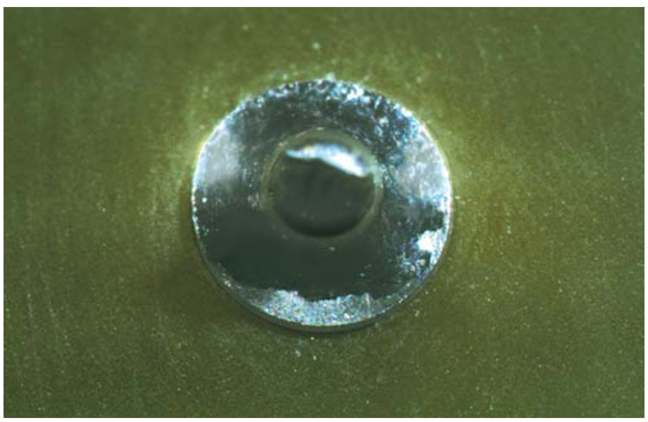


Figure 7-98

Acceptable – Class 1,2,3

- Minimum 75% of land area covered with wetted solder on the solder source side, see Figure 7-98.

Defect – Class 1,2,3

- Does not meet requirements of Table 7-4.

7.3.5.6 Supported Holes – Solder Conditions – Solder in Lead Bend

Solder in the bend radius is not cause for rejection provided the lead is properly formed and the topside bend radius is discernible.

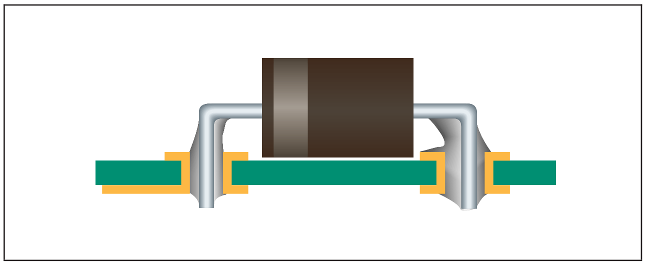


Figure 7-99

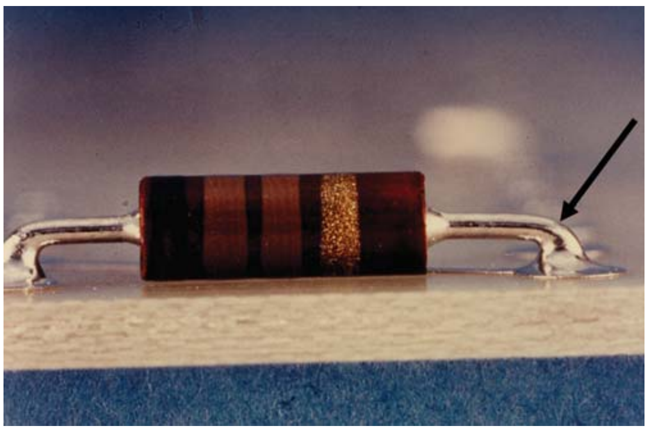


Figure 7-100

Acceptable – Class 1,2,3

- Solder in lead bend area does not contact the component body.
- Solder does not obscure the stress relief bend of through-hole components.

Defect – Class 1,2,3

- Solder in lead bend area contacts the component body.
- Solder that obscures the stress relief bend of through-hole components.

7.3.5.7 Supported Holes – Solder Conditions – Touching Through-Hole Component Body

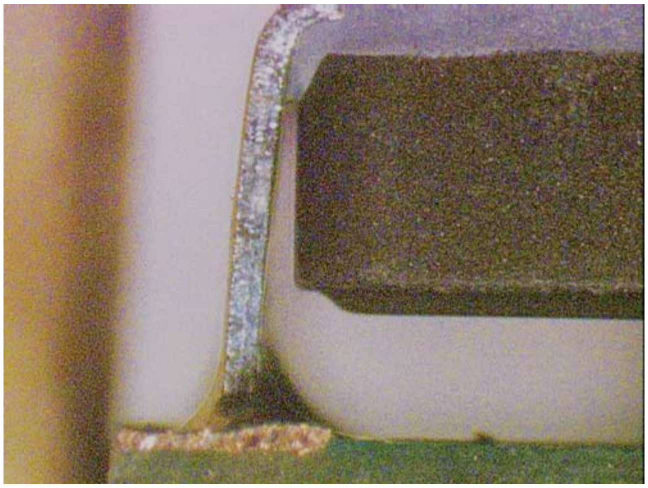


Figure 7-101

Acceptable – Class 1,2,3

- Solder does not touch the component body or end seal.

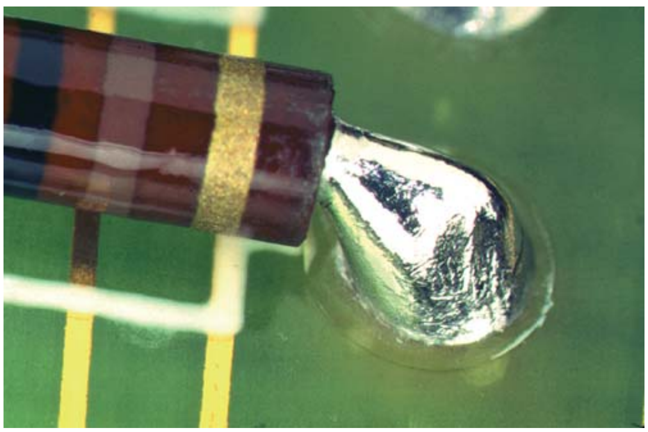


Figure 7-102

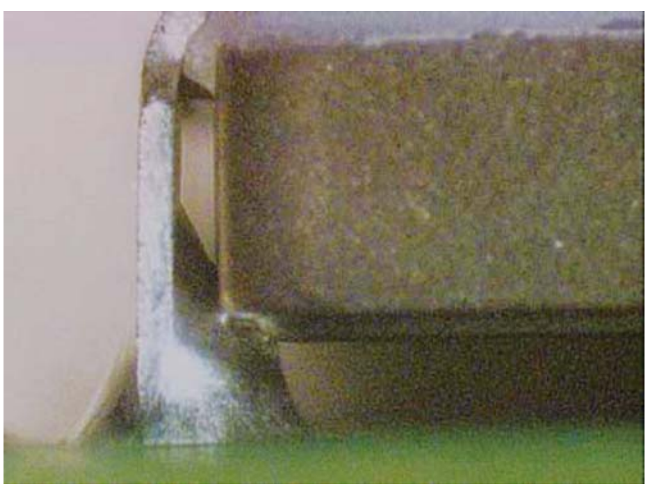


Figure 7-103

Defect – Class 1,2,3

- Solder contacts the component body or end seal. Exception, see 7.3.5.8.
- Solder obscures the stress relief bend.

7.3.5.8 Supported Holes – Solder Conditions – Meniscus in Solder

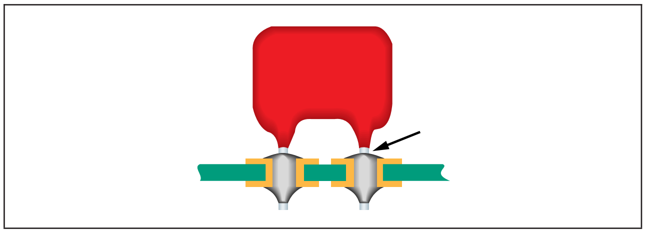


Figure 7-104

Target – Class 1,2,3

• There is 1.2 mm [0.05 in] separation between the coating meniscus and the solder fillet.

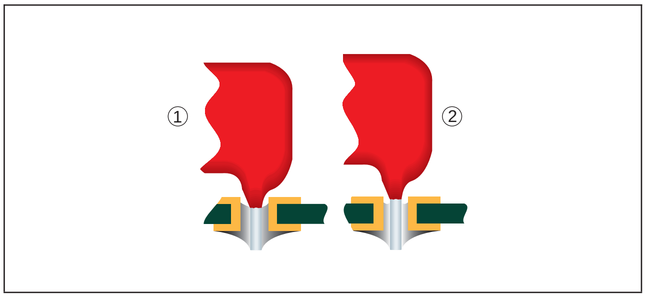


Figure 7-105
1. Coating meniscus embedded in solder.
2. Coating meniscus in plated through-hole but not in solder.

Acceptable – Class 1,2,3

• Coating meniscus is not embedded in the solder and the solder connections meet the requirements of Table 7-4.

Acceptable – Class 1,2

• Components with a coating meniscus can be mounted with the meniscus into the solder provided, see Figure 7-105-1:
  – 360° wetting lead to land on the solder source side.
  – Lead coating meniscus is not discernible within the connection on the solder source side.

Process Indicator – Class 2,3

• Coating meniscus is in the plated through-hole but not embedded in the solder joint, see Figure 7-105-2.

Defect – Class 3

• Coating meniscus is embedded in the solder connection, see Figure 7-105-1.
• Does not meet requirements of Table 7-4.

7.3.5.8 Supported Holes – Solder Conditions – Meniscus in Solder (cont.)

Figure 7-106

Defect – Class 1,2

- The meniscus is discernible in the solder on the solder source side.
- When components are mounted with coating meniscus into the solder, do not exhibit 360° wetting on solder source side.

7.3.5.9 Lead Cutting after Soldering

The following criteria apply to printed board assemblies where the connections have been trimmed after soldering. Leads may be trimmed after soldering provided the cutters do not damage the component or solder connection due to physical shock. For Classes 2 and 3, when lead cutting is performed after soldering, the solder terminations **shall** be visually inspected at 10X to ensure that the original solder connection has not been damaged, i.e., fractured or deformed. As an alternative to visual inspection, the solder connections may be reflowed. If the solder connection is reflowed this is considered part of the soldering process and is not to be considered rework. This requirement is not intended to apply to components that are designed such that a portion of the lead is intended to be removed after soldering, i.e., break away tie bars.

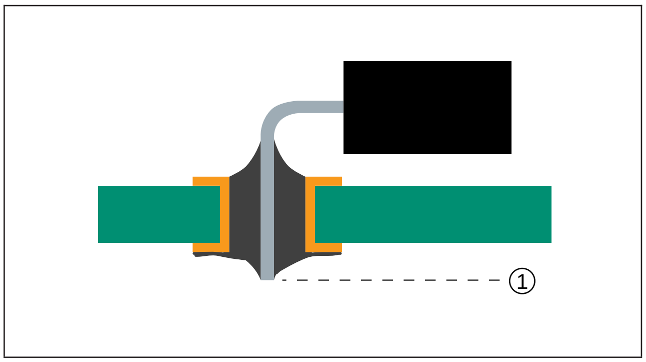


Figure 7-107
1. Lead protrusion

Acceptable – Class 1,2,3

- No fractures between lead and solder.
- Lead protrusion within specification, see 7.3.3.

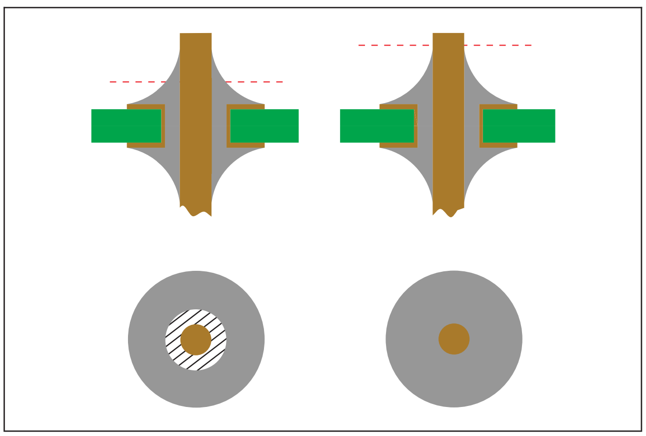


Figure 7-108

Defect – Class 1,2,3

- Evidence of fracture between lead and solder fillet.

Defect – Class 3

- Lead trimming that cuts into the solder fillet and is not reflowed.

7.3.5.10 Supported Holes – Coated Wire Insulation in Solder

These requirements apply when the solder connection meets the minimum requirements of Table 7-4. See 6.2.2 for extruded insulation clearance requirements.

This section applies to coatings that may extend into the connection during soldering operations, provided the material is not corrosive.

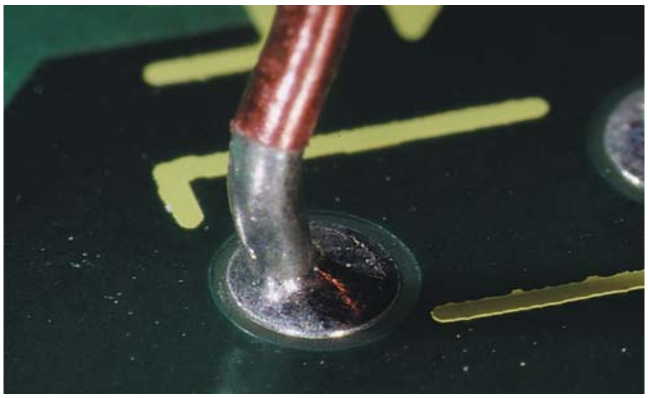


Figure 7-109

Target – Class 1,2,3

- Clearance of one wire diameter between solder fillet and insulation.

Figure 7-110

Acceptable – Class 1,2,3

- Coating is entering solder connection on primary side and meets minimum requirements of Table 7-4.

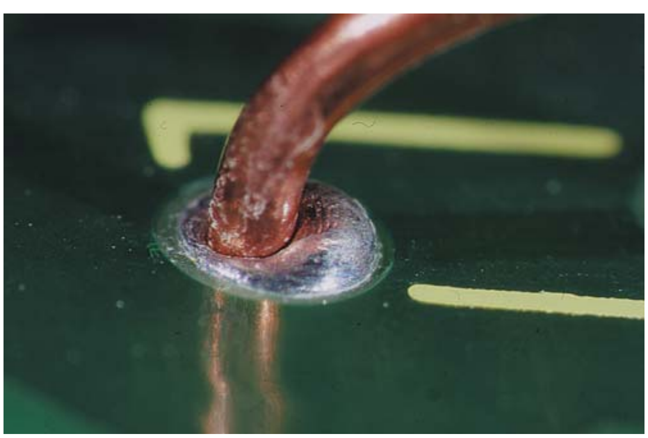


Figure 7-111

Defect – Class 1,2,3

- Solder connection exhibits poor wetting and does not meet the minimum requirements of Table 7-4.
- Coating is discernible on secondary side.

7.3.5.11 Supported Holes – Interfacial Connection without Lead – Vias

Supported holes used for interfacial connection not exposed to solder because of permanent or temporary masks need not be filled with solder. Supported holes or vias without leads, after exposure to wave, dip or drag soldering equipment are to meet these acceptability requirements.

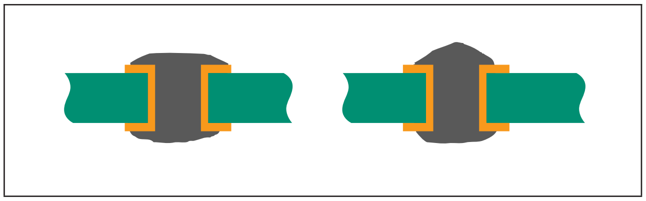


Figure 7-112

Target – Class 1,2,3

- Holes are completely filled with solder.
- The tops of lands show good wetting.

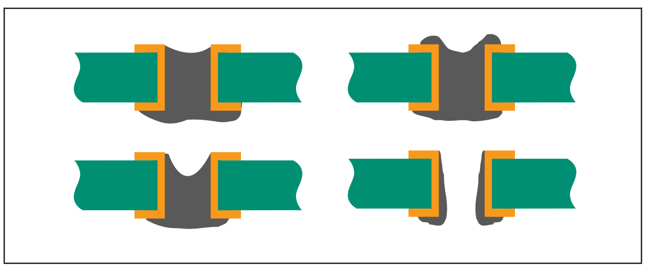


Figure 7-113

Acceptable – Class 1,2,3

- Sides of holes are wetted with solder.

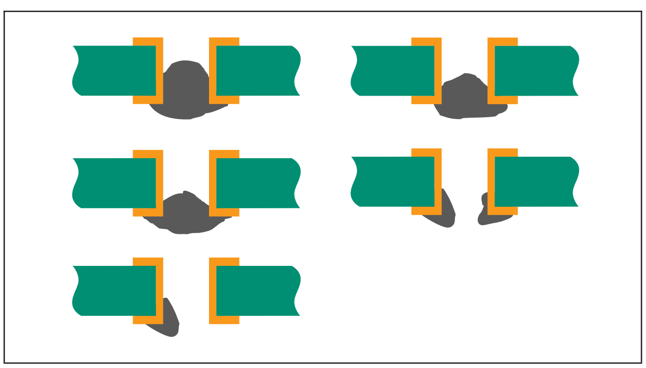


Figure 7-114

Acceptable – Class 1
Process Indicator – Class 2,3

- Solder has not wetted side of holes.

Note: There is no defect condition for this.

Note: Solder capped PTHs have the possibility of entrapping contaminants that are difficult to remove if cleaning is required.

7.3.5.12 Supported Holes – Board in Board

No board in board criteria have been established for Class 3 assemblies.

From IPC-T-50: ‘‘Daughterboard – A printed board assembly that is fastened and electrically connected to a motherboard or backplane.’’

When required, attachment will include additional mechanical support aids, e.g., adhesives or hardware, to ensure the connections will not be damaged in the intended service environment.

Table 7-5 Board in Board – Minimum Acceptable Solder Conditions[1]

Criteria	Class 1	Class 2
Vertical fill of solder, Note 2	75%	
Fillet and wetting solder connection width on primary side (solder destination side) of PCA (motherboard) to lands on both sides of daughterboard.	50%	75%
Percentage of land area on PCA (motherboard) covered with wetted solder on primary side (solder destination side).	0%	
Fillet and wetting solder connection width on secondary side (solder source side) of PCA (motherboard) to lands on both sides of daughterboard.	50%	75%
Percentage of land area on PCA (motherboard) covered with wetted solder on secondary side (solder source side)	75%	

Note 1. Wetted solder refers to solder applied by the solder process.
Note 2. The 25% unfilled height includes both source and destination side depressions.

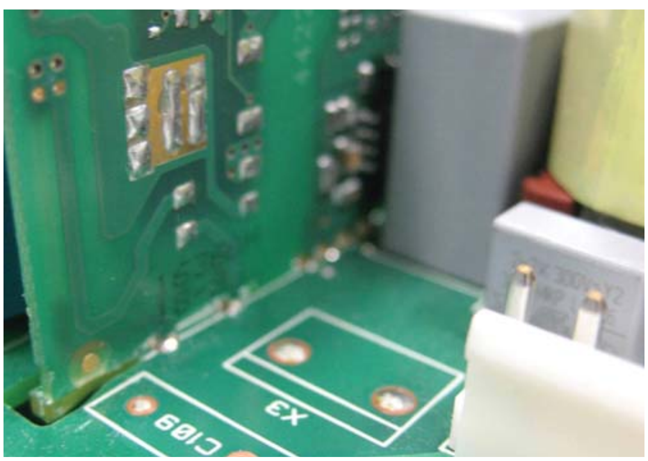


Figure 7-115

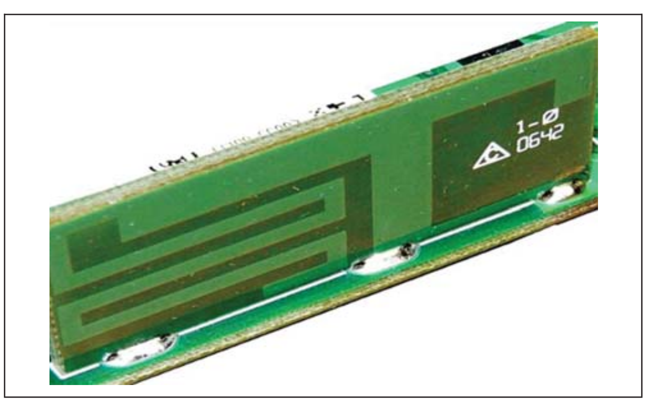


Figure 7-116

Acceptable – Class 1,2

- Daughterboard is mounted perpendicular to PCA.
- Daughterboard is flush to PCA.
- Mechanical constraints, if required, are properly attached.
- Vertical fill of solder is 75%.

7.3.5.12 Supported Holes – Board in Board (cont.)

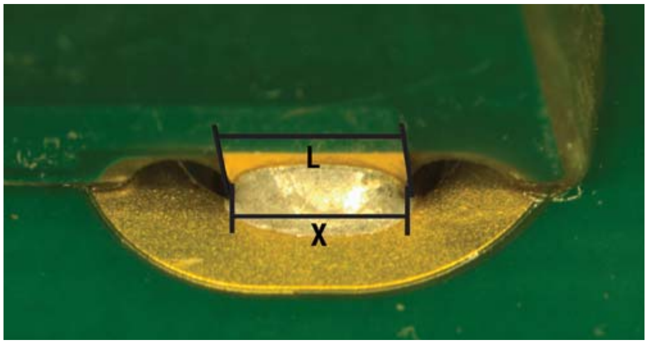


Figure 7-117

Acceptable – Class 1

- Solder is wetted a minimum of 50% width (X) of each of the sides of the daughterboard lands (L) to PCA on secondary side (solder source side).
- Solder is wetted a minimum of 50% width (X) of each of the sides of the daughterboard land (L) to PCA on primary side (solder destination side).

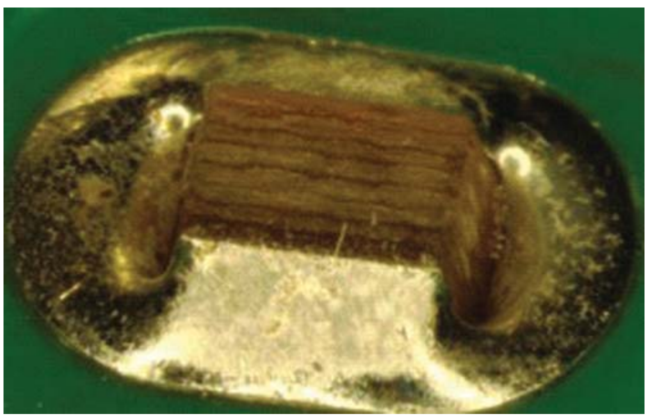


Figure 7-118

Figure 7-119

Acceptable – Class 2

- Solder is wetted a minimum of 75% width (X) of each of the sides of the daughterboard land (L) to PCA on secondary side (solder source side).
- Solder is wetted a minimum of 75% width (X) of each of the sides of the daughterboard land (L) to PCA on primary side (solder destination side).

7.3.5.12 Supported Holes – Board in Board (cont.)

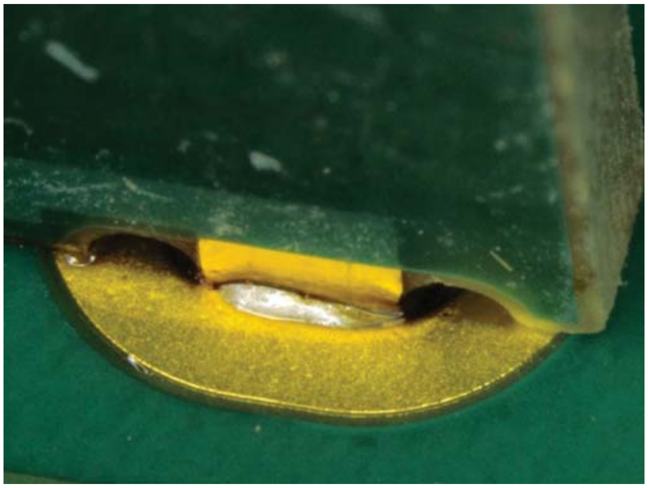


Figure 7-120

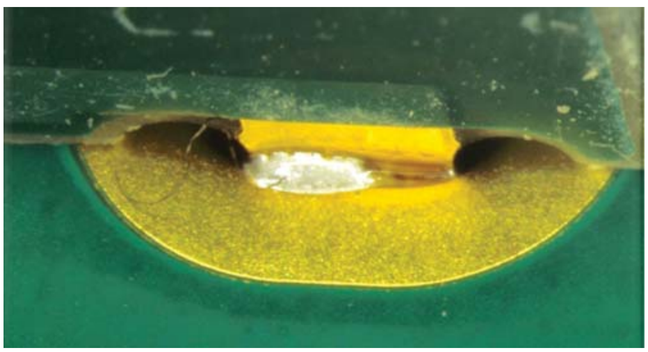


Figure 7-121

Defect – Class 1,2

- Daughterboard angle stresses mounting through-hole tabs.
- Required mechanical constraints not present or not properly attached.
- Vertical fill of solder is less than 75%.
- Solder not wetted to each of the sides of daughterboard lands or PCA land.

Defect – Class 1

- Solder is wetted less than 50% width (X) of both sides of the daughterboard land (L) to PCA on secondary side (solder source side).
- Solder is wetted less than 50% width (X) of each of the sides of the daughterboard land (L) to PCA on primary side (solder destination side).

Defect – Class 2

- Solder is wetted less than 75% width (X) of each of the sides of the daughterboard land (L) to PCA on secondary side (solder source side).
- Solder is wetted less than 75% width (X) of each of the sides of the daughterboard land (L) to PCA on primary side (solder destination side).

7.4 Unsupported Holes

7.4.1 Unsupported Holes – Axial Leads – Horizontal

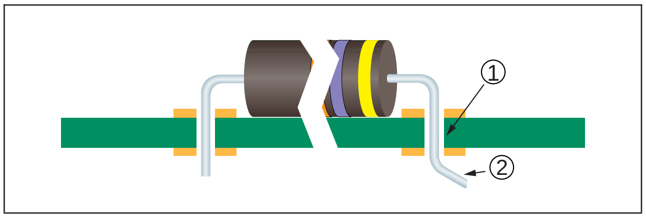


Figure 7-122

1. No plating in barrel
2. Clinch required for Class 3, see 7.4.4

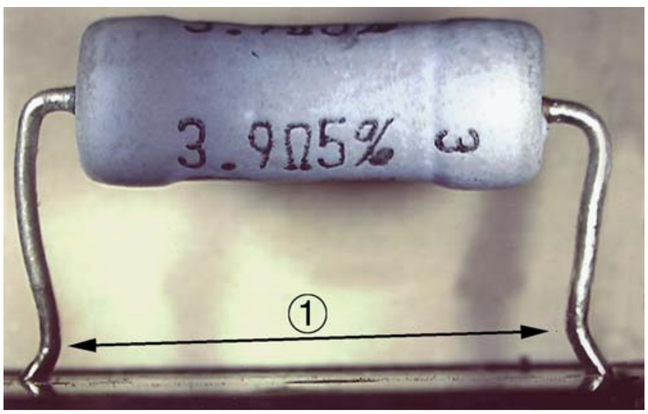


Figure 7-123

1. Lead form

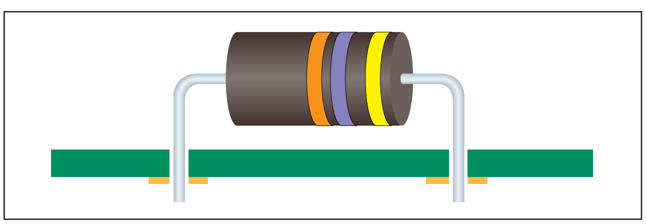


Figure 7-124

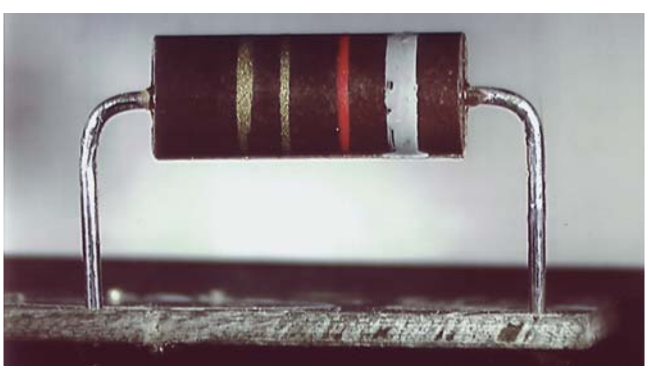


Figure 7-125

Target – Class 1,2,3

- The entire body length of the component is in contact with the board surface.
- Components required to be mounted off the board are at minimum 1.5 mm [0.06 in] from the board surface, e.g., high heat dissipating.
- Components required to be mounted off the board are provided with lead forms at the board surface or other mechanical support to prevent lifting of solder land.

Defect – Class 1,2,3

- Components required to be mounted off the board are not provided with lead forms at the board surface or other mechanical support to prevent lifting of solder land.
- Components required to be mounted above the board surface are less than 1.5 mm [0.06 in].
- Component height exceeds user-determined dimension.

7.4.2 Unsupported Holes – Axial Leads – Vertical

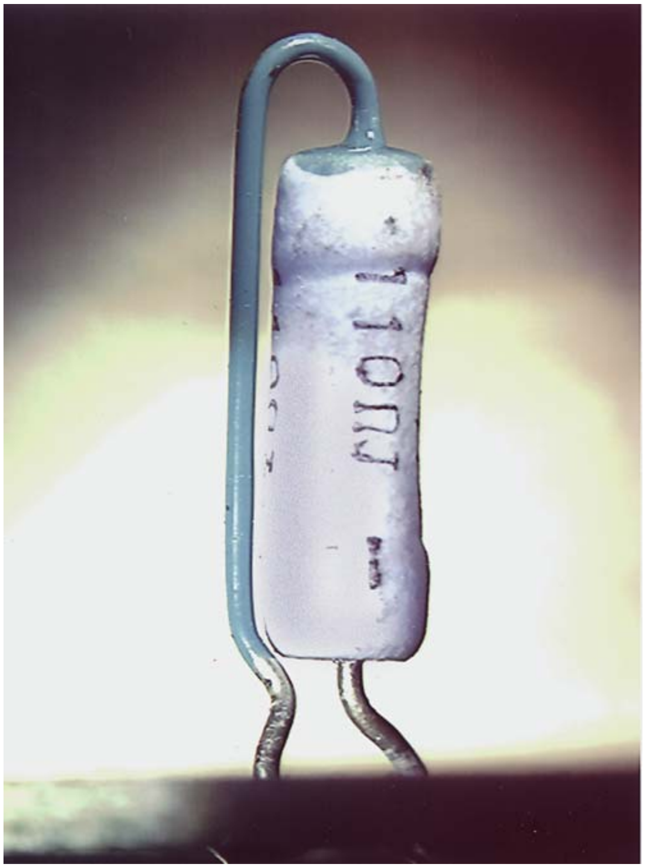


Figure 7-126

Target – Class 1,2,3

- Components that are mounted above the board surface in unsupported holes are provided with lead forms or other mechanical support to prevent lifting of solder land.

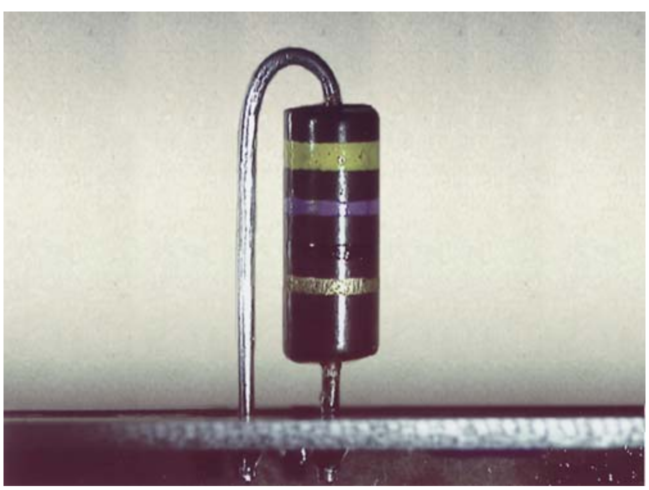


Figure 7-127

Defect – Class 1,2,3

- Components mounted above the board in unsupported holes are mounted without lead form at the board surface or other mechanical support.

7.4.3 Unsupported Holes – Wire/Lead Protrusion

Note: High frequency applications may require more precise control of lead extensions to prevent violation of functional design considerations.

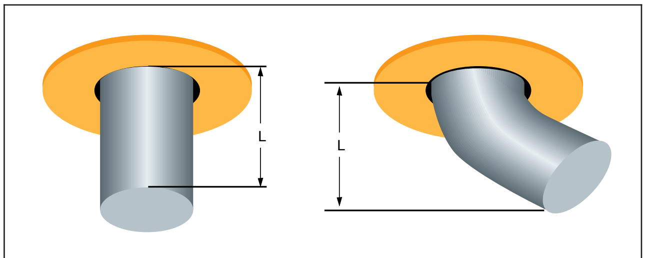


Figure 7-128

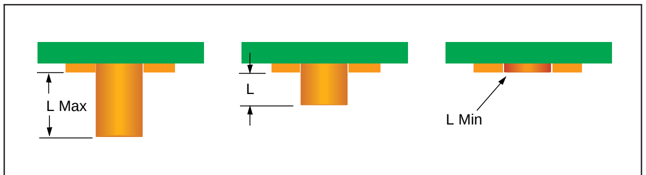


Figure 7-129

Acceptable – Class 1,2,3

- The leads protrude beyond the land within the specified minimum and maximum (L) of Table 7-6, provided there is no danger of violating minimum electrical clearance.

Table 7-6 Protrusion of Leads in Unsupported Holes

	Class 1	Class 2	Class 3
(L) Min.	End is discernible in solder		Sufficient to clinch
(L) Max.[1]	Does not violate minimum electrical clearance		

Note 1. Lead protrusion should not exceed 2.5 mm [0.1 in] if there is a possibility of violation of minimum electrical spacing, damage to soldered connections due to lead deflection.

Defect – Class 1,2,3

- Lead protrusion does not meet Table 7-6 requirements.
- Lead protrusion violates minimum electrical clearance.
- Lead protrusion exceeds maximum design height requirements.

7.4.4 Unsupported Holes – Wire/Lead Clinches

This section applies to terminations with a clinching requirement. Other requirements may be specified on relevant specifications or drawings. Partially clinched leads for part retention are considered as unclenched leads and need to meet protrusion requirements.

The clinch should be sufficient to provide mechanical restraint during the soldering process. The orientation of the clinch relative to any conductor is optional. DIP leads should have at least two diagonally opposing leads partially bent outward. Tempered leads and leads greater than 1.3 mm [0.05 in] should not be bent nor formed for mounting purposes. Tempered leads are not terminated with a full-clinched configuration.

The lead meets the requirements of Table 7-6 when measured vertically from the land surface and does not violate minimum electrical clearance requirements.

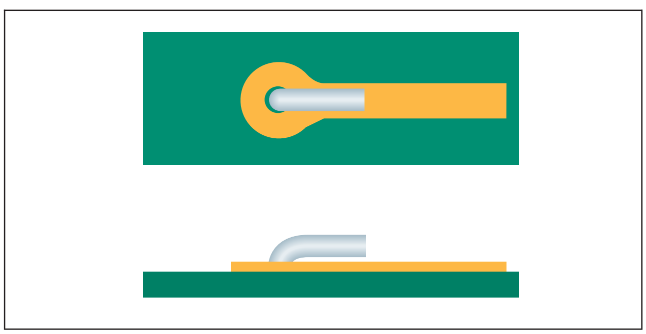


Figure 7-130

Target – Class 1,2,3

- Lead end is parallel to the board and direction of the clinch is along the connecting conductor.

7.4.4 Unsupported Holes – Wire/Lead Clinches (cont.)

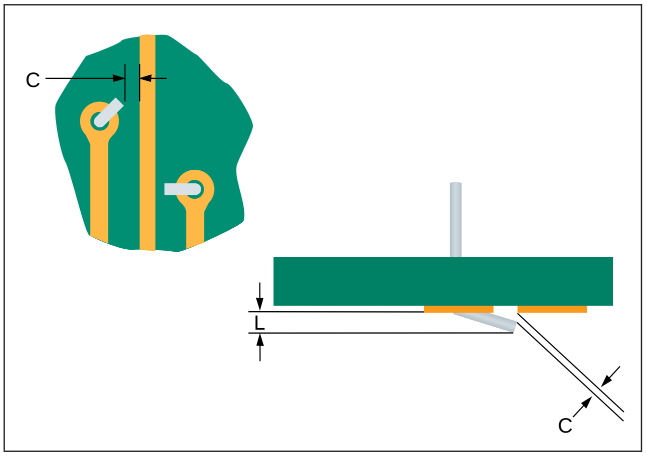


Figure 7-131

Acceptable – Class 1,2,3

- The clinched lead does not violate the minimum electrical clearance (C) between noncommon conductors.
- The protrusion (L) beyond the land is not greater than the similar length allowed for straight-through leads.
- The leads protrude beyond the land within the specified minimum and maximum (L) of Table 7-6, provided there is no violation of minimum electrical clearance.

Acceptable – Class 3

- Lead in unsupported hole is clinched a minimum of 45°.

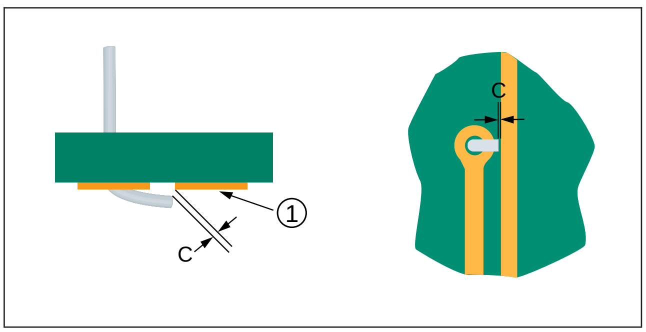


Figure 7-132
1. Noncommon conductor

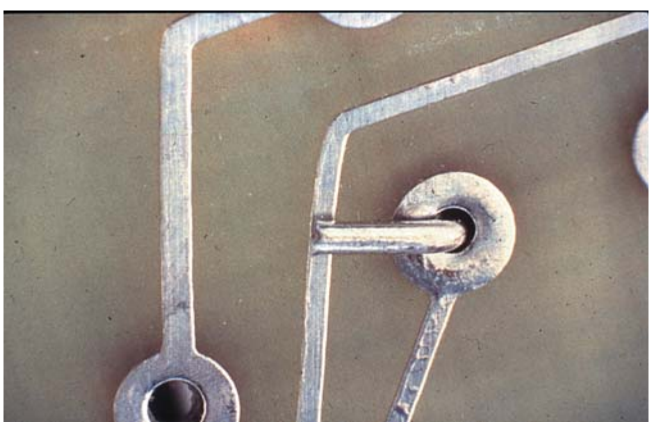


Figure 7-133

Defect – Class 1,2,3

- The lead is clinched toward an electrically noncommon conductor and violates minimum electrical clearance (C).
- Lead protrusion is insufficient for clinch, if required.

Defect – Class 3

- Lead in unsupported hole is not clinched a minimum of 45° (not shown).

7.4.5 Unsupported Holes – Solder

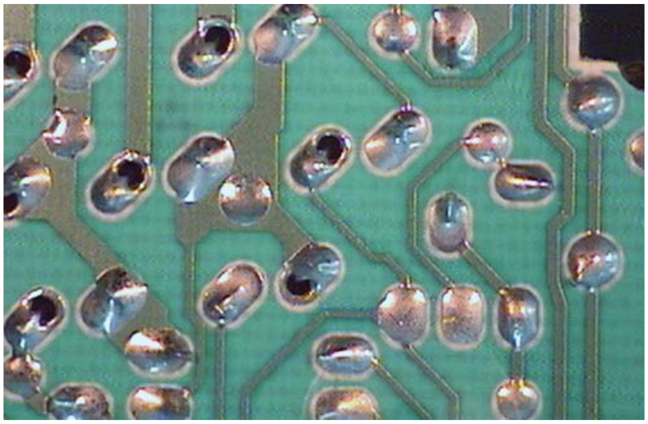


Figure 7-134

Table 7-7 Unsupported Holes with Component Leads, Minimum Acceptable Conditions[1,4]

Criteria	Class 1	Class 2	Class 3
A. Fillet wetted to lead and land	270°		330°, Note 2
B. Percentage of land area covered with wetted solder, Note 3	75%		

Note 1. A and B are applicable to both sides of double sided boards with functional lands on both sides.
Note 2. For Class 3, lead is wetted in the clinched area.
Note 3. Solder is not required to cap or cover the hole.
Note 4. Wetted solder refers to solder applied by the solder process.

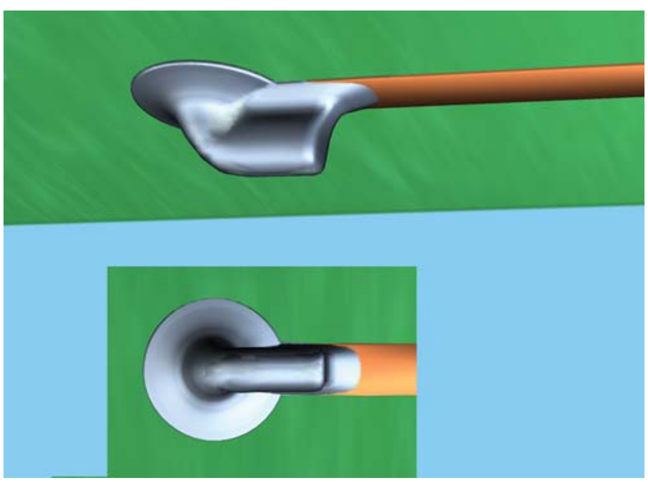


Figure 7-135

Target – Class 1,2,3

- Solder termination (land and lead) covered with wetted solder and outline of lead discernible in the solder fillet.
- No void areas or surface imperfections.
- Lead and land are well wetted.
- Lead is clinched.
- 100% solder fillet around lead.

7.4.5 Unsupported Holes – Solder (cont.)

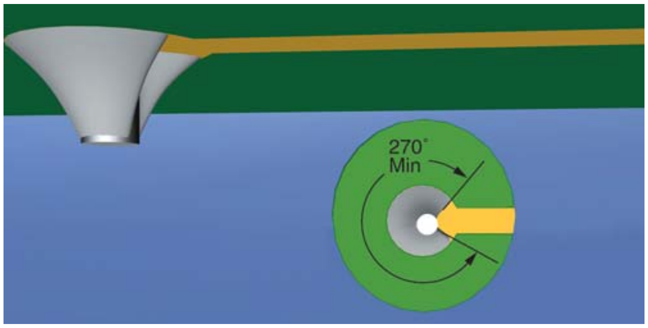


Figure 7-136

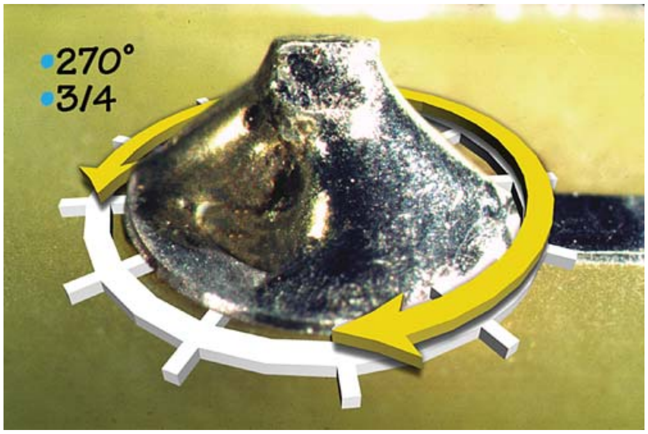


Figure 7-137

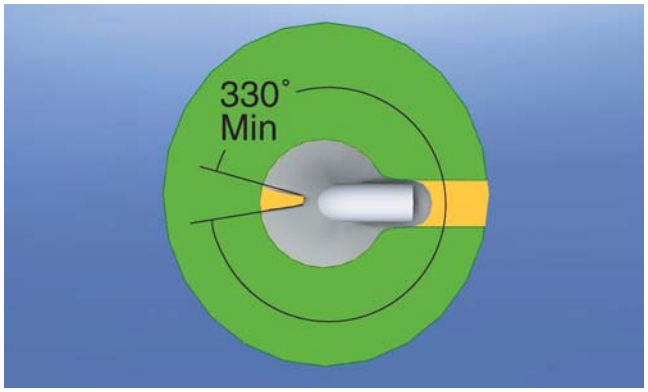


Figure 7-138

Acceptable – Class 1,2

- Solder coverage meets requirements of Table 7-7.

Acceptable – Class 3

- Lead is wetted in the clinched area.
- Minimum of 330° fillet and wetting.

Acceptable – Class 1,2,3

- Minimum 75% of land area covered with wetted solder on the secondary side (not shown).

7.4.5 Unsupported Holes – Solder (cont.)

Figure 7-139

Defect – Class 1,2

- Less than 75% land coverage.
- Solder connection of straight through termination does not meet minimum of 270° circumferential fillet or wetting.

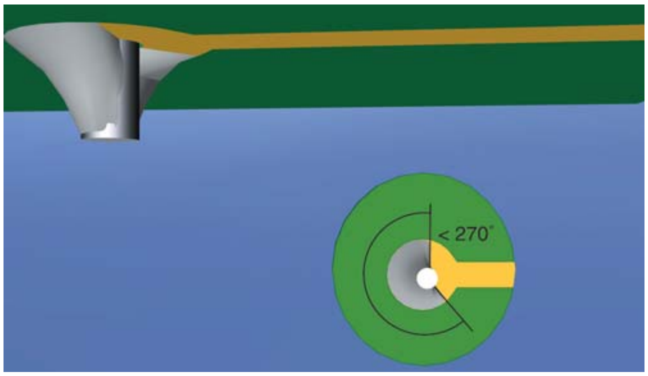


Figure 7-140

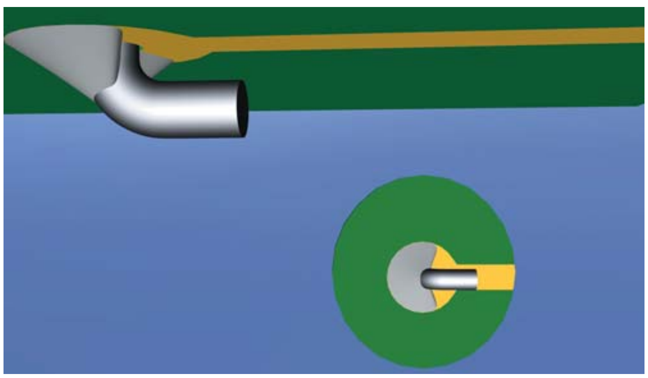


Figure 7-141

Defect – Class 3

- Solder connection does not meet 330° circumferential fillet or wetting.
- Lead not clinched (not shown).
- Lead not wetted in clinched area.
- Less than 75% land coverage.

Figure 7-142

Defect – Class 1,2,3

- Lead not discernible due to excess solder.

7.4.6 Unsupported Holes – Lead Cutting after Soldering

The criteria in 7.3.5.9 are also applicable to solder connections in unsupported holes.

7.5 Jumper Wires

These criteria do not constitute authority for repair to assemblies without prior customer consent, see 1.1. This section establishes visual acceptability criteria for the installation of discrete wires (jumper wires, etc.) used to interconnect components where there is no continuous printed circuit.

Information concerning rework and repair can be found in IPC-7711/7721.

The following items are addressed:

- Wire selection
- Wire routing
- Adhesive staking of wire
- Solder termination

They may be terminated in plated holes, and/or to terminal standoffs, conductor lands, and component leads.

Jumper wires are considered as components and are covered by an engineering instruction document for routing, termination, staking and wire type.

Keep jumper wires as short as practical and unless otherwise documented do not route over or under other replaceable components. Design constraints such as real estate availability and minimum electrical clearance need to be taken into consideration when routing or staking wires. A jumper wire 25 mm [1 in] maximum in length whose path does not pass over conductive areas and does not violate the designed spacing requirements may be uninsulated. Insulation, when required on the jumper wires, **shall** be compatible with conformal coating when conformal coating is required.

Acceptable – Class 1,2,3

- The insulation is in contact with the solder but does not interfere with formation of an acceptable connection.

Defect – Class 1,2,3

- Insulation interferes with formation of the solder connection.

7.5.1 Jumper Wires – Wire Selection

The following considerations are made when selecting wires for jumpers:

1. Wire is insulated if greater than 25 mm [1 in] in length or is liable to short between lands or component leads.
2. Silver plated stranded wire should not be used. Under some conditions corrosion of the wire can occur.
3. Select the smallest diameter wire that will carry the required current needs.
4. The insulation of the wire should withstand soldering temperatures, have some resistance to abrasion, and have a dielectric resistance equal to or better than the board insulation material.
5. Recommended wire is solid, insulated, plated copper wire.
6. Chemical solutions, pastes, and creams used to strip solid wires do not cause degradation to the wire.

7.5.2 Jumper Wires – Wire Routing

Unless otherwise specified by high speed/high frequency requirements, route jumper wires the shortest route in straight legs as possible, avoiding test points, to points of termination. Allow enough length for routing, stripping and attachment.

Jumper wire routing on assemblies having the same part number should be the same pattern.

Routing **shall** be documented for each part number and followed without deviation.

Do not allow jumper wires to pass over or under any component, however, they may pass over parts such as thermal mounting plates, brackets and components that are bonded to the PWB.

Jumpers may pass over solder lands if sufficient slack is provided so they can be moved away from the solder land for component replacement.

Contact with heat sinks specific to high temperature generating components **shall** be avoided.

Except for connectors at the edge of the board, do not pass jumpers through component foot prints unless the layout of the assembly prohibits the routing in other areas.

Do not pass jumpers over patterns or vias used as a test point.

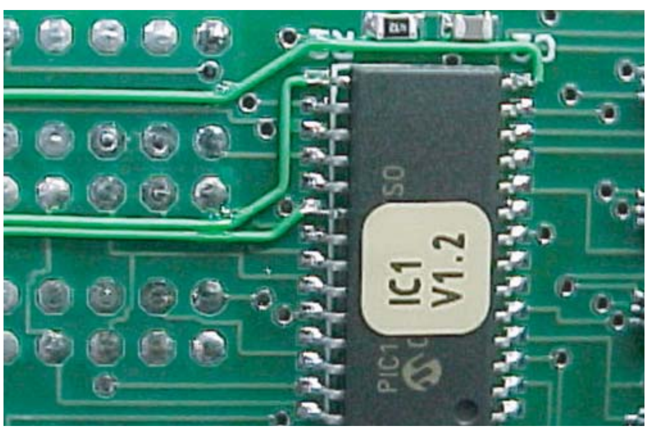


Figure 7-143

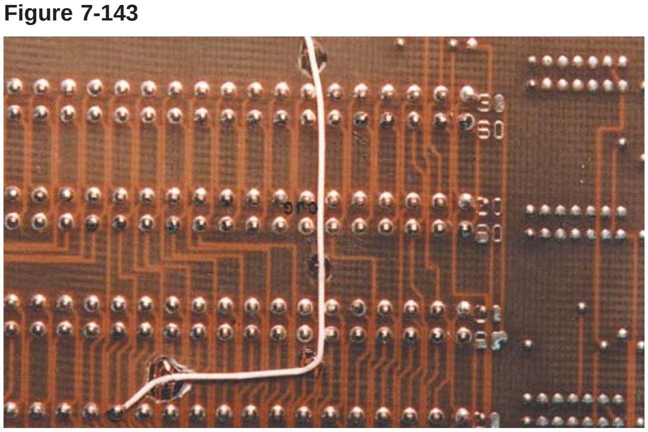


Figure 7-144

Target – Class 1,2,3

- Wire routed shortest route.
- Wire does not pass over or under component.
- Wire does not pass over land patterns or vias used as test points.
- Wire does not cross component footprint or lands.

7.5.2 Jumper Wires – Wire Routing (cont.)

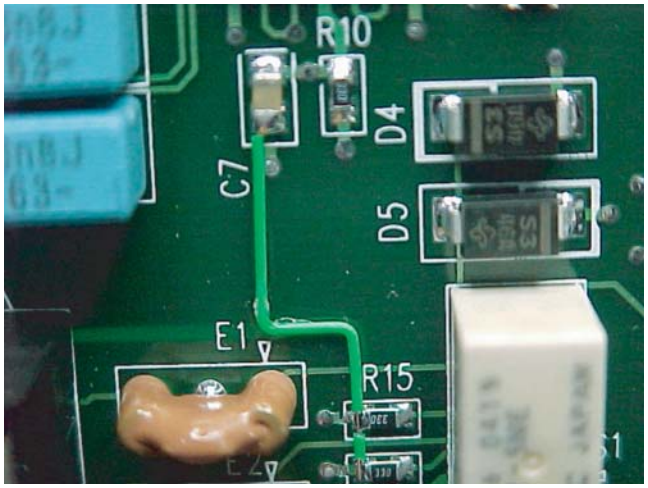


Figure 7-145

Acceptable – Class 1,2,3

- Lands not covered by wire.
- Sufficient slack in wire to allow relocation from unavoidable lands during component replacement or test.
- The wire is not so loose that it can extend above the height of adjacent components.

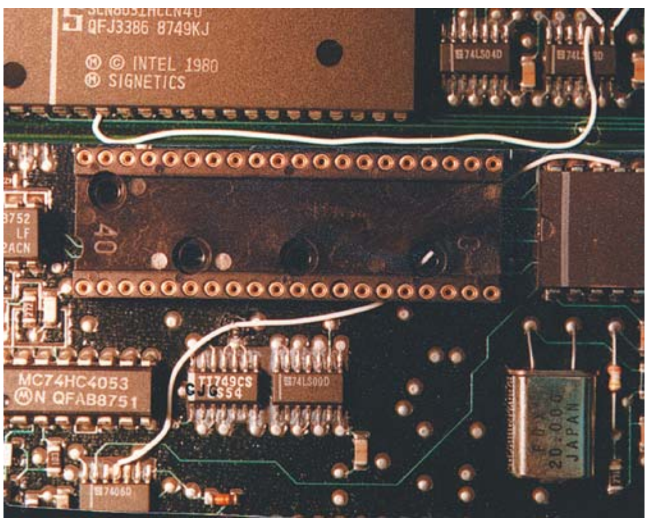


Figure 7-146

Acceptable – Class 1
Process Indicator – Class 2,3

- Insufficient slack in wire to allow relocation from unavoidable lands during component replacement.
- Unavoidable crossing of component footprint or land area.

Acceptable – Class 1
Defect – Class 2,3

- Wire routed under or over components.
- Routing of wire(s) overhang or wrap over the edge of the board.
- The wire is loose and can extend above the height of adjacent components.

Note: Take in consideration the trapping of contaminants when wires are routed under components. When routed over components consider the implications of wires coming in contact with heat sinks or hot components and electrical interference in RF applications.

7.5.3 Jumper Wires – Wire Staking

Jumper wires may be staked to the base material (or integral thermal mounting plate or hardware) by adhesive or tape (dots or strips).

All adhesive must be fully cured before acceptance. Consider the end-use product environment as well as subsequent process compatibility when selecting the appropriate staking method.

Spot bond so that the stake fillet is sufficient to secure the wire with no excessive spillover onto adjacent lands or components.

Staking **shall not** be on a removable or socketed component. Where design constraints are an obstacle, staking is to be discussed with the customer.

Jumper wires **shall not** be staked to, or allowed to touch, any moving parts. Wires are staked within the radius of each bend for each change of direction.

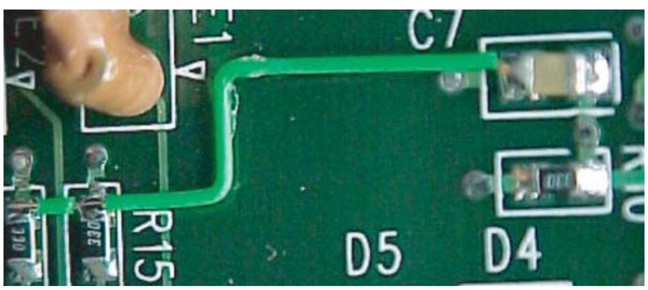


Figure 7-147

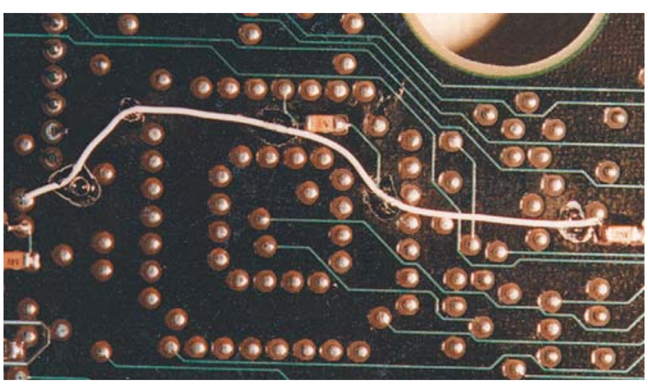


Figure 7-148

Acceptable – Class 1,2,3

- Jumper wires are staked at intervals as specified by engineering documentation or:
  - At all changes of direction to restrict movement of wire.
  - As close to the solder connection as possible.
- Staking tape/adhesive do not overhang the board edge(s) or violate edge spacing requirements.

7.5.3 Jumper Wires – Wire Staking (cont.)

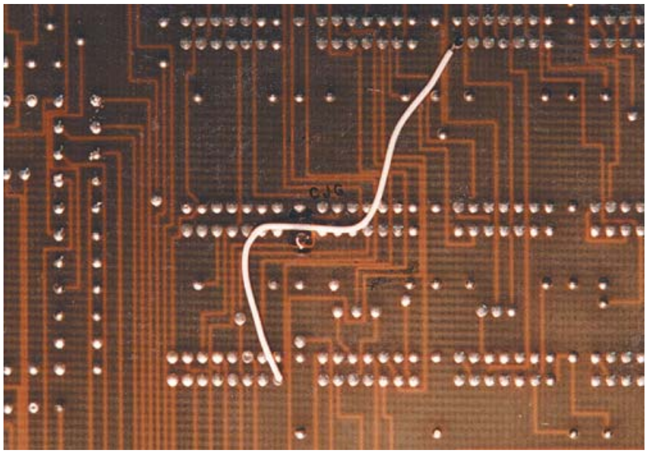


Figure 7-149

Acceptable – Class 1
Defect – Class 2,3

- Jumper wires are not staked as specified.
- Staking tape/adhesive overhang the board edge(s) or violate edge spacing requirements.

Defect – Class 1,2,3

- Adhesive, when used, is not cured.
- Jumper wires are stacked to or touching any moving parts.

7.5.4 Jumper Wires – Supported Holes

Jumper wires may be attached by any of the following methods.

This section is intended to show jumper wire practices that are used in original manufacturing. See IPC-7711/7721 for additional jumper wire information when affecting repairs and modifications.

For jumper wires attached to components other than axial leaded, lap solder the wire to the component lead.

Assure the solder connection length and insulation clearance meet the minimum/maximum acceptability requirements, see 6.2.2.

7.5.4.1 Jumper Wires – Supported Holes – Lead in Hole

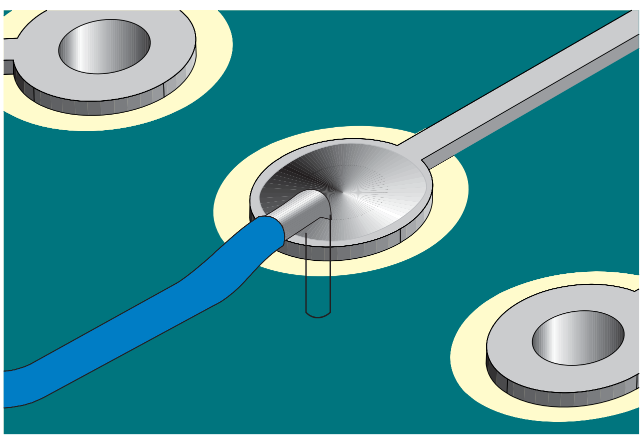


Figure 7-150

Acceptable – Class 1,2,3

• Wires soldered into a PTH/via hole.

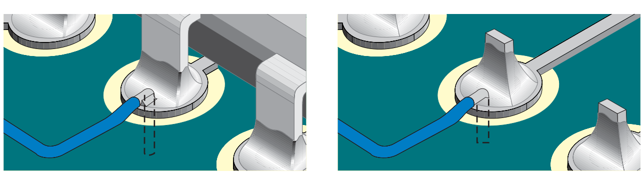


Figure 7-151

Acceptable – Class 1,2
Defect – Class 3

• Wire soldered into PTH with component lead.

7.5.5 Jumper Wires – Wrapped Attachment

The jumper wire ends are attached to component lead projections by wrapping the wire. Jumper wires 30 AWG and smaller do not need to comply with clause 6.14.

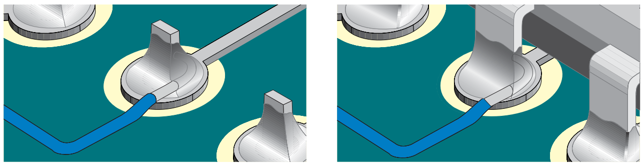


Figure 7-152

Figure 7-153

Target – Class 1,2,3

- Wire is wrapped 180° to 270° and soldered to a component lead.

Acceptable – Class 1,2,3

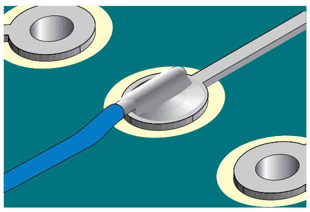
- Wire is wrapped a minimum of 90° on a flat lead or 180° on a round lead.
- Acceptable solder connection at wire/lead interface.
- Wire contour or end is discernible in the solder connection.
- Wire overhang of component termination does not violate minimum electrical clearance.

Defect – Class 1,2,3

- Wire is wrapped less than 90° on flat or less than 180° on round leads.
- Wire overhang violates minimum electrical clearance.

7.5.6 Jumper Wires – Lap Soldered

The following criteria apply when soldering to a land or a component lead and land. When soldering to a land, the available contact area is defined as the land diameter. When soldering to a component lead and land, the available contact area is the distance from the edge of the component land to the knee of the lead.



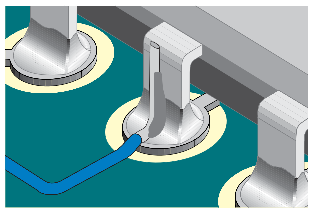


Figure 7-154

Acceptable – Class 1,2,3

- Solder connection extends a minimum of three wire diameters when the available contact area is at least three wire diameters.
- Wire discernible in the solder.
- Solder fillet on wire that is lap soldered to a lead is at least 75% of the distance from edge of land to knee of lead.
- Wire lap soldered to lead does not extend beyond the knee of the component lead.

Acceptable – Class 1,2

- Solder connection is 100% of the land or the land/lead when the available contact area is less than three wire diameters.

Acceptable – Class 3

- Solder connection is 100% of the land or the land/lead when the available contact area is less than three wire diameters and is staked or otherwise mechanically secured.

7.5.6 Jumper Wires – Lap Soldered (cont.)

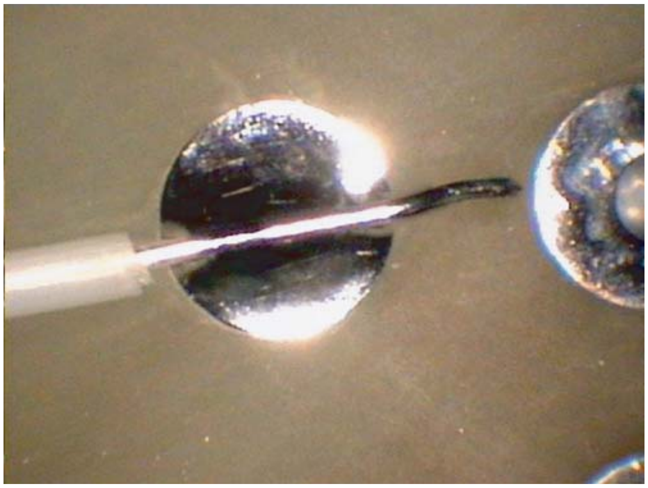


Figure 7-155

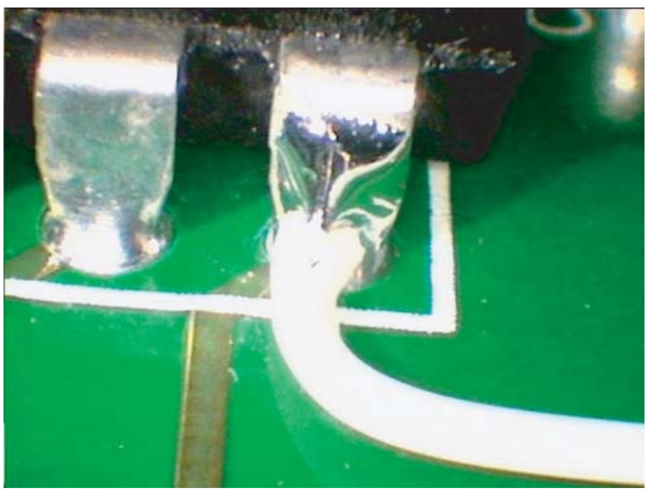


Figure 7-156

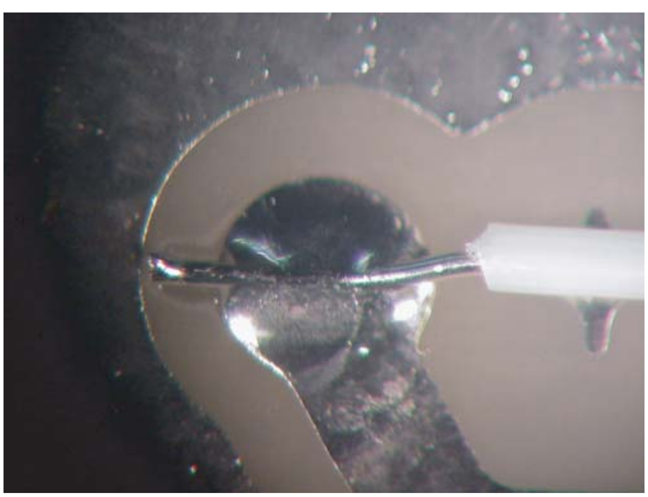


Figure 7-157

Defect – Class 1,2

- Solder connection is less than three wire diameters when the available contact area is at least three wire diameters.
- Solder connection is less than 100% of the land or land/lead when the available contact area is less than three wire diameters.

Defect – Class 3

- Solder connection is less than three wire diameters when the available contact area is at least three wire diameters.
- Solder connection is less than three wire diameters without staking or other mechanical support.

Defect – Class 1,2,3

- Wire that is lap soldered is less than 75% from edge of land to knee of lead.
- Wire extends beyond the knee of component lead.
- Lead violates minimum electrical clearance.

8 Surface Mount Assemblies

This section covers acceptability requirements for the fabrication of surface mount assemblies.

In addition to the criteria in this section the criteria of Section 5 are applicable.

The following topics are addressed in this section:

8 Surface Mount Assemblies (cont.)

8.1 Staking Adhesive

8.1.1 Staking Adhesive – Component Bonding

These criteria are for adhesive added before component attachment.

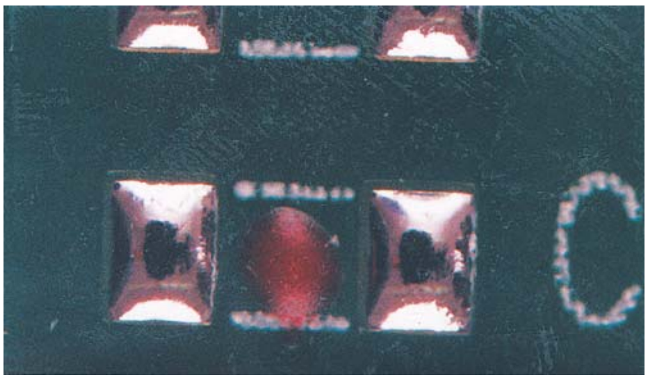


Figure 8-1

Target – Class 1,2,3

- No adhesive present on solderable surfaces of the termination area.
- Adhesive is centered between the lands.

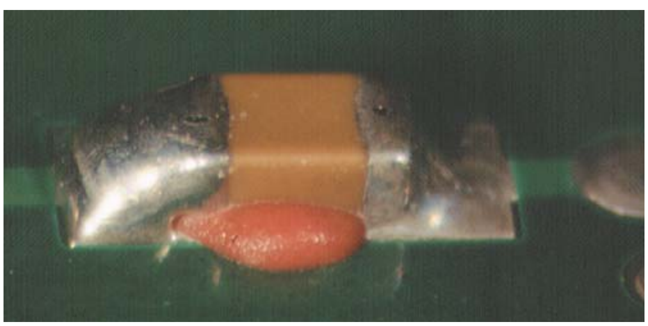


Figure 8-2

Acceptable – Class 1
Process Indicator – Class 2

- Adhesive material extending from under the component is visible in the termination area, but end joint width meets minimum requirements.

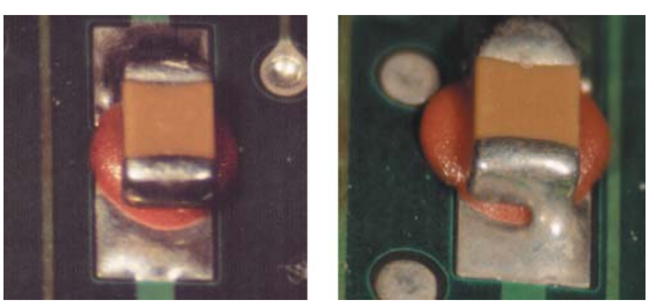


Figure 8-3

Defect – Class 1,2

- Adhesive material is visible in the termination area and the solder connection does not meet minimum requirements.

Defect – Class 3

- Adhesive materials extending from under the component are visible in the termination area.

8.1.2 Staking Adhesive – Mechanical Strength

These criteria are for adhesive added after component attachment.

Note: The circumference bonding may have one or more adhesive points.

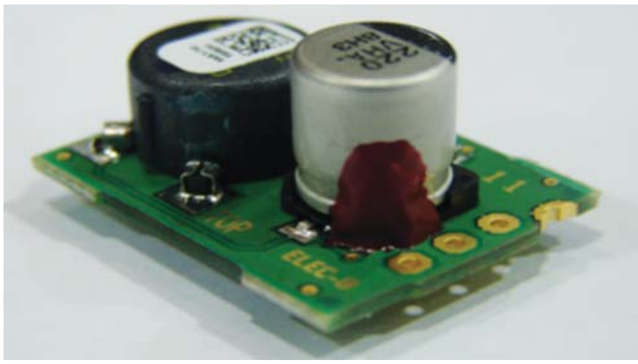


Figure 8-4

Acceptable – Class 1,2,3

- On round components adhesive adheres to a minimum 25% of the component height.
- On round components a minimum of three beads of staking material placed approximately evenly around the periphery of the component.
- Rectangular components are staked at each corner a minimum 25% of the height of the component body.
- Adhesion to mounting surfaces is evident.
- Staking is completely cured and homogenous.
- Staking does not interfere with stress relief.
- Slight flow under the component body does not damage the components or affect form, fit and function.

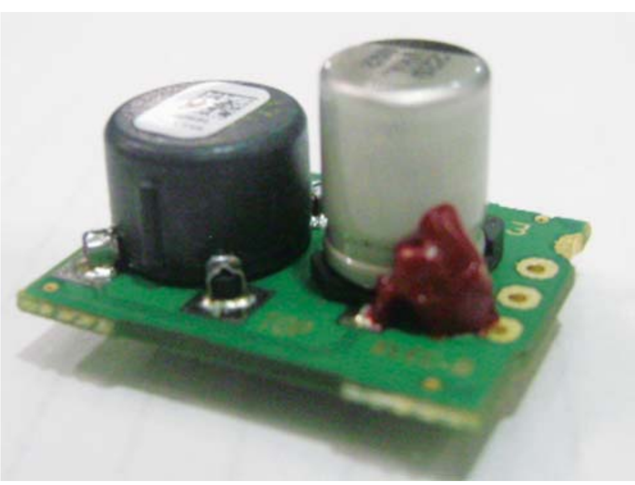


Figure 8-5

Acceptable – Class 1
Process Indicator – Class 2,3

- Adhesive on lands or conductive patterns does not interfere with the formation of solder connection.

8.1.2 Staking Adhesive – Mechanical Strength (cont.)

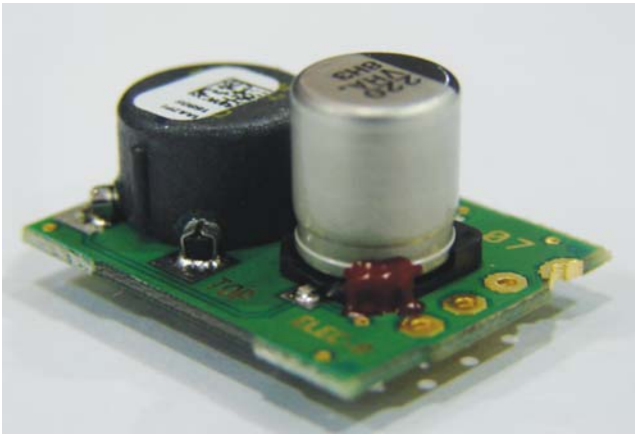


Figure 8-6

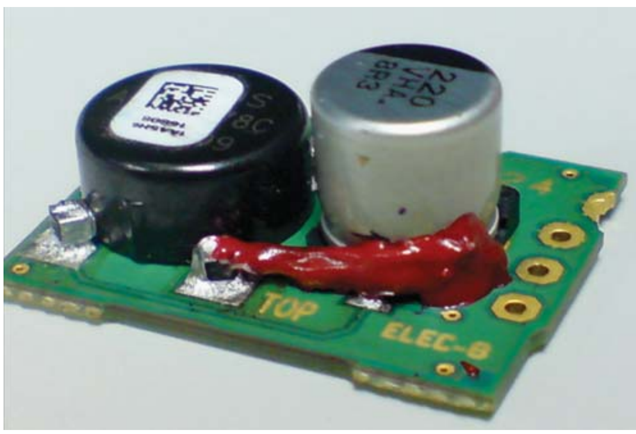


Figure 8-7

Not Established – Class 1
Defect – Class 2,3

- Round components where adhesive adheres to less than 25% of the component height.
- On round components there are less than three beads of staking material.
- Rectangular components are not staked at each corner a minimum 25% of the height of the component body.

Defect – Class 1,2,3

- No evidence of adhesion to mounting surfaces.
- The adhesive interferes with the formation of required solder connections.
- Adhesive is not completely cured and homogenous.
- Adhesive interferes with stress relief.

8.2 SMT Leads

8.2.1 SMT Leads – Plastic Components

In the following criteria, the words ''plastic component'' are used in the generic sense to differentiate between plastic components and those made of other materials, e.g., ceramic/alumina or metal (normally hermetically sealed).

Unless otherwise specified, solder **shall not** touch a package body or end seal. Exceptions are when a copper lead or termination configuration causes the solder fillet to contact a plastic component body, such as:

- Plastic SOIC family (small outline packages such as SOT, SOD).
- Space from the top of the lead to the bottom of a plastic component is 0.15 mm [0.006 in] or less.
- Connectors, provided solder does not go into the cavity.
- Leadless components where the designed land extends past the component termination area.
- When agreed between Manufacturer and User.

8.2.2 SMT Leads – Damage

These criteria are applicable whether leads are formed manually or by machine or die.

Acceptable – Class 1,2,3

- No nicks or deformation exceeding 10% of the diameter, width or thickness of the lead. See 5.2.1 for exposed basis metal criteria.

Defect – Class 1,2,3

- Lead is damaged or deformed more than 10% of the diameter, width or thickness of the lead.
- Lead is deformed from repeated or careless bending.
- Heavy indentations such as serrated pliers mark.

8.2.3 SMT Leads – Flattening

Components with axial leads of round cross-section may be flattened (coined) for positive seating in surface mounting. Intentionally flattened areas of leads are excluded from the 10% deformation requirement of 8.2.2.

Acceptable – Class 1,2
Defect – Class 3

- The thickness of the flattened lead is less than 40% of the original diameter.

8.3 SMT Connections

SMT connection criteria are provided in 8.3.1 through 8.3.16, as appropriate.

Some dimensions, e.g., solder thickness, are not inspectable conditions and are identified by notes.

Dimension (G) is the solder fillet from the top of the land to the bottom of the termination. Dimension (G) is the prime parameter in the determination of solder connection reliability for leadless components. A thick (G) is desirable. Additional information related to reliability of surface mount connections is available in IPC-D-279, IPC-SM-785 and IPC-9701.

Designs with via in land may preclude meeting fillet height criteria. Solder acceptance criteria should be defined between the Manufacturer and User.

Components with surfaces and/or termination ends or sides that are not wettable by design are exempt from solder wetting requirements in those areas. Solder fillet wetting to the sides or ends of the leads is not required unless specifically stated.

Solder fillet may extend through the top bend. Solder should not extend under the body of surface mount components whose leads are made of Alloy 42 or similar metals.

Some components cannot be tilted due to mating requirements with enclosures or panels, for example toggle switches, potentiometers, LCDs, and LEDs. Such restrictions should be identified in drawings.

For components with multiple termination types, e.g., TO-252 (D-Pak), each termination type **shall** meet the requirements of its applicable individual termination type.

8.3 SMT Connections (cont.)

Target – Class 1,2,3

- No evidence of tilted or raised component.

Acceptable – Class 1,2,3

- Component tilted/raised does not:
  - Violate minimum electrical clearance.
  - Exceed maximum component height requirements.
  - Affect form, fit or function.

Defect – Class 1,2,3

- Component tilted/raised:
  - Violates minimum electrical clearance.
  - Exceeds maximum component height requirements.
  - Affects form, fit or function.

8.3.1 Chip Components – Bottom Only Terminations

Connections formed to chip components with bottom only terminations **shall** meet dimensional and solder fillet requirements in Table 8-1 and 8.3.1.1 through 8.3.1.8. The widths of the component termination and land are (W) and (P), respectively, and the termination overhang describes the condition where the smaller extends beyond the larger termination, i.e., W or P. The length of the component termination is (R) and the length of the land is (S).

Criteria for tall profile components with bottom only terminations are in 8.3.10.

Table 8-1 Dimensional Criteria – Chip Component – Bottom Only Termination Features

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W) or 50% (P), whichever is less, Note 1		25% (W) or 25% (P), whichever is less, Note 1
End Overhang	B	Not permitted		
Minimum End Joint Width	C	50% (W) or 50% (P), whichever is less, Note 4		75% (W) or 75% (P), whichever is less, Note 4
Minimum Side Joint Length	D	Note 3		
Maximum Fillet Height	E	Note 3		
Minimum Fillet Height	F	Note 3		
Solder Thickness	G	Note 3		
Minimum End Overlap	J	Note 3	50% (R)	75% (R)
Land Width	P	Note 2		
Termination Length	R	Note 2		
Land Length	S	Note 2		
Termination Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size, determined by design.
Note 3. Wetting is evident.
Note 4: (C) is measured at the narrowest point of the required fillet.

8.3.1.1 Chip Components – Bottom Only Terminations – Side Overhang (A)

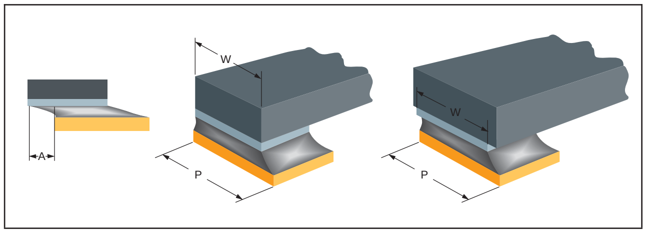


Figure 8-8

Target – Class 1,2,3

- No side overhang.

Acceptable – Class 1,2

- Side overhang (A) is less than or equal to 50% width of component termination area (W) or 50% width of land (P), whichever is less.

Acceptable – Class 3

- Side overhang (A) is less than or equal to 25% width of component termination area (W) or 25% width of land (P), whichever is less.

Defect – Class 1,2

- Side overhang (A) is greater than 50% component termination width (W) or 50% land width (P), whichever is less.

Defect – Class 3

- Side overhang (A) is greater than 25% component termination width (W) or 25% land width (P), whichever is less.

8.3.1.2 Chip Components – Bottom Only Terminations – End Overhang (B)

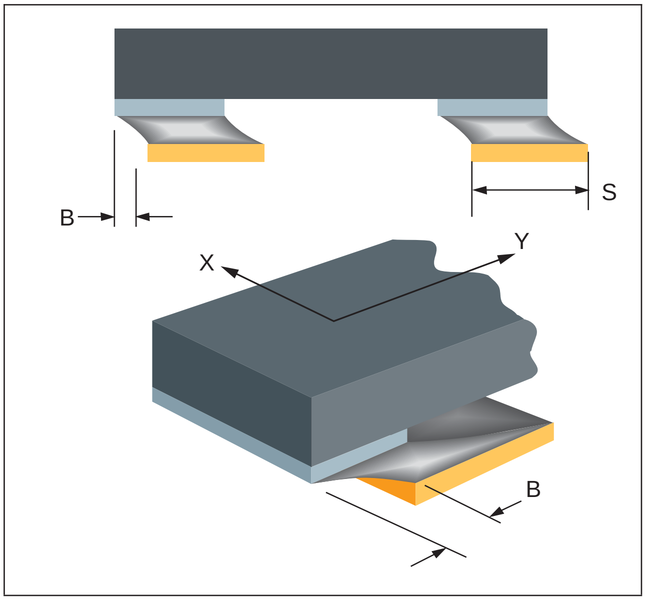


Figure 8-9

Defect – Class 1,2,3

• End overhang (B) in Y axis is not permitted.

8.3.1.3 Chip Components – Bottom Only Terminations – End Joint Width (C)

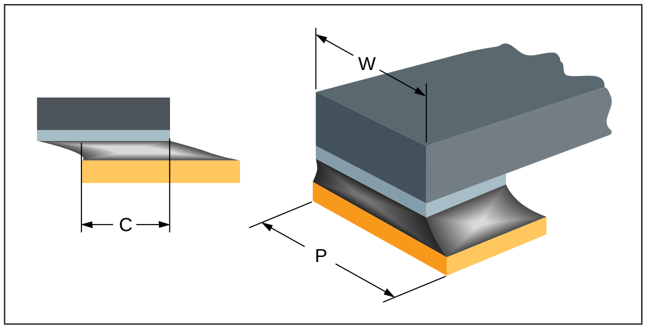


Figure 8-10

Target – Class 1,2,3

- End joint width (C) is equal to the width of the component termination (W) or width of land (P), whichever is less.

Acceptable – Class 1,2

- Minimum end joint width (C) is 50% width of component termination (W) or 50% width of land (P), whichever is less.

Acceptable – Class 3

- Minimum end joint width (C) is 75% width of component termination (W) or 75% width of land (P), whichever is less.

Defect – Class 1,2

- End joint width (C) is less than 50% width of component termination (W) or less than 50% width of land (P), whichever is less.

Defect – Class 3

- End joint width (C) is less than 75% width of component termination (W) or less than 75% width of land (P), whichever is less.

8.3.1.4 Chip Components – Bottom Only Terminations – Side Joint Length (D)

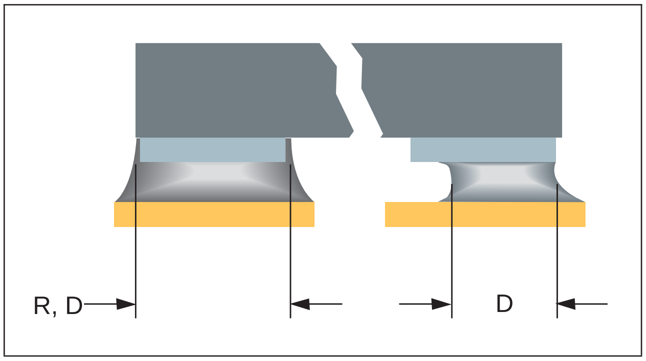


Figure 8-11

Target – Class 1,2,3

- Side joint length (D) equals component termination length (R).

Acceptable – Class 1,2,3

- Any side joint length (D) is acceptable if all other solder requirements are met.

8.3.1.5 Chip Components – Bottom Only Terminations – Maximum Fillet Height (E)

Maximum fillet height (E) requirements are not specified for Classes 1, 2 or 3. However, wetting is evident.

Defect – Class 1,2,3

- No wetting evident.

8.3.1.6 Chip Components – Bottom Only Terminations – Minimum Fillet Height (F)

Minimum fillet height (F) requirements are not specified for Classes 1, 2 or 3. However, wetting is evident.

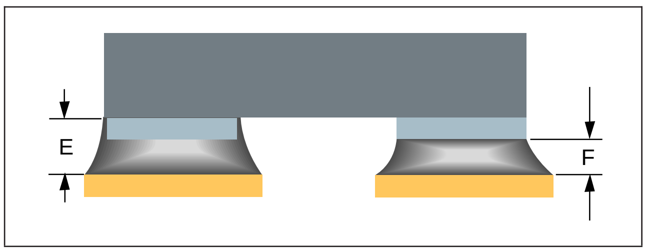


Figure 8-12

Defect – Class 1,2,3

- No wetting evident.

8.3.1.7 Chip Components – Bottom Only Terminations – Solder Thickness (G)

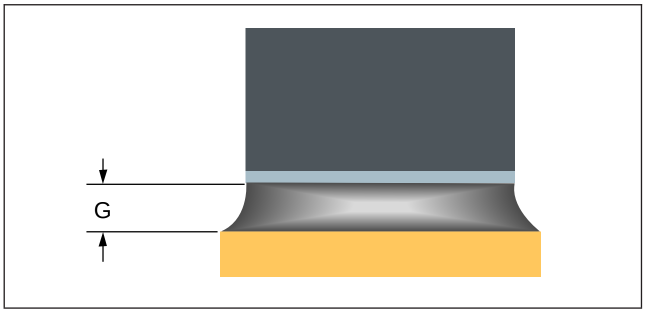


Figure 8-13

Acceptable – Class 1,2,3

- Wetting is evident.

Defect – Class 1,2,3

- No wetting evident.

8.3.1.8 Chip Components – Bottom Only Terminations – End Overlap (J)

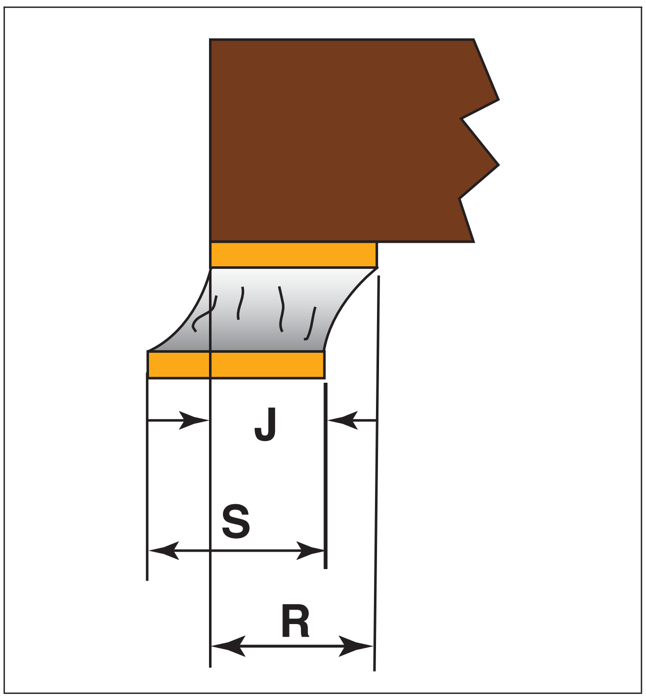


Figure 8-14

Acceptable – Class 1

- Wetted fillet is evident.

Acceptable – Class 2

- End overlap (J) between the component termination and the land is minimum 50% the length of component termination (R).

Acceptable – Class 3

- End overlap (J) between the component termination and the land is minimum of 75% the length of component termination (R).

Defect – Class 1,2,3

- Component termination area and land do not overlap.

Defect – Class 2

- End overlap (J) is less than 50% of the length of component termination (R).

Defect – Class 3

- End overlap (J) is less than 75% of the length of component termination (R).

8.3.2 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s)

These criteria apply to component types such as chip resistor, chip capacitor, network passive parts (R-NET, etc., that have this style of termination) and cylindrical components with square ends.

Solder connections to components having terminations of a square or rectangular configuration **shall** meet the dimensional and solder fillet requirements in Table 8-2 and 8.3.2.1 through 8.3.2.10.2. For one-sided termination, the solderable side is the vertical end face of the component.

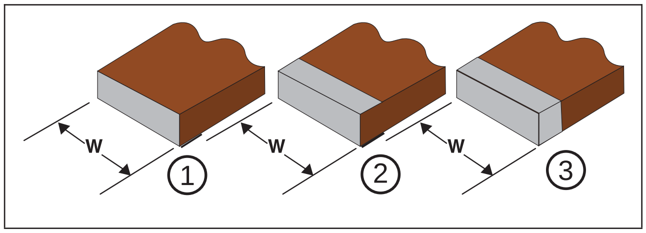


Figure 8-15
1. **One or two face termination**
2. **Three face termation**
3. **Five face termination**

Table 8-2 Dimensional Criteria – Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s)

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W) or 50% (P), whichever is less, Note 1		25% (W) or 25% (P), whichever is less, Note 1
End Overhang	B	Not permitted		
Minimum End Joint Width	C	50% (W) or 50% (P), whichever is less, Note 5		75% (W) or 75% (P), whichever is less, Note 5
Minimum Side Joint Length	D	Note 3		
Maximum Fillet Height	E	Note 4		
Minimum Fillet Height	F	Wetting is evident on the vertical surface(s) of the component termination.		(G) + 25% (H) or (G) + 0.5 mm [0.02 in], whichever is less.
Solder Thickness	G	Note 3		
Termination Height	H	Note 2		
Minimum End Overlap	J	Required		25% (R)
Width of Land	P	Note 2		
Termination Length	R	Note 2		
Termination Width	W	Note 2		
Side Mounting/Billboarding, Notes 6,7				
Width to Height Ratio		Does not exceed 2:1		
End Cap and Land Wetting		100% wetting land to end metallization contact areas		
Minimum End Overlap	J	100%		
Maximum Side Overhang	A	Not permitted		
End Overhang	B	Not permitted		
Maximum Component Size		No limits		1206, Note 8

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified dimension, or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. The maximum fillet may overhang the land and/or extend onto the top or side metallization but does not touch the top or side of the component.
Note 5: (C) is measured at the narrowest point of the required fillet.
Note 6: These criteria are for chip components that may flip (rotate) onto the narrow edge during assembly, and only apply to component with 3 or 5 side terminations.
Note 7: These criteria may not be acceptable for certain high frequency or high vibration applications.
Note 8: Component size may be larger than 1206 if the component is less than a 1.25:1 width to height ratio and has five termination faces.

8.3.2.1 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Side Overhang (A)

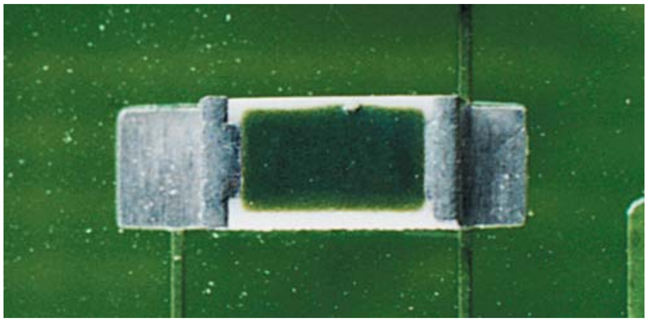


Figure 8-16

Target – Class 1,2,3

- No side overhang.

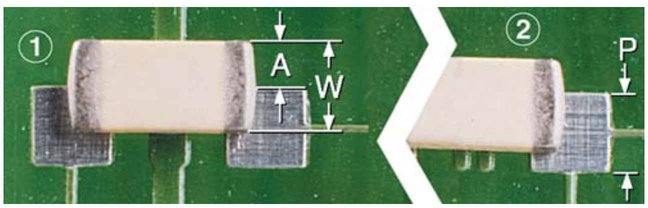


Figure 8-17
1. Class 1,2
2. Class 3

Acceptable – Class 1,2

- Side overhang (A) is less than or equal to 50% width of component termination area (W) or 50% width of land (P), whichever is less.

Acceptable – Class 3

- Side overhang (A) is less than or equal to 25% width of component termination area (W) or 25% width of land (P), whichever is less.

8.3.2.1 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Side Overhang (A) (cont.)

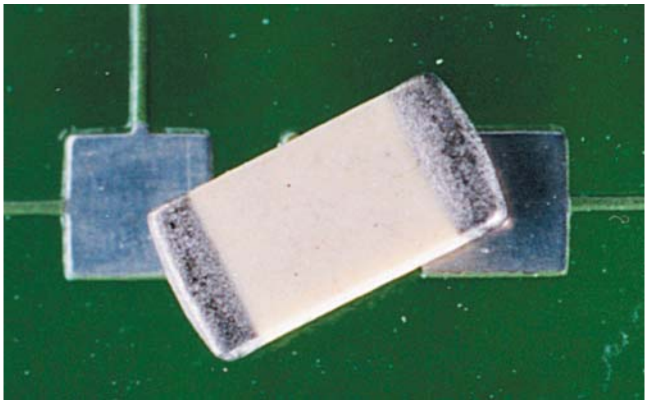


Figure 8-18

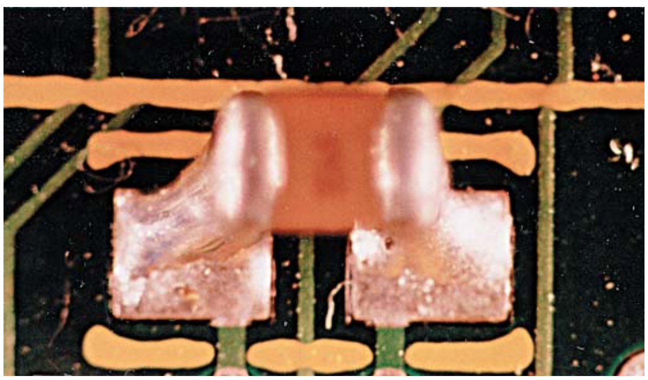


Figure 8-19

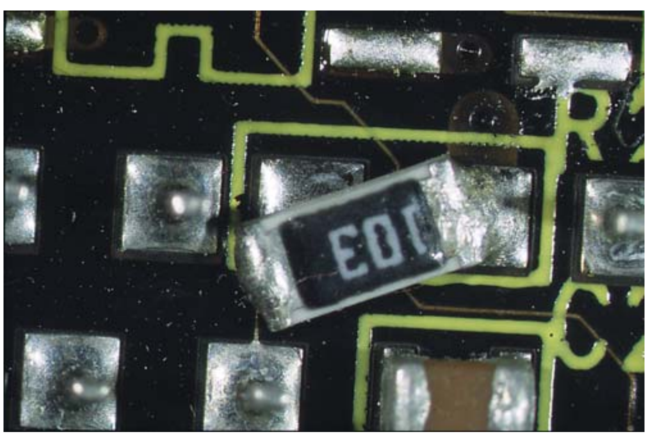


Figure 8-20

Defect – Class 1,2

- Side overhang (A) is greater than 50% component termination width (W) or 50% land width (P), whichever is less.

Defect – Class 3

- Side overhang (A) is greater than 25% component termination width (W) or 25% land width (P), whichever is less.

8.3.2.2 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – End Overhang (B)

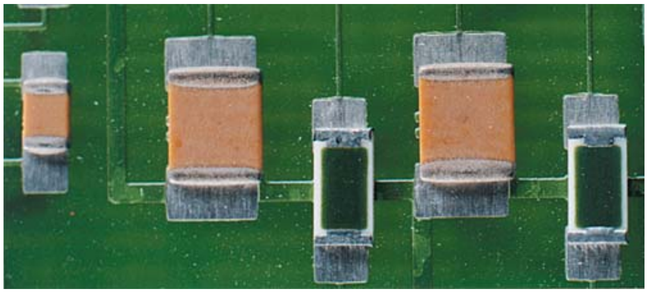


Figure 8-21

Target – Class 1,2,3

- No end overhang.

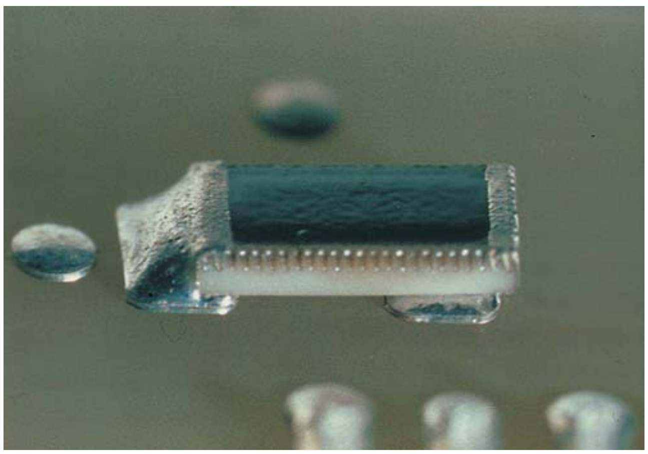


Figure 8-22

Defect – Class 1,2,3

- Termination overhangs land.

8.3.2.3 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – End Joint Width (C)

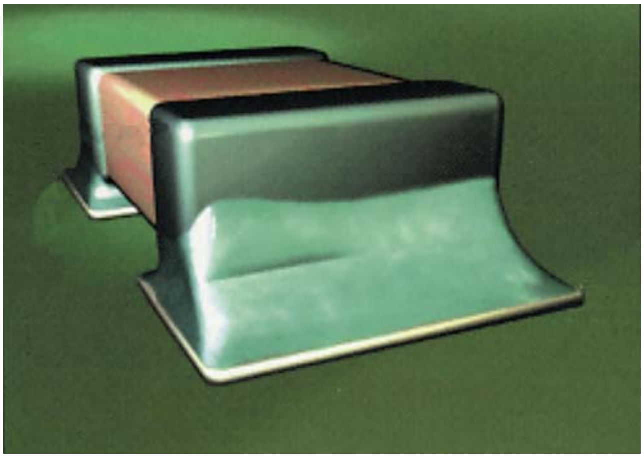


Figure 8-23

Target – Class 1,2,3

- End joint width is equal to component termination width or width of land, whichever is less.

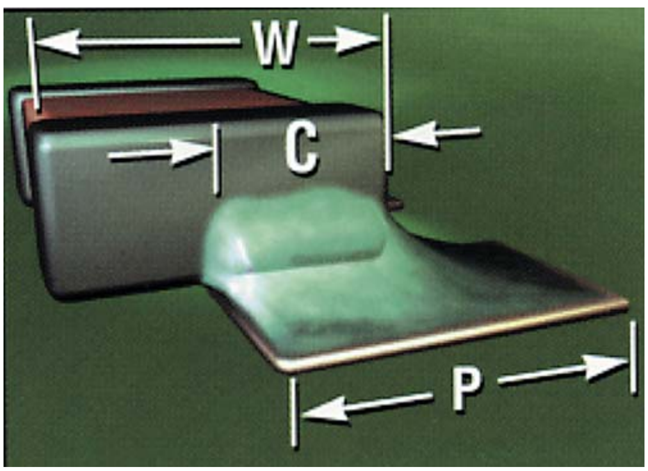


Figure 8-24

Acceptable – Class 1,2

- End joint width (C) is minimum 50% of component termination width (W) or 50% land width (P), whichever is less.

Figure 8-25

8.3.2.3 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – End Joint Width (C) (cont.)

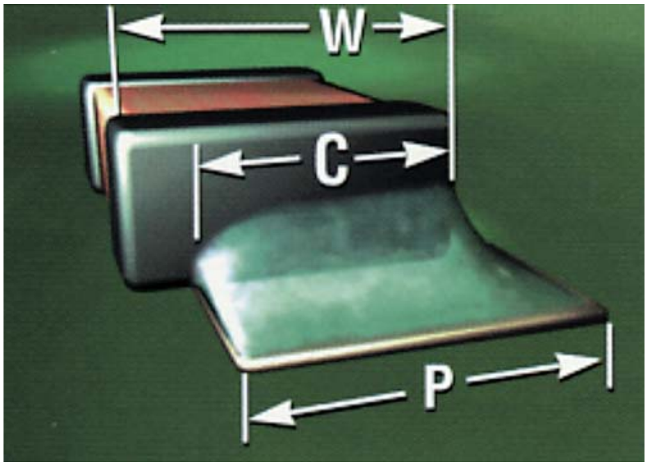


Figure 8-26

Acceptable – Class 3

- End joint width (C) is minimum 75% of component termination (W) or 75% land width (P), whichever is less.

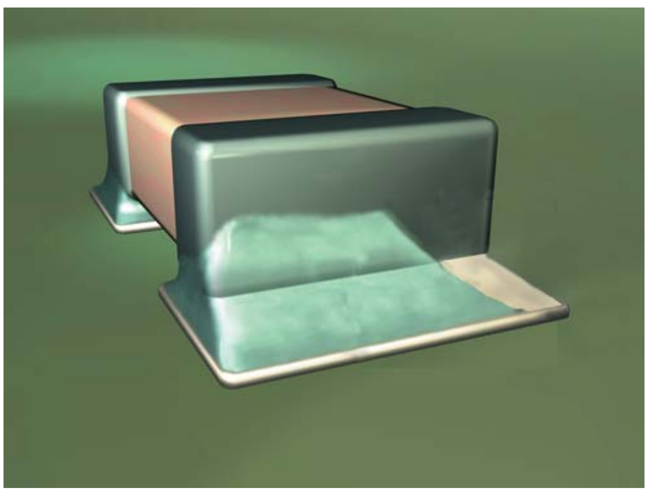


Figure 8-27

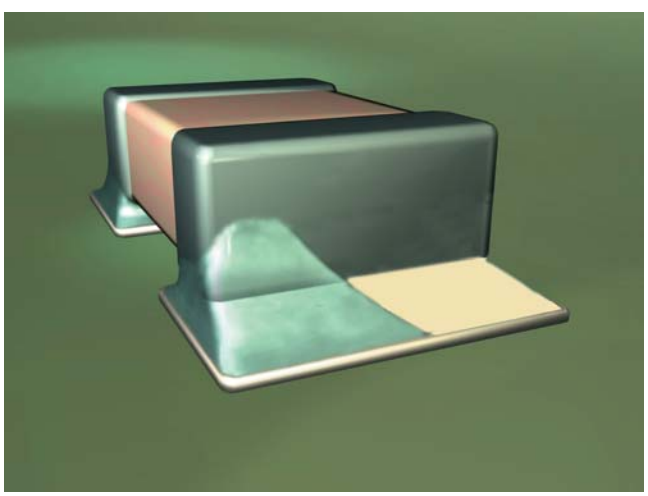


Figure 8-28

Defect – Class 1,2,3

- Less than minimum acceptable end joint width.

8.3.2.4 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Side Joint Length (D)

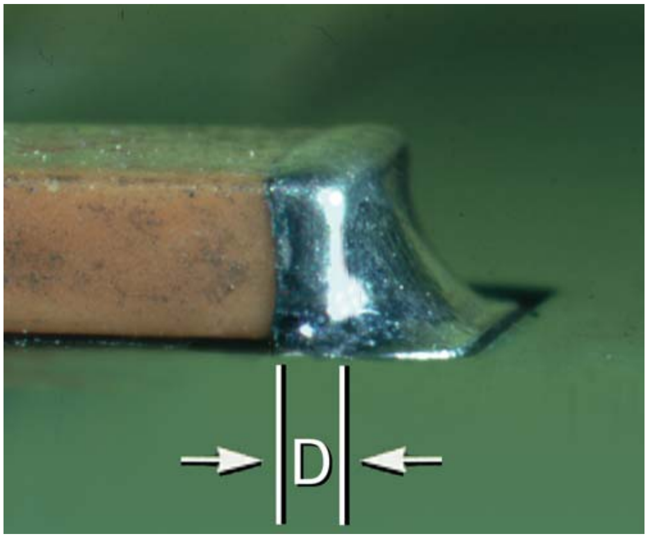


Figure 8-29

Target – Class 1,2,3

- Side joint length equals length of component termination.

Acceptable – Class 1,2,3

- Side joint length is not required. However, a wetted fillet is evident.

Defect – Class 1,2,3

- No wetted fillet.

8.3.2.5 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Maximum Fillet Height (E)

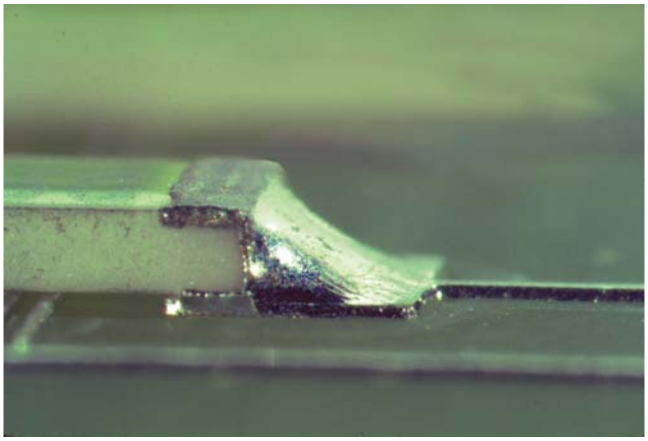


Figure 8-30

Target – Class 1,2,3

- Maximum fillet height is the solder thickness plus component termination height.

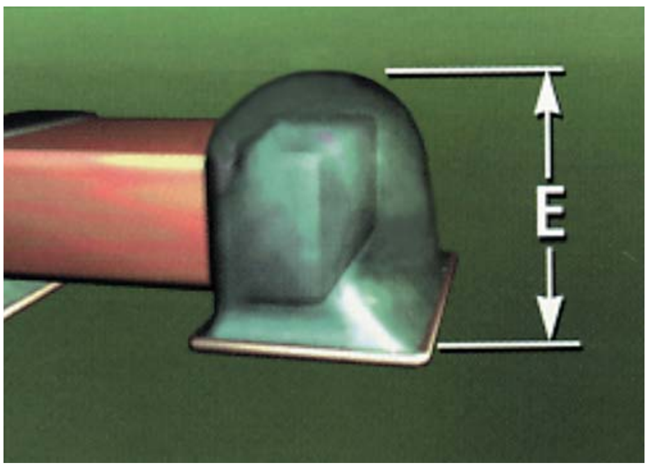


Figure 8-31

Acceptable – Class 1,2,3

- Maximum fillet height (E) may overhang the land and/or extend onto the top or side metallization, but does not touch the top or side of the component.

Defect – Class 1,2,3

- Solder fillet extends onto the top of the component body.

8.3.2.6 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Minimum Fillet Height (F)

Figure 8-32

Acceptable – Class 1,2

- Minimum fillet height (F) exhibits wetting on the vertical surface(s) of the component termination.

Acceptable – Class 3

- Minimum fillet height (F) is solder thickness (G) plus either 25% termination height (H), or 0.5 mm [0.02 in], whichever is less.

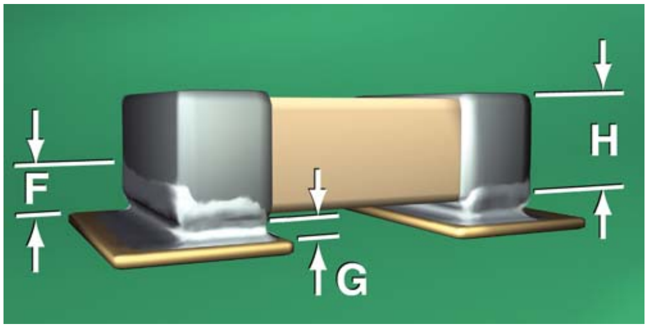


Figure 8-33

Defect – Class 1,2

- No fillet height evident on face of component.

Defect – Class 3

- Minimum fillet height (F) is less than solder thickness (G) plus either 25% (H), or solder thickness (G) plus 0.5 mm [0.02 in], whichever is less.

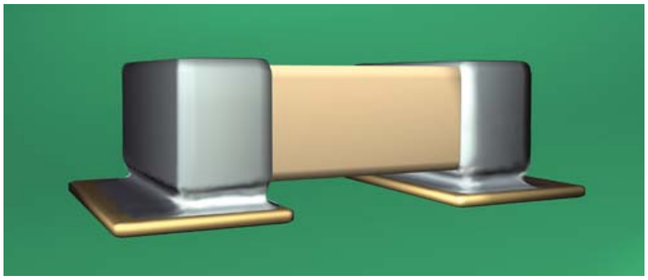


Figure 8-34

Defect – Class 1,2,3

- Insufficient solder.
- A wetted fillet is not evident.

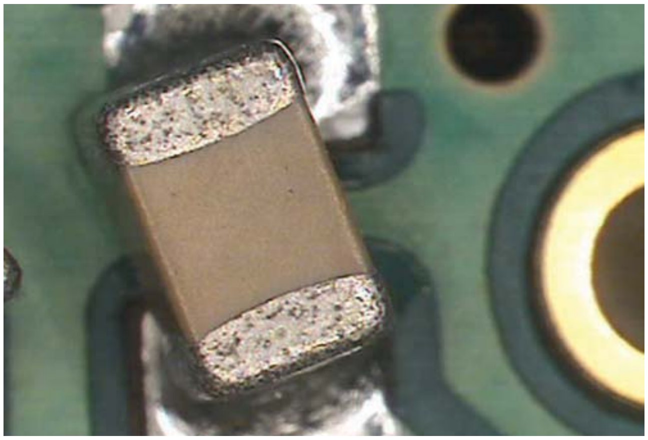


Figure 8-35

8.3.2.7 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Solder Thickness (G)

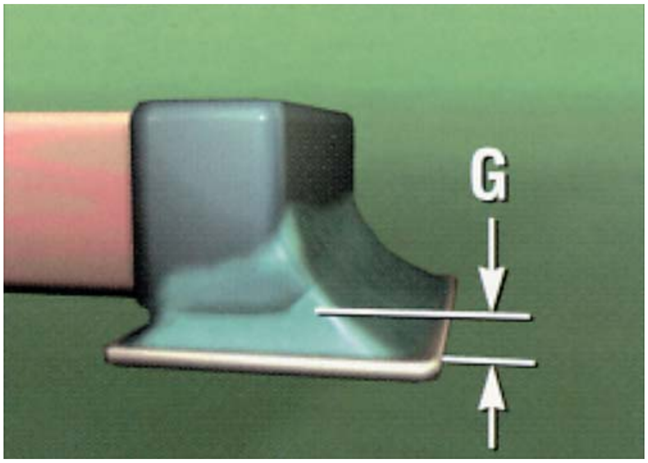


Figure 8-36

Acceptable – Class 1,2,3

- Wetted fillet evident.

Defect – Class 1,2,3

- No wetted fillet.

8.3.2.8 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – End Overlap (J)

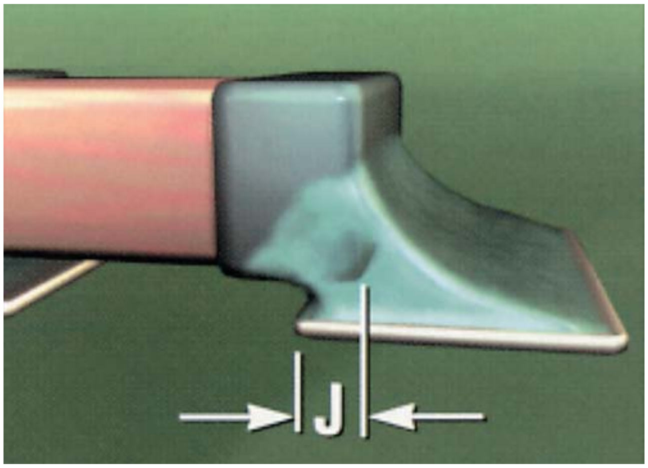


Figure 8-37

Acceptable – Class 1,2

- Evidence of overlap contact (J) between the component termination and the land is required.

Acceptable – Class 3

- Minimum 25% overlap contact (J) between the component termination and the land.

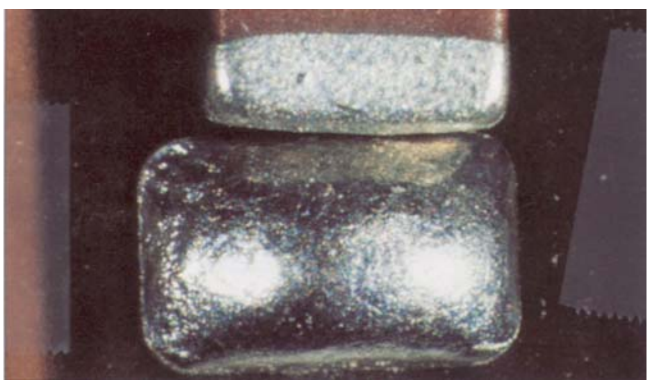


Figure 8-38

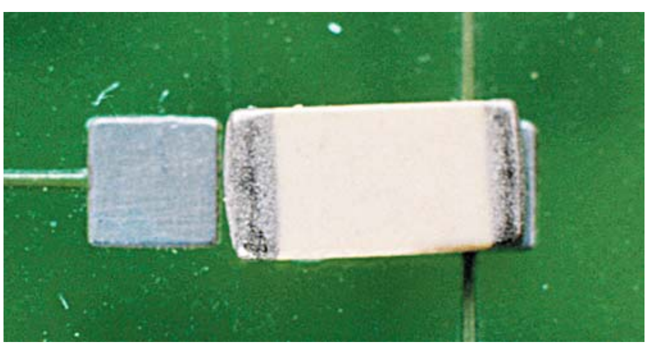


Figure 8-39

Defect – Class 1,2,3

- Insufficient end overlap.

Defect – Class 3

- Less than 25% overlap contact (J) between the component termination and the land.

8.3.2.9 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Termination Variations

8.3.2.9.1 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Termination Variations – Mounting on Side (Billboarding)

This section provides criteria for chip components that may flip (rotate) onto the narrow edge during assembly.

These criteria may not be acceptable for certain high frequency or high vibration applications.

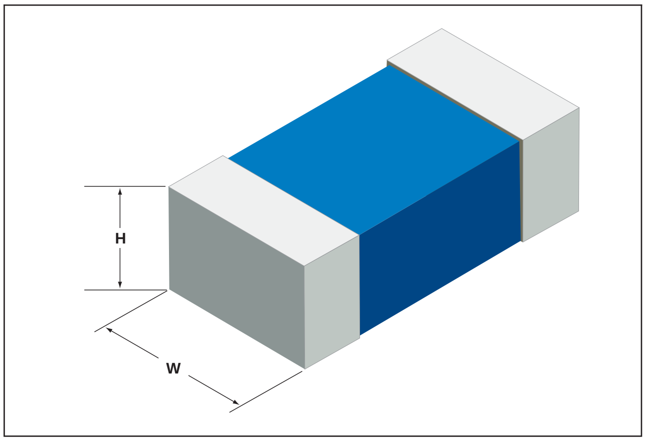


Figure 8-40

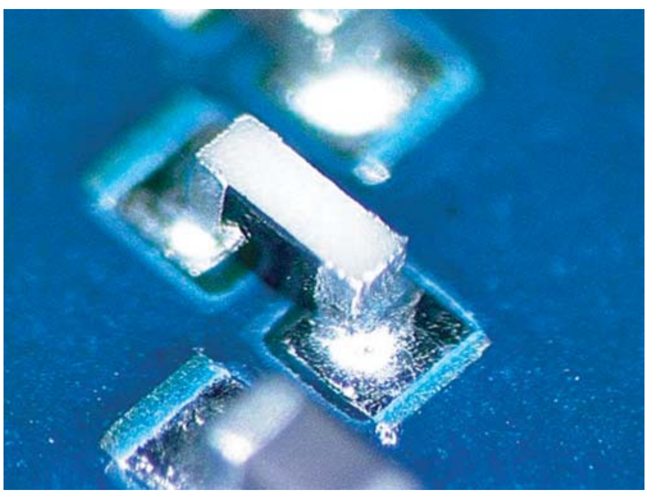


Figure 8-41

Acceptable – Class 1,2

- Width (W) to height (H) ratio does not exceed two to one (2:1) ratio; see Figure 8-40.
- Complete wetting to land and end cap metallization.
- Overlap contact between 100% of the component termination (metallization) and the land.
- Component has three or more termination faces (metallization).
- There is evidence of wetting on the three vertical faces of the termination area.

Acceptable – Class 3

- For components size 1206 or smaller:
  - Width (W) to height (H) ratio does not exceed two to one (2:1); see Figure 8-41.
  - Complete wetting at land to end cap metallization.
  - Overlap contact between 100% of the component termination (metallization) and the land.
  - Component has three or more termination faces (metallization).
  - There is evidence of wetting on the three vertical faces of the termination area.
- For components larger than size 1206:
  - Width (W) to height (H) ratio that does not exceed 1.25:1 ratio.
  - Component has five termination faces (metallization).
  - Complete wetting at land to end cap metallization.
  - Overlap contact between 100% of the component termination (metallization) and the land.
  - There is evidence of wetting on the three vertical faces of the termination area.

8.3.2.9.1 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Termination Variations – Mounting on Side (Billboarding) (cont.)

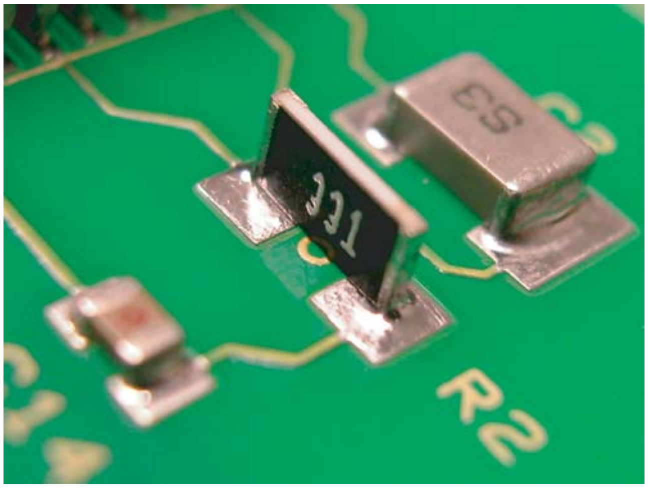


Figure 8-42

Defect – Class 1,2

- Width to height ratio exceeds two to one (2:1) ratio.
- Incomplete wetting at land or end cap metallization.
- Less than 100% overlap of the component termination (metallization) and the land.
- Component overhangs the end or side of the land.
- Component has less than three termination faces (metallization).

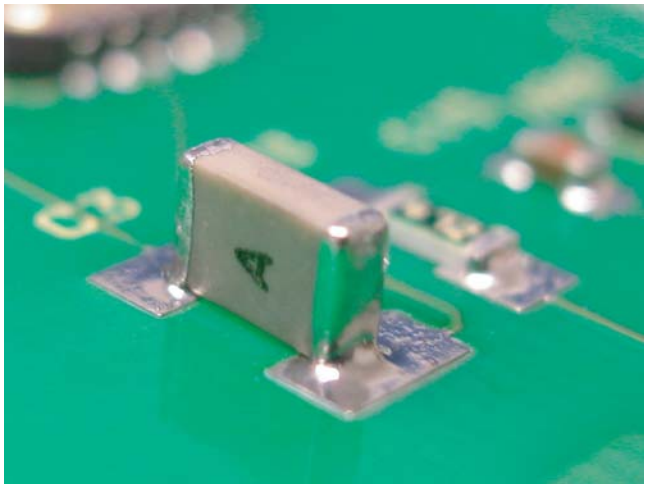


Figure 8-43

Defect – Class 3

- For components size 1206 or smaller:
  - Width (W) to height (H) ratio exceeds two to one (2:1).
  - Incomplete wetting of at least three component termination faces to the land.
  - Less than 100% overlap of the component termination (metallization) and the land.
  - Component overhangs the end or side of the land.
  - Component has less than three termination faces (metallization).
- For components larger than size 1206, see Figure 8-43.
  - Incomplete wetting of at least three component termination faces to the land.
  - Less than 100% overlap of the component termination (metallization) and the land.
  - Component overhangs the end or side of the land.
  - Width (W) to height (H) ratio exceeds 1.25 to 1.
  - Component does not have five termination sides.

8.3.2.9.2 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Termination Variations – Mounting Upside Down

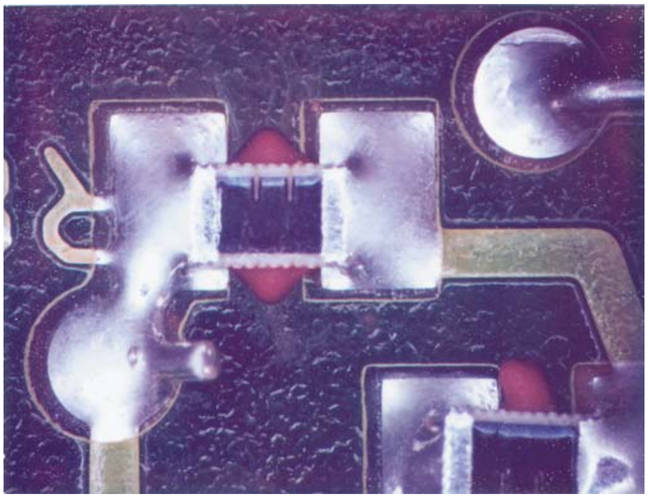


Figure 8-44

Target – Class 1,2,3

- Element of chip component with surface deposited electrical element is mounted away from the board.

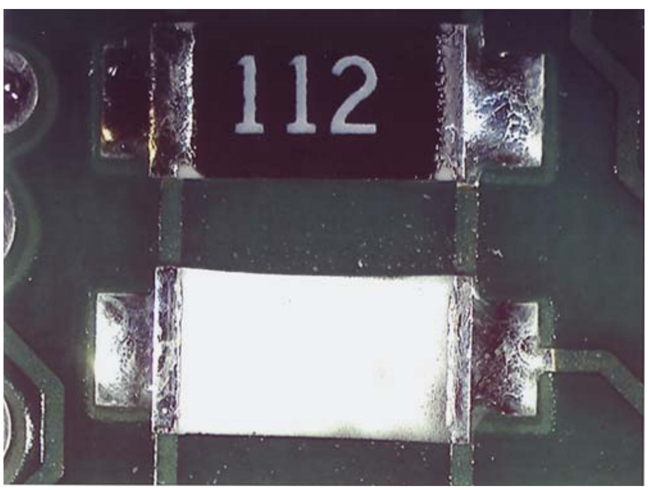


Figure 8-45

Acceptable – Class 1
Process Indicator – Class 2,3

- 1, 3, 5 side termination chip components with surface deposited electrical element is mounted toward the board.

Defect – 1,2,3

- 2-sided termination with component mounted upside down.

8.3.2.9.3 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Termination Variations – Stacking

These criteria are applicable when stacking is a requirement.

When stacking components, the top termination area of a component becomes the land for the next higher component.

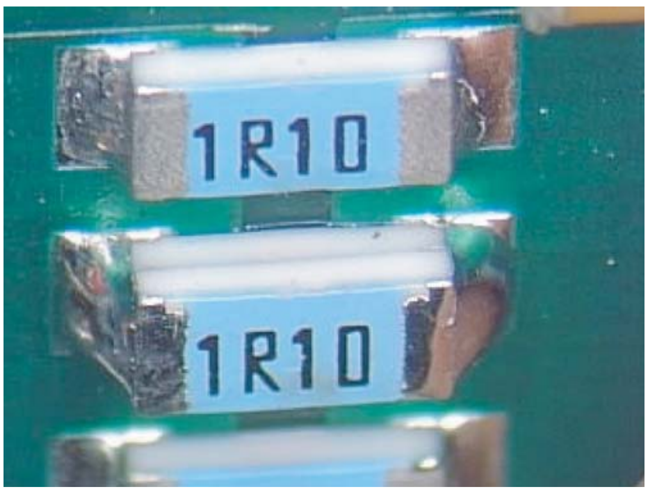


Figure 8-46

Acceptable – Class 1,2,3

- When permitted by drawing.
- Stacking order meets drawing requirements.
- Stacked components meet the criteria of Table 8-2, for the applicable class of acceptance.
- Side overhang does not preclude formation of required solder fillets.

Defect – Class 1,2,3

- Stacked components when not required by drawing.
- Stacking order does not meet drawing requirements.
- Stacked components do not meet the criteria of Table 8-2, for the applicable class of acceptance.
- Side overhang precludes formation of required solder fillets.

8.3.2.9.4 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Termination Variations – Tombstoning

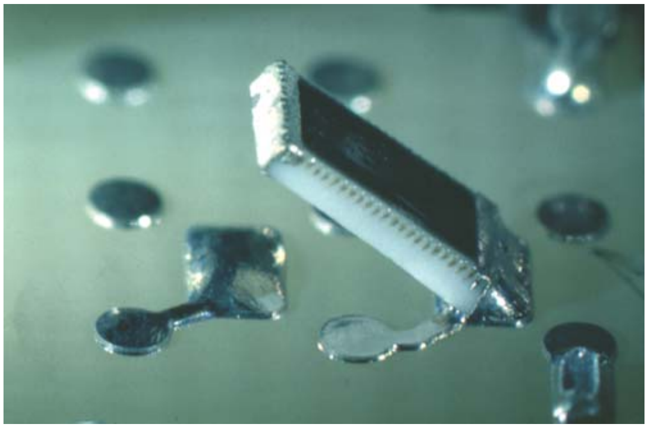


Figure 8-47

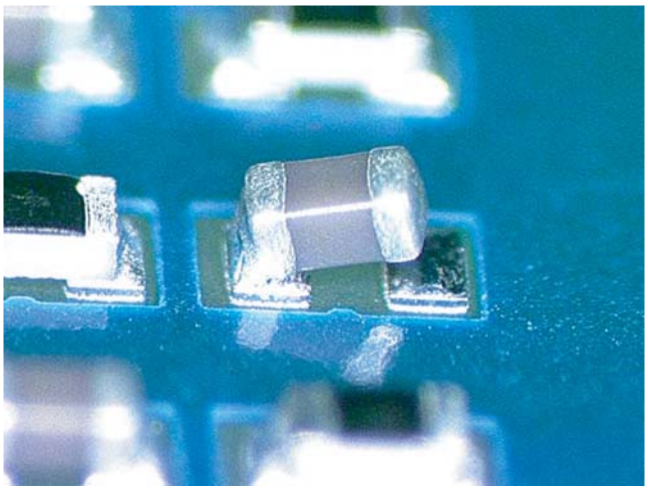


Figure 8-48

Defect – Class 1,2,3

• Chip components standing on a terminal end (tombstoning).

8.3.2.10 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Termination Variations – Center Terminations

These criteria are also applicable to cylindrical chip components with side terminations, see Figure 8-50.

8.3.2.10.1 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Termination Variations – Center Terminations – Solder Width of Side Termination

Target – Class 1,2,3

- Width of the side termination(s) is equal to component termination width or width of land, whichever is less.

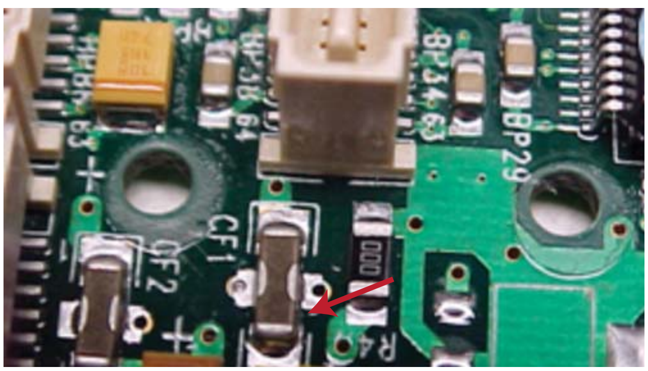


Figure 8-49

Acceptable – Class 1,2

- Width of the side termination(s) is minimum 50% of component termination width or 50% land width, whichever is less.

Acceptable – Class 3

- Width of the side termination is minimum 75% of component termination or 75% land width, whichever is less.

Defect – Class 1,2,3

- Less than minimum acceptable end joint width.

8.3.2.10.2 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) – Termination Variations – Center Terminations – Minimum Fillet Height of Side Termination

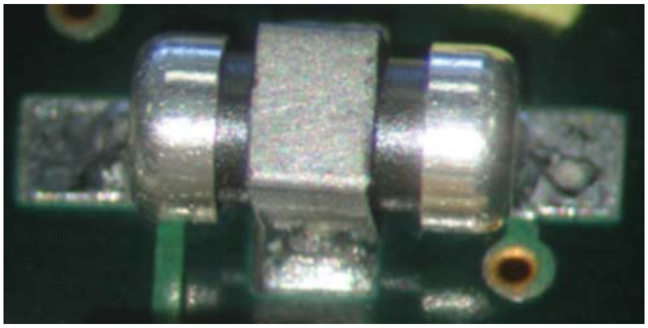


Figure 8-50

Acceptable – Class 1,2,3

- Wetting is evident on the vertical surface(s) of the component side termination.

Figure 8-51

Defect – Class 1,2,3

- No fillet height evident on side termination of component.
- A wetted fillet is not evident.

8.3.3 Cylindrical End Cap Terminations

This component is sometimes referred to as MELF (Metal Electrode Leadless Face). Solder connections to components having cylindrical end cap terminations **shall** meet the dimensional and solder fillet requirements in Table 8-3 and 8.3.3.1 through 8.3.3.8. 8.3.2.10 has criteria for cylindrical components that also have side terminations, see Figure 8-50.

Table 8-3 Dimensional Criteria – Cylindrical End Cap Termination

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	25% (W) or 25% (P), whichever is less, Note 1		
End Overhang	B	Not permitted		
Minimum End Joint Width, Note 2	C	Note 4	50% (W) or 50% (P), whichever is less	
Minimum Side Joint Length	D	Notes 4, 6	50% (R) or 50% (S), whichever is less, Note 6	75% (R) or 75% (S), whichever is less, Note 6
Maximum Fillet Height	E	Note 5		
Minimum Fillet Height (end and side)	F	Wetting is evident on the vertical surface(s) of the component termination.		(G) + 25% (W) or (G) + 1 mm [0.04 in], whichever is less.
Solder Thickness	G	Note 4		
Minimum End Overlap	J	Notes 4, 6	50% (R), Note 6	75% (R), Note 6
Land Width	P	Note 3		
Termination Length	R	Note 3		
Land Length	S	Note 3		
Termination Diameter	W	Note 3		

Note 1. Does not violate minimum electrical clearance.
Note 2. (C) is measured at the narrowest point of the required fillet.
Note 3. Unspecified dimension, or variable in size as determined by design.
Note 4. Wetting is evident.
Note 5. The maximum fillet may overhang the land or extend onto the top metallization but does not touch the top of the component body. Solder may touch the bottom half of the component body.
Note 6. Does not apply to components with end-only terminations.

8.3.3.1 Cylindrical End Cap Terminations – Side Overhang (A)

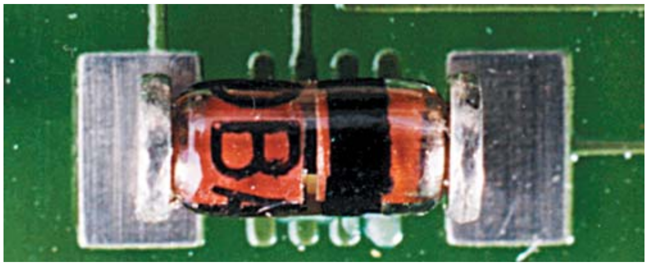


Figure 8-52

Target – Class 1,2,3

- No side overhang.

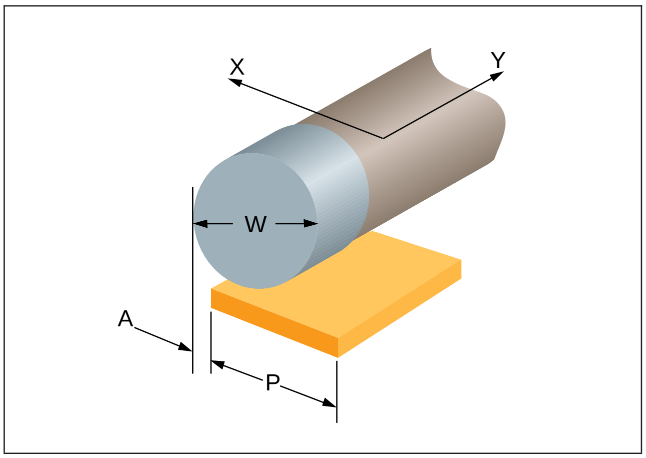


Figure 8-53

Acceptable – Class 1,2,3

- Side overhang (A) is 25% or less of the diameter of component width (W) or land width (P), whichever is less.

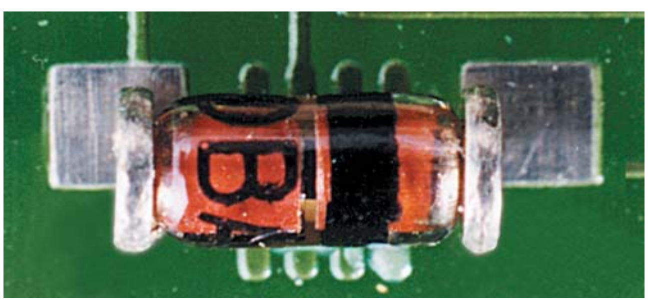


Figure 8-54

Defect – Class 1,2,3

- Side overhang (A) is greater than 25% of component diameter, (W), or land width (P), whichever is less.

8.3.3.2 Cylindrical End Cap Terminations – End Overhang (B)

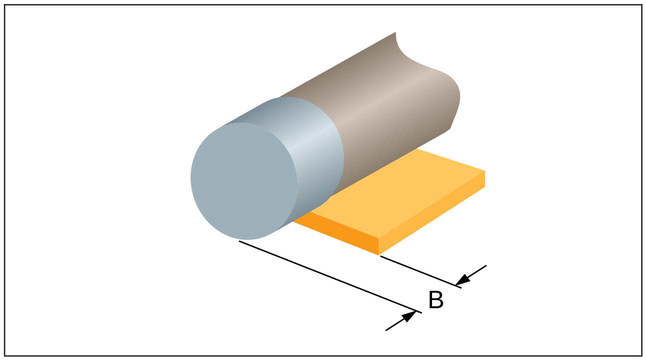


Figure 8-55

Target – Class 1,2,3

- No end overhang (B).

Defect – Class 1,2,3

- Any end overhang (B).

8.3.3.3 Cylindrical End Cap Terminations – End Joint Width (C)

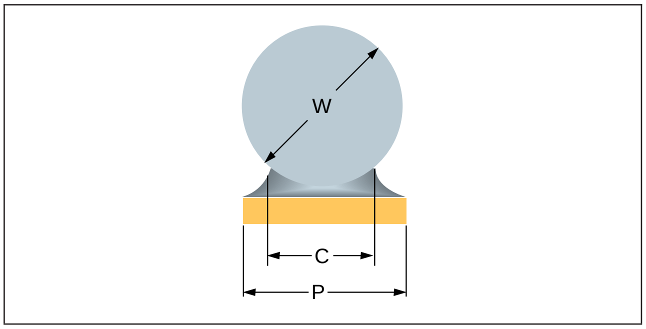


Figure 8-56

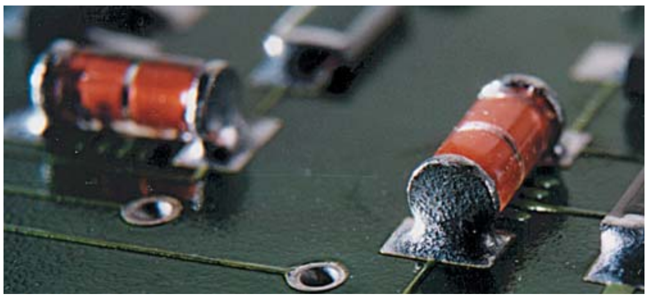


Figure 8-57

Figure 8-58

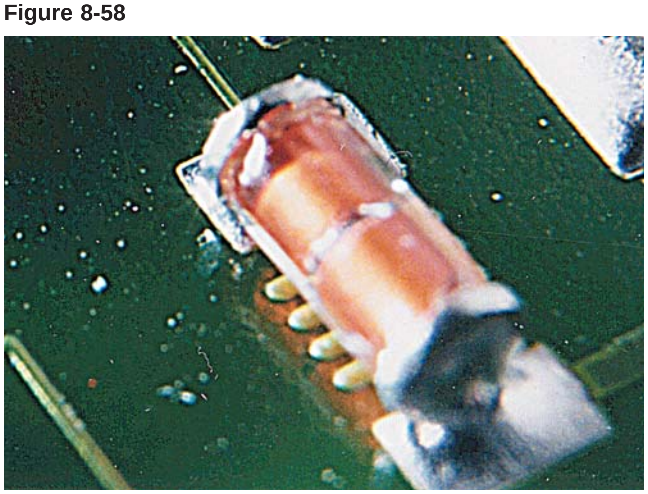


Figure 8-59

Target – Class 1,2,3

- End joint width is equal to or greater than the component diameter (W) or width of the land (P), whichever is less.

Acceptable – Class 1

- End solder joint exhibits a wetted fillet.

Acceptable – Class 2,3

- End joint width (C) is minimum 50% component diameter (W) or land width (P), whichever is less.

Defect – Class 1

- End solder joint does not exhibit a wetted fillet.

Defect – Class 2,3

- End joint width (C) is less than 50% component diameter (W), or land width (P), whichever is less.

8.3.3.4 Cylindrical End Cap Terminations – Side Joint Length (D)

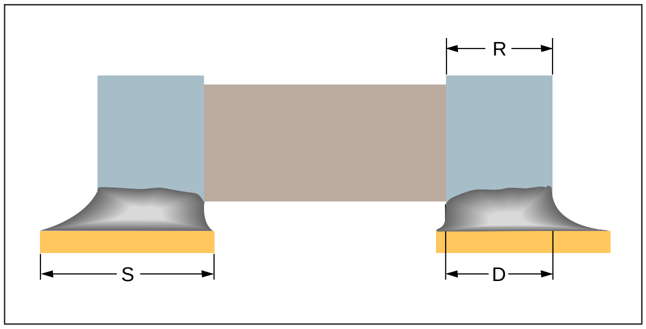


Figure 8-60

Figure 8-61

Target – Class 1,2,3

- Side joint length (D) is equal to the length of component termination (R) or land length (S), whichever is less.

Acceptable – Class 1

- Side joint length (D) exhibits a wetted fillet.

Acceptable – Class 2

- Side joint length (D) is minimum 50% length of component termination (R) or land length (S), whichever is less.

Acceptable – Class 3

- Side joint length (D) is minimum 75% length of component termination (R) or land length (S), whichever is less.

Defect – Class 1

- Side joint length (D) does not exhibit a wetted fillet.

Defect – Class 2

- Side joint length (D) is less than 50% length of component termination (R) or land length (S), whichever is less.

Defect – Class 3

- Side joint length (D) is less than 75% length of component termination (R) or land length (S), whichever is less.

8.3.3.5 Cylindrical End Cap Terminations – Maximum Fillet Height (E)

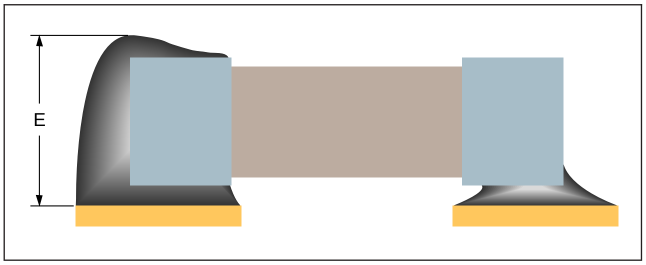


Figure 8-62

Acceptable – Class 1,2,3

- Maximum fillet height (E) may overhang the land and/or extend onto the top of the end cap metallization, but not extend further onto the component body.

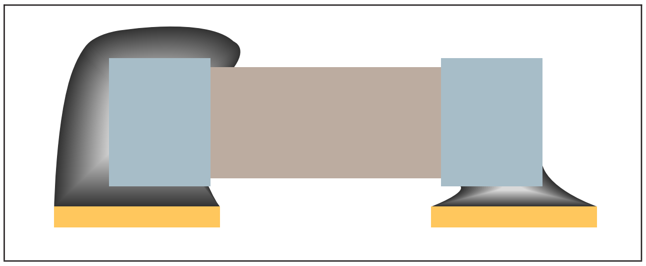


Figure 8-63

Defect – Class 1,2,3

- Solder fillet extends onto the component body top.

8.3.3.6 Cylindrical End Cap Terminations – Minimum Fillet Height (F)

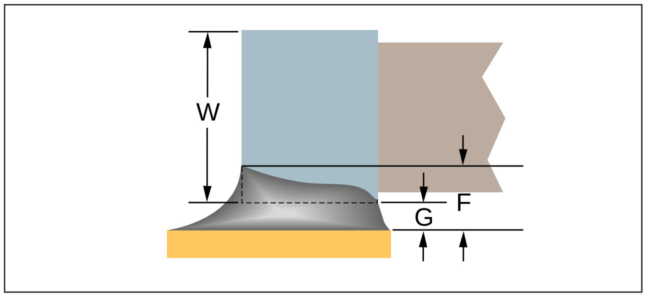


Figure 8-64

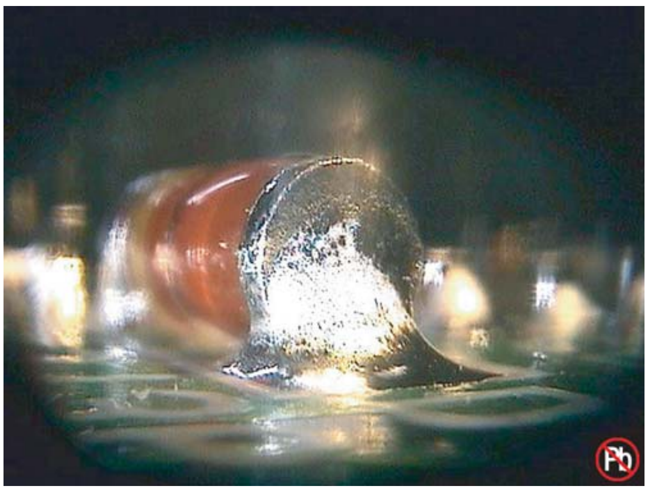


Figure 8-65

Acceptable – Class 1,2

- Minimum fillet height (F) exhibits wetting on the vertical surfaces of the component termination.

Acceptable – Class 3

- Minimum fillet height (F) is solder thickness (G) plus either 25% diameter (W) of the component end cap or 1 mm [0.04 in], whichever is less.

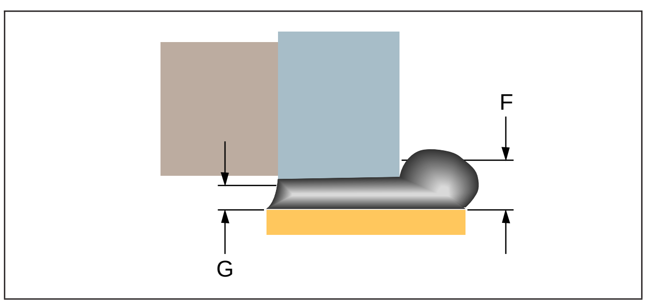


Figure 8-66

Defect – Class 1,2,3

- Minimum fillet height (F) does not exhibit wetting.

Defect – Class 3

- Minimum fillet height (F) is less than the solder thickness (G) plus either 25% diameter (W) of the component end cap or 1 mm [0.04 in], whichever is less.

8.3.3.7 Cylindrical End Cap Terminations – Solder Thickness (G)

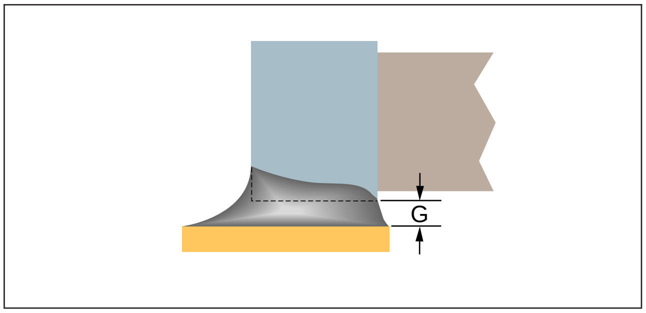


Figure 8-67

Acceptable – Class 1,2,3

- Wetted fillet evident.

Defect – Class 1,2,3

- No wetted fillet.

8.3.3.8 Cylindrical End Cap Terminations – End Overlap (J)

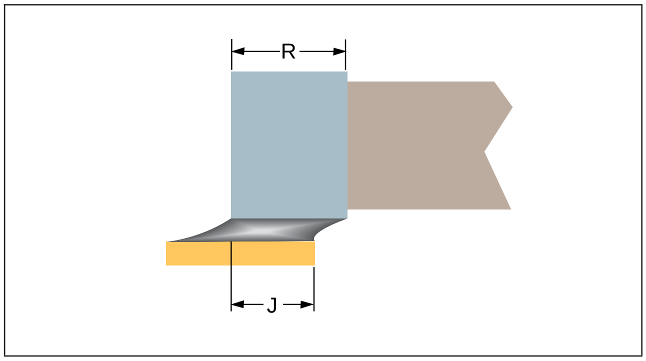


Figure 8-68

Acceptable – Class 1

- Wetted fillet is evident.

Acceptable – Class 2

- End overlap (J) between the component termination and the land is minimum 50% the length of component termination (R).

Acceptable – Class 3

- End overlap (J) between the component termination and the land is minimum of 75% the length of component termination (R).

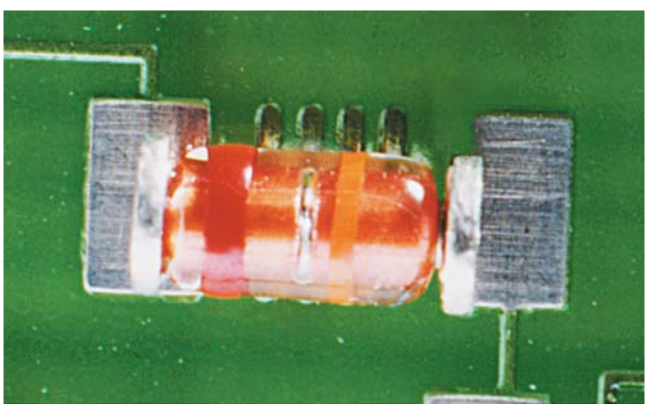


Figure 8-69

Defect – Class 1,2,3

- Component termination area and land do not overlap.

Defect – Class 2

- End overlap (J) is less than 50% of the length of component termination (R).

Defect – Class 3

- End overlap (J) is less than 75% of the length of component termination (R).

8.3.4 Castellated Terminations

Connections formed to castellated terminations of leadless chip components **shall** meet the dimensional and solder fillet requirements in Table 8-4 and 8.3.4.1 through 8.3.4.7. The solder fillet may contact the bottom of the component.

Table 8-4 Dimensional Criteria – Castellated Terminations

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W), Note 1		25% (W), Note 1
End Overhang	B	Not permitted		
Minimum End Joint Width	C	50% (W), Note 5		75% (W), Note 5
Minimum Side Joint Length	D	Note 3	Depth of castellation	
Maximum Fillet Height	E	Notes 1, 4		
Minimum Fillet Height	F	Note 3	(G) + 25% (H)	(G) + 50% (H)
Solder Thickness	G	Note 3		
Castellation Height	H	Note 2		
Land Length	S	Note 2		
Castellation Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified dimension, or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. The maximum fillet may extend past the top of the castellation provided it does not contact the component body.
Note 5. (C) is measured at the narrowest point of the required fillet.

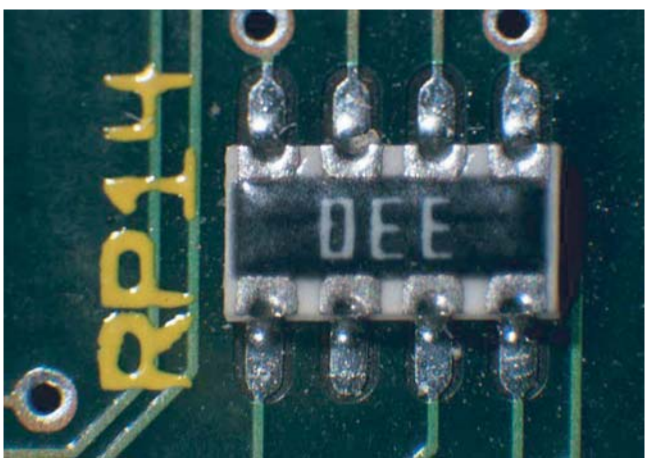


Figure 8-70

8.3.4.1 Castellated Terminations – Side Overhang (A)

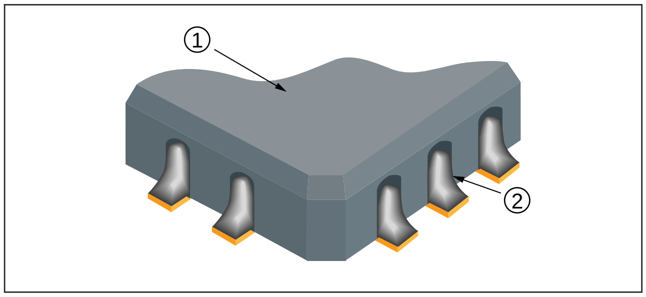


Figure 8-71

1. Leadless chip carrier
2. Castellations (Terminations)

Target – Class 1,2,3

- No side overhang.

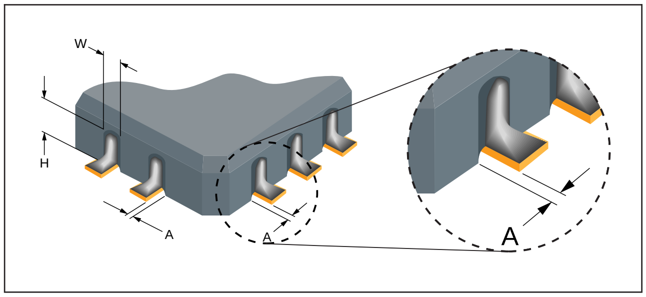


Figure 8-72

Acceptable – Class 1,2

- Maximum side overhang (A) is 50% castellation width (W).

Acceptable – Class 3

- Maximum side overhang (A) is 25% castellation width (W).

Defect – Class 1,2

- Side overhang (A) exceeds 50% castellation width (W).

Defect – Class 3

- Side overhang (A) exceeds 25% castellation width (W).

8.3.4.2 Castellated Terminations – End Overhang (B)

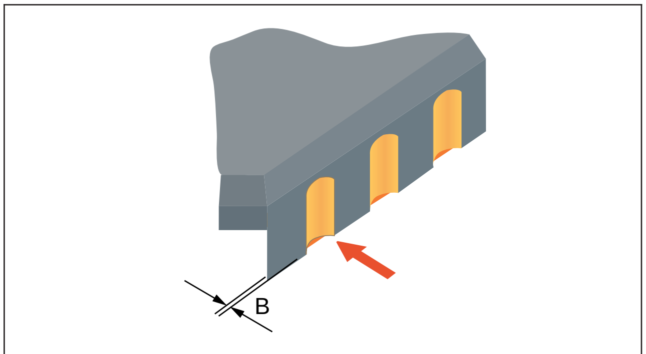


Figure 8-73

Acceptable – Class 1,2,3

• No end overhang.

Defect – Class 1,2,3

• End overhang (B).

8.3.4.3 Castellated Terminations – Minimum End Joint Width (C)

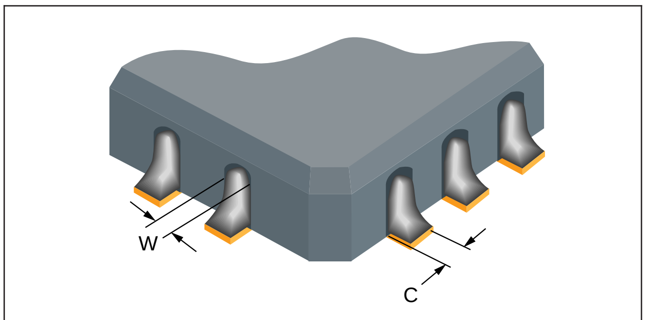


Figure 8-74

Target – Class 1,2,3

• End joint width (C) is equal to castellation width (W).

Acceptable – Class 1,2

• Minimum end joint width (C) is 50% castellation width (W).

Acceptable – Class 3

• Minimum end joint width (C) is 75% castellation width (W).

Defect – Class 1,2

• End joint width (C) is less than 50% castellation width (W).

Defect – Class 3

• End joint width (C) is less than 75% castellation width (W).

8.3.4.4 Castellated Terminations – Minimum Side Joint Length (D)

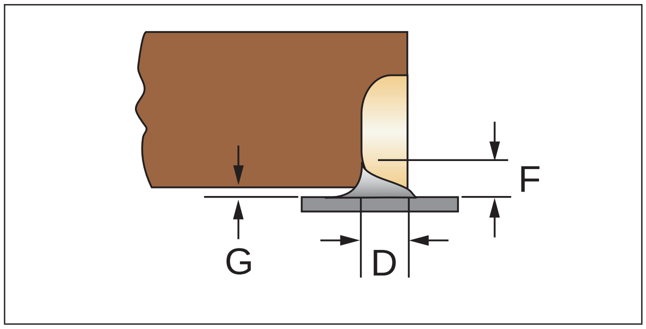


Figure 8-75

Acceptable – Class 1

- Wetted fillet evident.

Acceptable – Class 1,2,3

- Solder extends from the back of the castellation onto the land at or beyond the edge of the component.

Defect – Class 1,2,3

- Wetted fillet not evident.
- Solder does not extend from the back of the castellation onto the land at or beyond the edge of the component.

8.3.4.5 Castellated Terminations – Maximum Fillet Height (E)

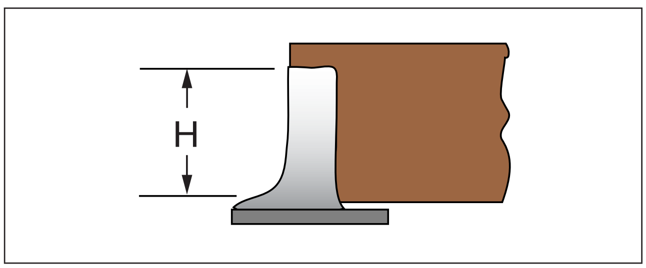


Figure 8-76

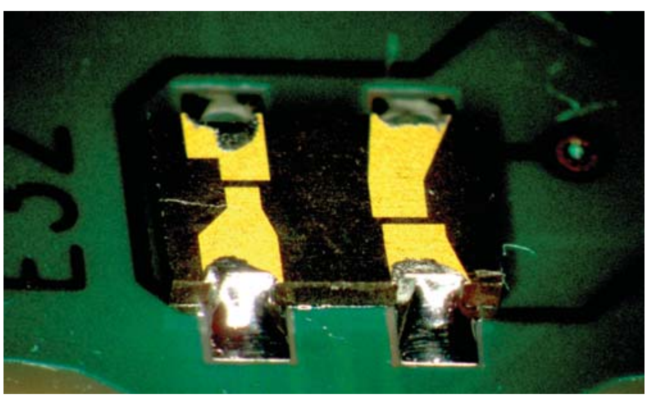


Figure 8-77

Acceptable – Class 1,2,3

- The maximum fillet may extend past the top of the castellation provided it does not extend onto the component body.

Defect – Class 1,2,3

- Solder fillet violates minimum electrical clearance.
- Solder extends past the top of the castellation onto the component body.

8.3.4.6 Castellated Terminations – Minimum Fillet Height (F)

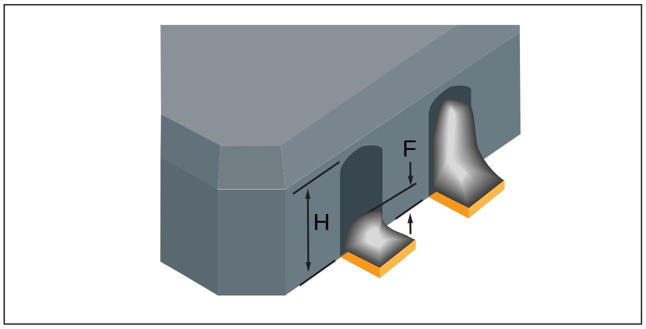


Figure 8-78

Acceptable – Class 1

- A wetted fillet is evident.

Acceptable – Class 2

- Minimum fillet height (F) is the solder thickness (G) (not shown) plus 25% castellation height (H).

Acceptable – Class 3

- Minimum fillet height (F) is the solder thickness (G) (not shown) plus 50% castellation height (H).

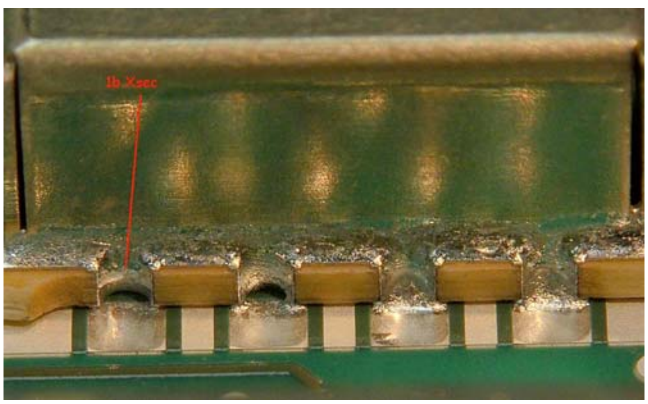


Figure 8-79

Defect – Class 1

- A wetted fillet is not evident.

Defect – Class 2

- Minimum fillet height (F) is less than solder thickness (G) (not shown) plus 25% castellation height (H).

Defect – Class 3

- Minimum fillet height (F) is less than solder thickness (G) (not shown) plus 50% castellation height (H).

8.3.4.7 Castellated Terminations – Solder Thickness (G)

Acceptable – Class 1,2,3

- Wetted fillet evident.

Defect – Class 1,2,3

- No wetted fillet.

8.3.5 Flat Gull Wing Leads

Connections formed to flat gull wing leads **shall** meet dimensional and solder fillet requirements in Table 8-5 and 8.3.5.1 through 8.3.5.8.

Table 8-5 Dimensional Criteria – Flat Gull Wing Leads

Feature		Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang		A	50% (W) or 0.5 mm [0.02 in], whichever is less, Note 1		25% (W) or 0.5 mm [0.02 in], whichever is less, Note 1
Maximum Toe Overhang		B	Note 1	Not permitted when (L) is less than 3 (W), Note 1	
Minimum End Joint Width		C	50% (W), Note 6		75% (W), Note 6
Minimum Side Joint Length	when (L) is ≥ 3 (W)	D	1 (W) or 0.5 mm [0.02 in], whichever is less, Note 7	3 (W) or 75% (L), whichever is longer, Note 7	
	when (L) is < 3 (W)			100% (L), Note 7	
Maximum Heel Fillet Height		E	Note 4		
Minimum Heel Fillet Height	(T) ≤ 0.4 mm [0.015 in]	F	Note 3	(G) + (T), Note 5	(G) + (T), Note 5
	(T) > 0.4 mm [0.015 in]			(G) + 50% (T), Note 5	
Solder Thickness		G	Note 3		
Formed Foot Length		L	Note 2		
Lead Thickness		T	Note 2		
Lead Width		W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified dimension, or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. Solder does not touch package body or end seal, see 8.2.1.
Note 5. In the case of a toe-down lead configuration, the minimum heel fillet height (F) extends at least to the mid-point of the outside lead bend.
Note 6. (C) is measured at the narrowest point of the required fillet.
Note 7. If Side Overhang (A) is present, then the Side Joint Length (D) on the overhanging portion of the lead is not inspectable.

8.3.5.1 Flat Gull Wing Leads – Side Overhang (A)

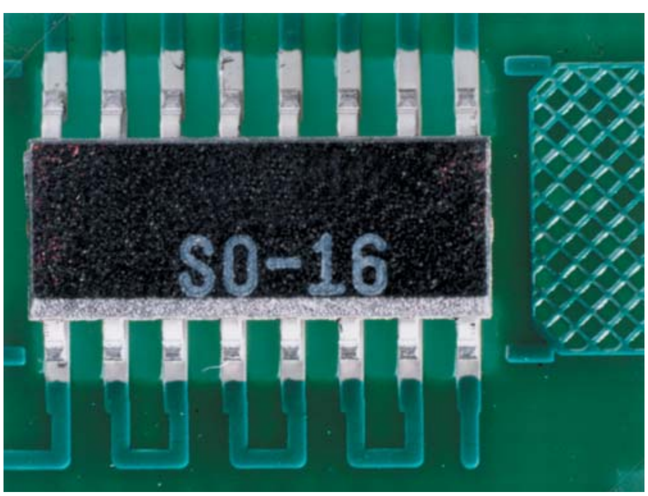


Figure 8-80

Target – Class 1,2,3

• No side overhang.

8.3.5.1 Flat Gull Wing Leads – Side Overhang (A) (cont.)

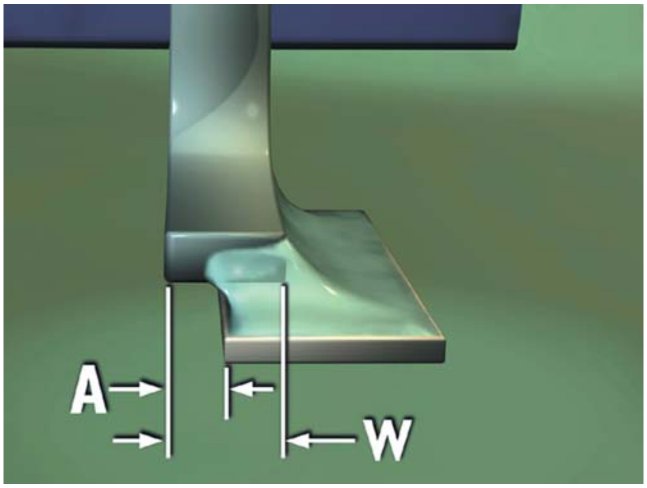


Figure 8-81

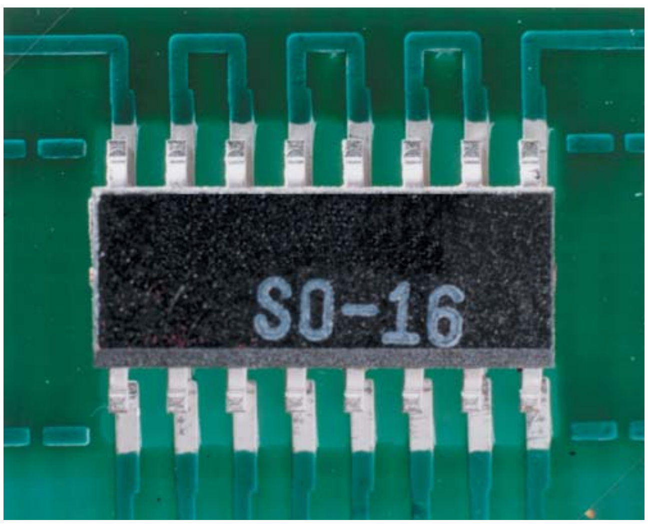


Figure 8-82

Acceptable – Class 1,2

- Maximum overhang (A) is not greater than 50% lead width (W) or 0.5 mm [0.02 in], whichever is less.

8.3.5.1 Flat Gull Wing Leads – Side Overhang (A) (cont.)

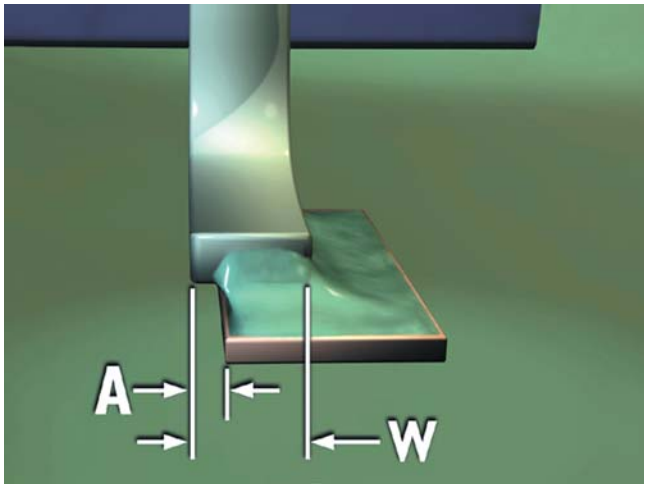


Figure 8-83

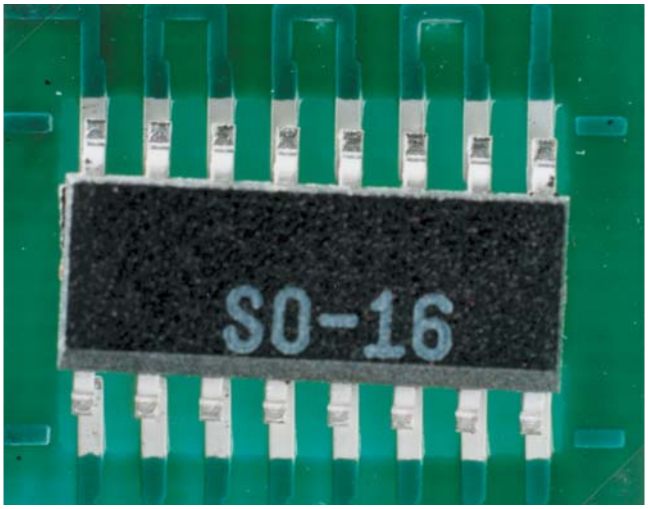


Figure 8-84

Acceptable – Class 3

- Maximum overhang (A) is not greater than 25% lead width (W) or 0.5 mm [0.02 in], whichever is less.

8.3.5.1 Flat Gull Wing Leads – Side Overhang (A) (cont.)

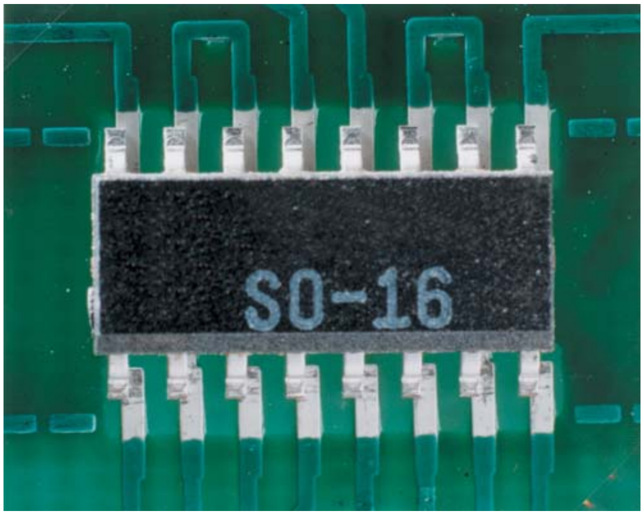


Figure 8-85

Defect – Class 1,2

- Side overhang (A) is greater than 50% lead width (W) or 0.5 mm [0.02 in], whichever is less.

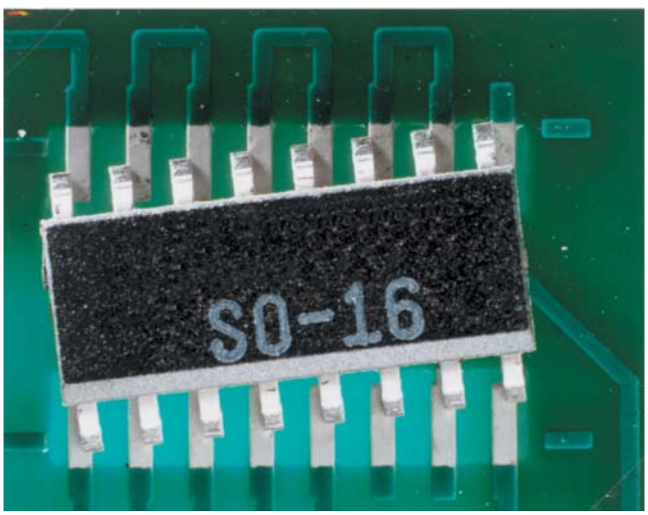


Figure 8-86

Defect – Class 3

- Side overhang (A) is greater than 25% lead width (W) or 0.5 mm [0.02 in], whichever is less.

8.3.5.2 Flat Gull Wing Leads – Toe Overhang (B)

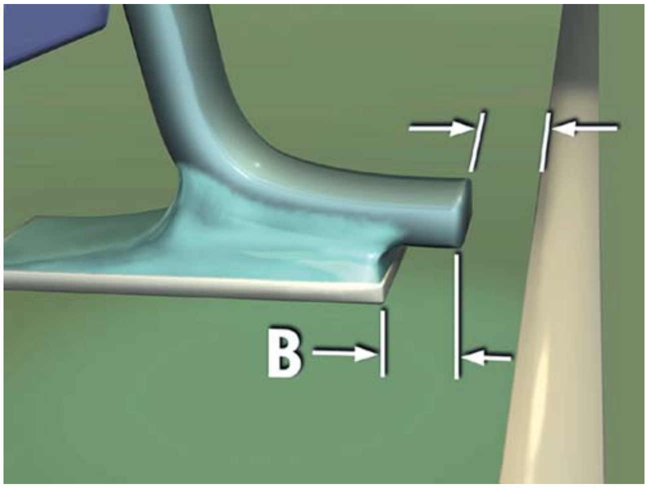


Figure 8-87

Acceptable – Class 2,3

- Formed foot length (L) is greater than three lead widths (W).

Acceptable – Class 1,2,3

- Toe overhang does not violate minimum electrical clearance.

Defect – Class 2,3

- Formed foot length (L) is less than three lead widths (W).

Defect – Class 1,2,3

- Toe overhang violates minimum electrical clearance.

8.3.5.3 Flat Gull Wing Leads – Minimum End Joint Width (C)

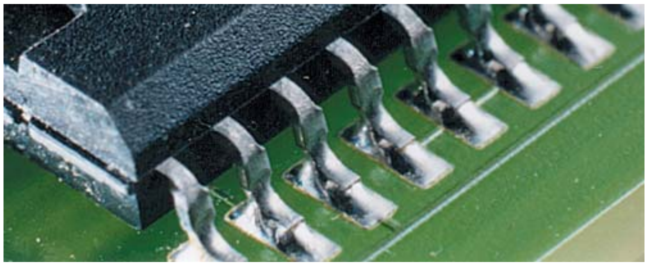


Figure 8-88

Target – Class 1,2,3

• End joint width is equal to or greater than lead width.

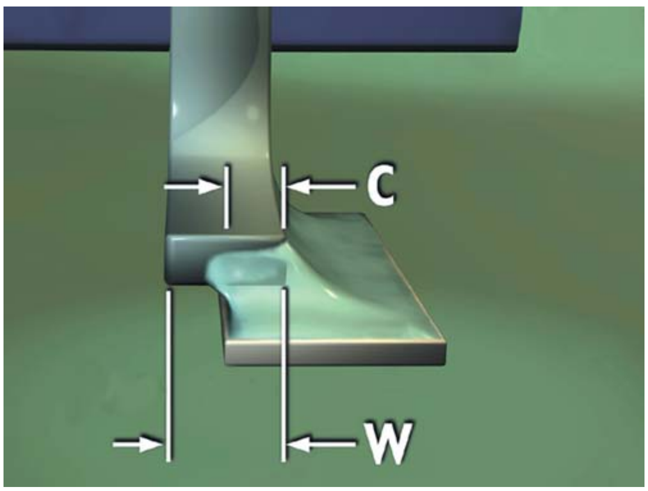


Figure 8-89

Acceptable – Class 1,2

• Minimum end joint width (C) is 50% lead width (W).

8.3.5.3 Flat Gull Wing Leads – Minimum End Joint Width (C) (cont.)

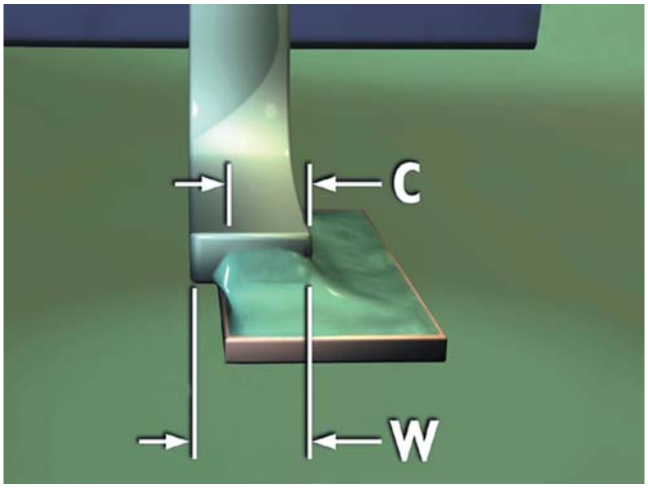


Figure 8-90

Acceptable – Class 3

- Minimum end joint width (C) is 75% lead width (W).

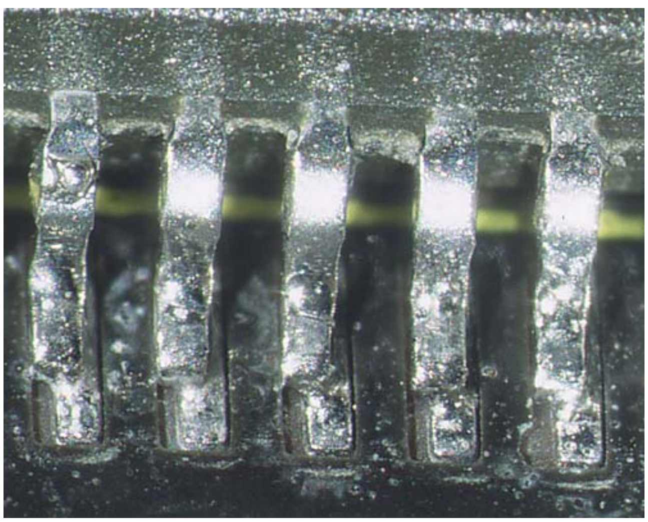


Figure 8-91

Defect – Class 1,2

- Minimum end joint width (C) is less than 50% lead width (W).

Defect – Class 3

- Minimum end joint width (C) is less than 75% lead width (W).

8.3.5.4 Flat Gull Wing Leads – Minimum Side Joint Length (D)

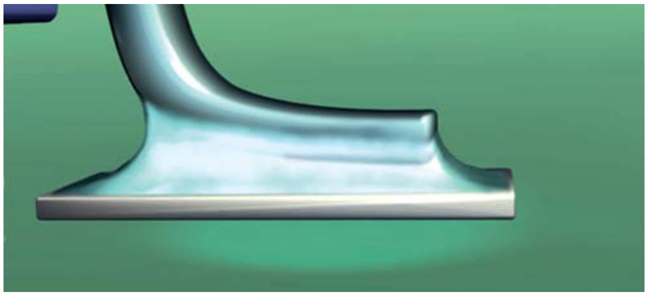


Figure 8-92

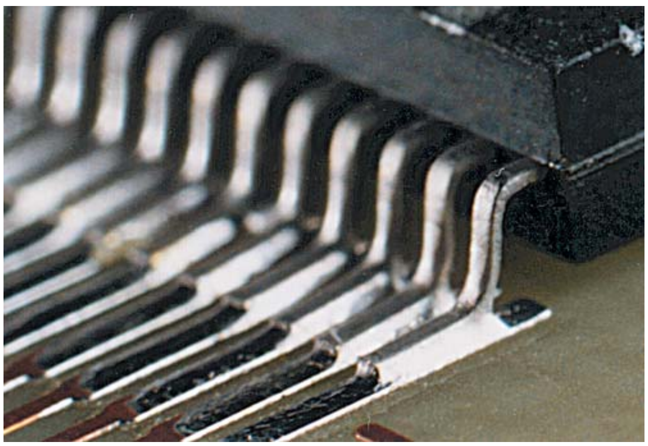


Figure 8-93

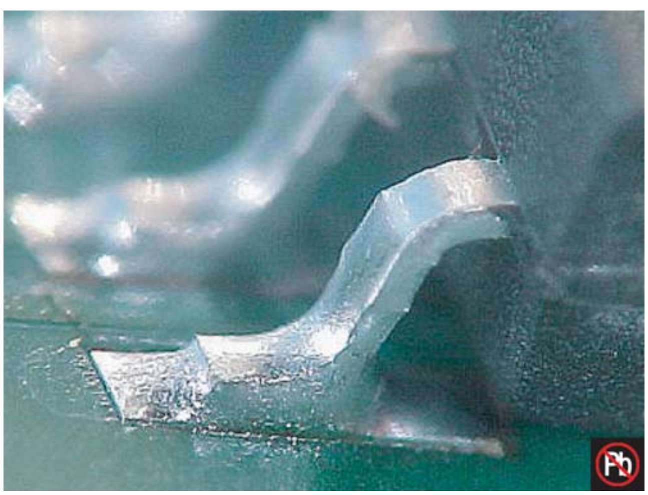


Figure 8-94

Target – Class 1,2,3

- Evidence of wetted fillet along full length of lead foot.

8.3.5.4 Flat Gull Wing Leads – Minimum Side Joint Length (D) (cont.)

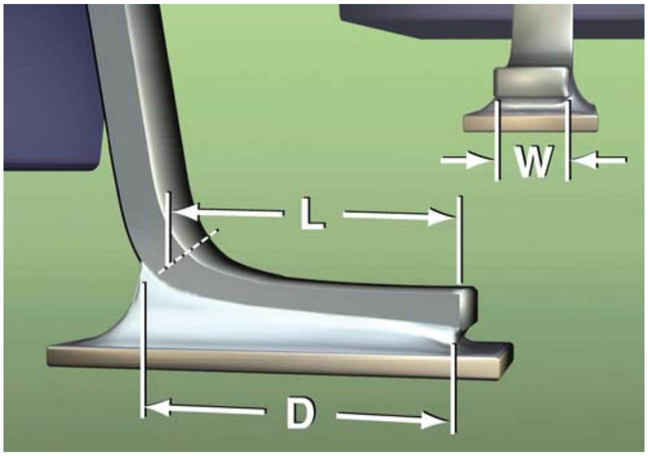


Figure 8-95

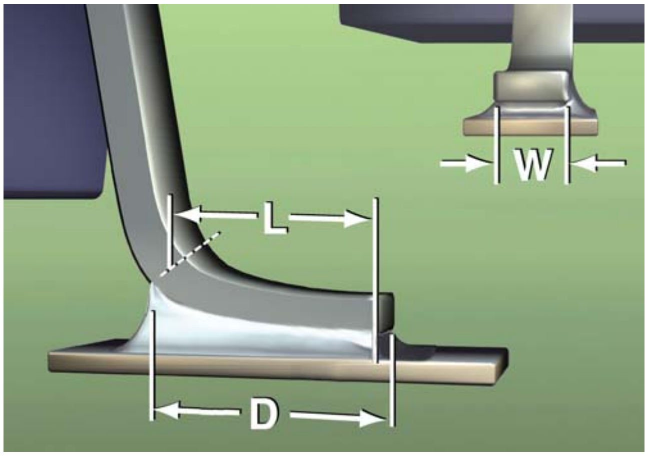


Figure 8-96

Acceptable – Class 1

- Minimum side joint length (D) is equal to lead width (W) or 0.5 mm [0.02 in], whichever is less (not shown).

Acceptable – Class 2,3

- When foot length (L) is greater than or equal to three lead widths (W), minimum side joint length (D) is equal to or greater than three lead widths (W) or 75% (L), whichever is longer, see Figure 8-95.
- When foot length (L) is less than three lead widths (W), minimum side joint length (D) is equal to 100% (L), see Figure 8-96.

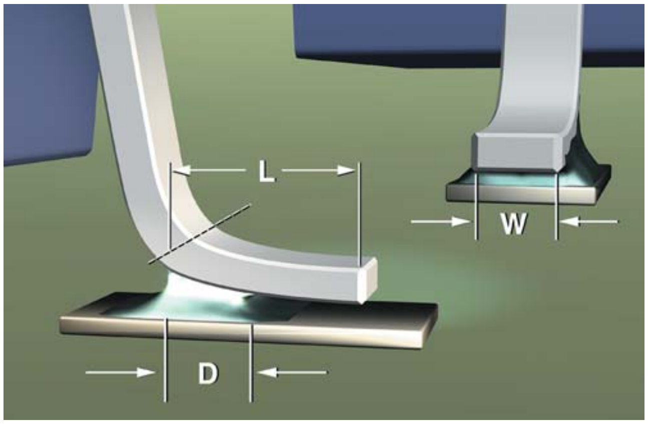


Figure 8-97

Defect – Class 1

- Minimum side joint length (D) is less than the lead width (W) or 0.5 mm [0.02 in], whichever is less.

Defect – Class 2,3

- When foot length (L) is greater than or equal to three lead widths (W), minimum side joint length (D) is less than three lead widths (W) or 75% (L), whichever is longer.
- When foot length (L) is less than three lead widths (W), minimum side joint length (D) is less than 100% (L).

8.3.5.5 Flat Gull Wing Leads – Maximum Heel Fillet Height (E)

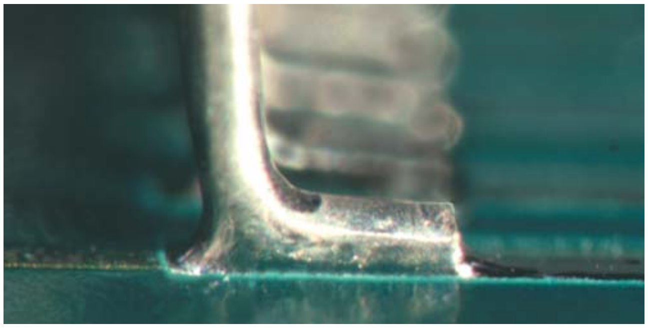


Figure 8-98

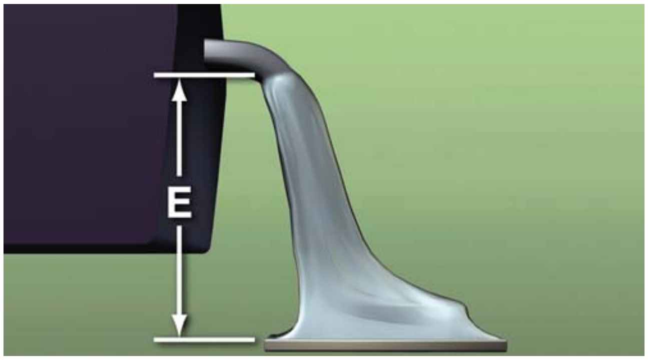


Figure 8-99

Target – Class 1,2,3

- Heel fillet extends above lead thickness but does not fill upper lead bend.
- Solder does not contact the component body.

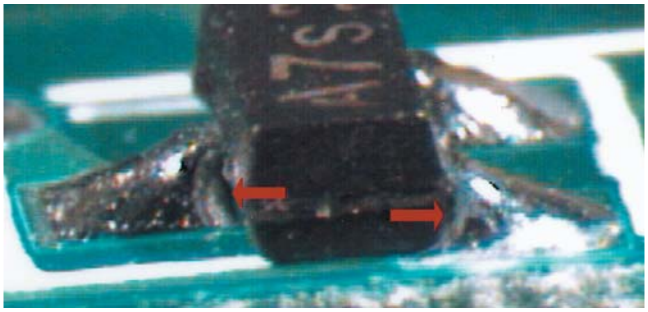


Figure 8-100

Acceptable – Class 1,2,3

- Solder touches a plastic SOIC family of components (small outline packages such as SOT, SOD), see Figure 8-100.
- Solder does not touch ceramic or metal component.

Defect – Class 1,2,3

- Solder touches the body of a plastic component, except for SOIC family of components (small outline packages such as SOT, SOD).
- Solder touches the body of a ceramic or metal component.

8.3.5.6 Flat Gull Wing Leads – Minimum Heel Fillet Height (F)

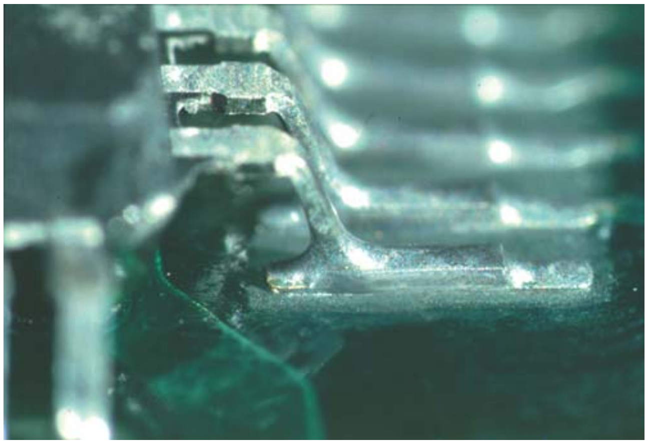


Figure 8-101

Target – Class 1,2,3

- Heel fillet height (F) is greater than solder thickness (G) plus lead thickness (T) but does not extend into knee bend radius.

Acceptable – Class 1

- A wetted fillet is evident.

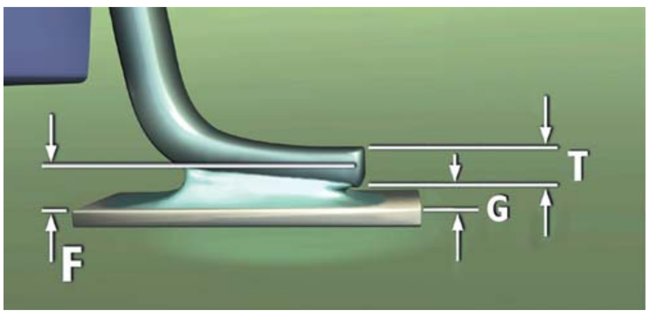


Figure 8-102

Acceptable – Class 2

- Where lead thickness (T) is equal to or less than 0.4 mm [0.015 in], the minimum heel fillet is solder thickness (G) + lead thickness (T).
- Where lead thickness (T) is greater than 0.4 mm [0.015 in], the minimum heel fillet is solder thickness (G) + 50% lead thickness (T).

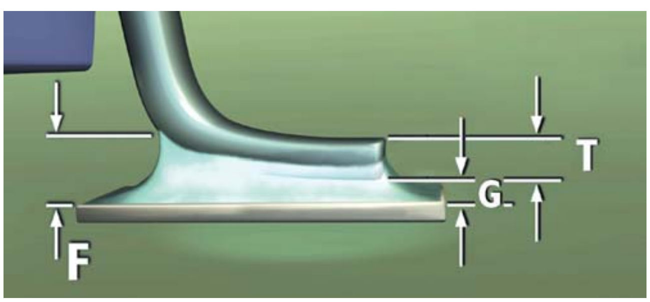


Figure 8-103

Acceptable – Class 3

- Minimum heel fillet height (F) is equal to solder thickness (G) plus lead thickness (T) at connection side.

Acceptable – Class 1,2,3

- In the case of a toe-down configuration, see Figure 8-104, the minimum heel fillet height (F) extends at least to the mid-point of the outside lead bend.

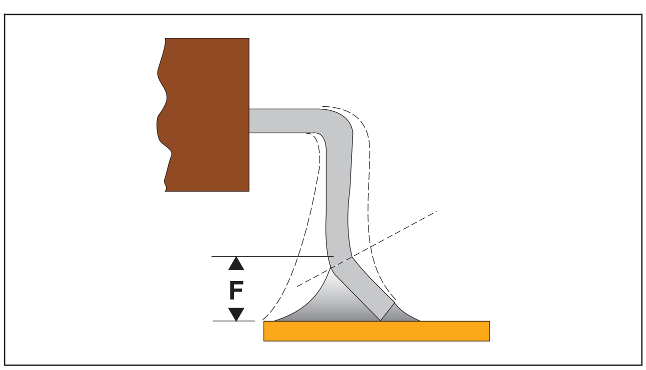


Figure 8-104

8.3.5.6 Flat Gull Wing Leads – Minimum Heel Fillet Height (F) (cont.)

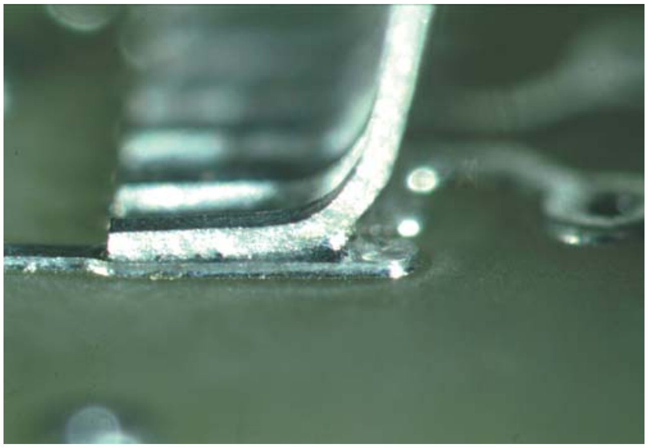


Figure 8-105

Defect – Class 1

- A wetted fillet is not evident.

Defect – Class 2

- Where lead thickness (T) is equal to or less than 0.4 mm [0.015 in], the minimum heel fillet is less than solder thickness (G) + lead thickness (T).
- Where lead thickness (T) is greater than 0.4 mm [0.015 in], the minimum heel fillet is less than solder thickness (G) + 50% lead thickness (T).

Defect – Class 3

- Minimum heel fillet height (F) is less than solder thickness (G) plus lead thickness (T) at connection side.

Defect – Class 1,2,3

- In the case of a toe-down configuration, the minimum heel fillet height (F) does not extend at least to the mid-point of the outside lead bend.

8.3.5.7 Flat Gull Wing Leads – Solder Thickness (G)

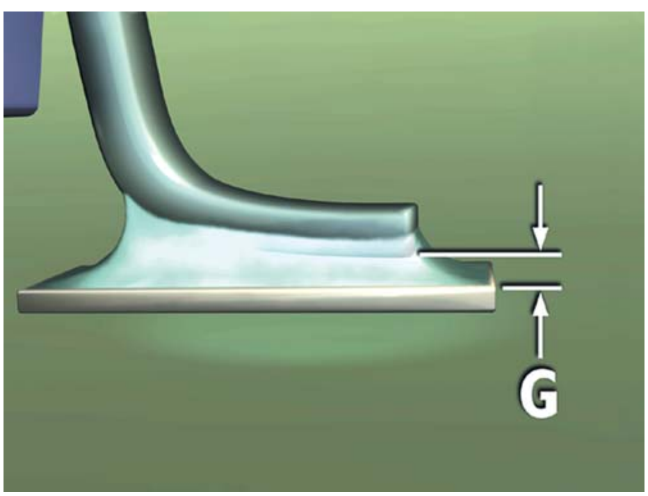


Figure 8-106

Acceptable – Class 1,2,3

- Wetted fillet evident.

Defect – Class 1,2,3

- No wetted fillet.

8.3.5.8 Flat Gull Wing Leads – Coplanarity

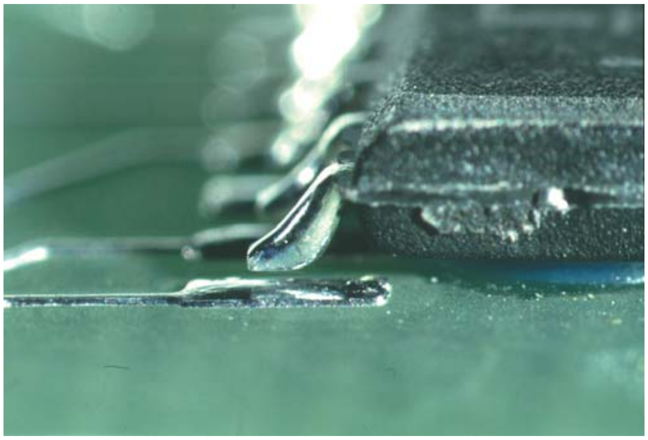


Figure 8-107

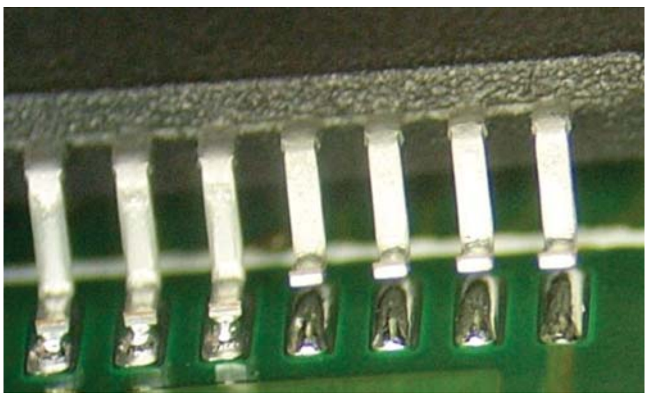


Figure 8-108

Defect – Class 1,2,3

- Component lead(s) out of alignment (coplanarity) preventing the formation of an acceptable solder connection.

8.3.6 Round or Flattened (Coined) Gull Wing Leads

Connections formed to round or flattened (coined) leads **shall** meet the dimensional and fillet requirements of Table 8-6 and 8.3.6.1 through 8.3.6.9.

Table 8-6 Dimensional Criteria – Round or Flattened (Coined) Gull Wing Lead Features

Feature	Dim	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W) or 0.5 mm [0.02 in], whichever is less, Note 1		25% (W) or 0.5 mm [0.02 in], whichever is less, Note 1
Maximum Toe Overhang	B	Not permitted when (L) is less than (W), Note 1		Not permitted when (L) is less than 1.5 (W), Note 1
Minimum End Joint Width	C	Note 3		75% (W)
Minimum Side Joint Length	D	100% (W), Note 6		150% (W), Note 6
Maximum Heel Fillet Height	E	Note 4		
Minimum Heel Fillet Height	F	Note 3	(G) + 50% (T), Note 4	(G) + (T), Note 4
Solder Thickness	G	Note 3		
Formed Foot Length	L	Note 2		
Minimum Side Joint Height	Q	Notes 3, 6	(G) + 50% (T), Note 6	
Thickness of Lead at Joint Side	T	Note 2		
Flattened Lead Width or Diameter of Round Lead	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified dimension, or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. Solder does not touch package body or end seal, see 8.2.1.
Note 5. In the case of a toe-down lead configuration, the minimum heel fillet height (F) extends at least to the mid-point of the outside lead bend.
Note 6. Side fillet (and corresponding Dimensions (D) & (Q)) would not form and therefore is not required on a side where acceptable side overhang (A) is present.

8.3.6.1 Round or Flattened (Coined) Gull Wing Leads – Side Overhang (A)

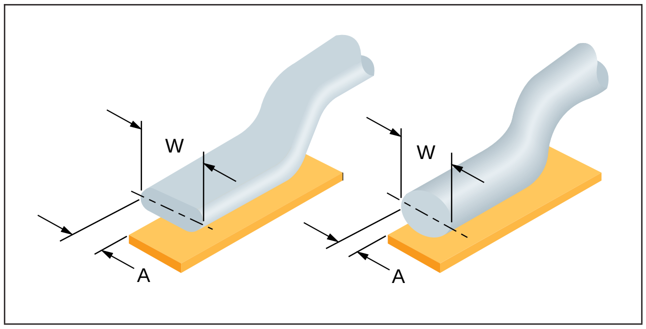


Figure 8-109

Target – Class 1,2,3

- No side overhang.

Acceptable – Class 1,2

- Side overhang (A) is not greater than 50% lead width/diameter (W) or 0.5 mm [0.02 in], whichever is less.

Acceptable – Class 3

- Side overhang (A) is not greater than 25% lead width/diameter (W) or 0.5 mm [0.02 in], whichever is less.

Defect – Class 1,2

- Side overhang (A) is greater than 50% lead width/diameter (W) or 0.5 mm [0.02 in], whichever is less.

Defect – Class 3

- Side overhang (A) is greater than 25% lead width/diameter (W) or 0.5 mm [0.02 in], whichever is less.

8.3.6.2 Round or Flattened (Coined) Gull Wing Leads – Toe Overhang (B)

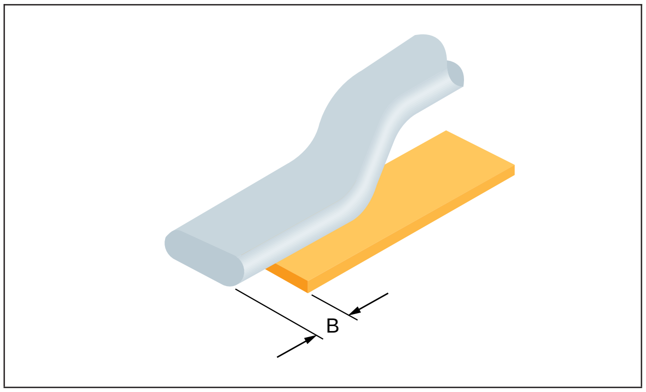


Figure 8-110

Acceptable – Class 1,2

- Formed foot length (L) is greater than or equal to lead/width diameter (W) and toe overhang (B) does not violate minimum electrical clearance.

Acceptable – Class 3

- Formed foot length (L) is greater than or equal to 1.5 lead/width diameter (W) and toe overhang (B) does not violate minimum electrical clearance.

Defect – Class 1,2

- Toe overhang (B) when formed foot length (L) is less than lead/width diameter (W).

Defect – Class 3

- Toe overhang (B) when formed foot length (L) is less than 1.5 lead/width diameter (W).

Defect – Class 1,2,3

- Toe overhang violates minimum electrical clearance.

8.3.6.3 Round or Flattened (Coined) Gull Wing Leads – Minimum End Joint Width (C)

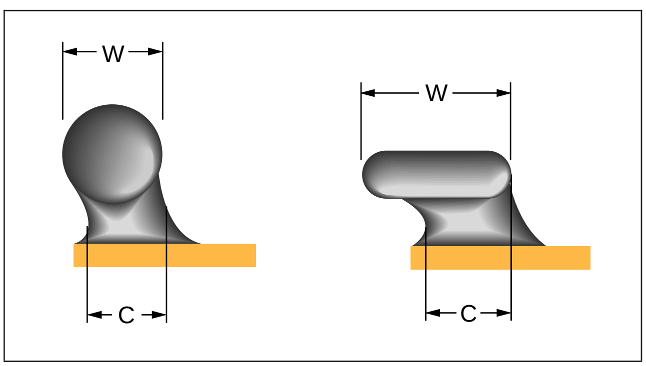


Figure 8-111

Target – Class 1,2,3

- End joint width (C) is equal to or greater than lead width/diameter (W).

Acceptable – Class 1,2

- Wetted fillet is evident.

Acceptable – Class 3

- End joint width (C) is minimum 75% lead width/diameter (W).

Defect – Class 1,2

- No evidence of wetted fillet.

Defect – Class 3

- Minimum end joint width (C) is less than 75% lead width/diameter (W).

8.3.6.4 Round or Flattened (Coined) Gull Wing Leads – Minimum Side Joint Length (D)

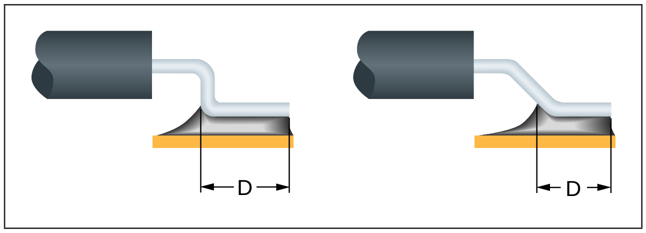


Figure 8-112

Acceptable – Class 1,2

- Side joint length (D) is equal to lead width/diameter (W).

Acceptable – Class 3

- Minimum side joint length (D) is equal to 150% lead width/diameter (W).

Defect – Class 1,2

- Side joint length (D) is less than lead width/diameter (W).

Defect – Class 3

- Minimum side joint length (D) is less than 150% the lead width/diameter (W).

8.3.6.5 Round or Flattened (Coined) Gull Wing Leads – Maximum Heel Fillet Height (E)

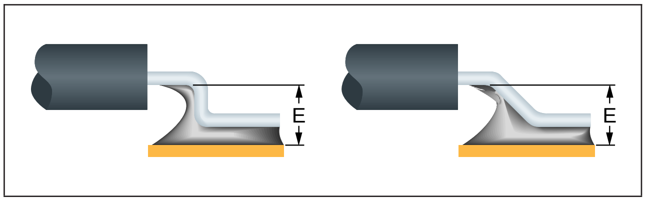


Figure 8-113

Target – Class 1,2,3

- Heel fillet extends above lead thickness but does not fill upper lead bend.
- Solder does not contact the component body.

Acceptable – Class 1,2,3

- Solder touches a plastic SOIC family of components (small outline packages such as SOT, SOD).
- Solder does not touch body of ceramic or metal component.

Defect – Class 1

- A wetted fillet is not evident.

Defect – Class 1,2,3

- Solder touches the body of a plastic component, except for SOIC family of components (small outline packages such as SOT, SOD).
- Solder touches the body of ceramic or metal component.
- Solder is excessive so that the minimum electrical clearance is violated.

8.3.6.6 Round or Flattened (Coined) Gull Wing Leads – Minimum Heel Fillet Height (F)

Acceptable – Class 1,2,3

- In the case of a toe-down configuration, the minimum heel fillet height (F) extends at least to the mid-point of the outside lead bend.

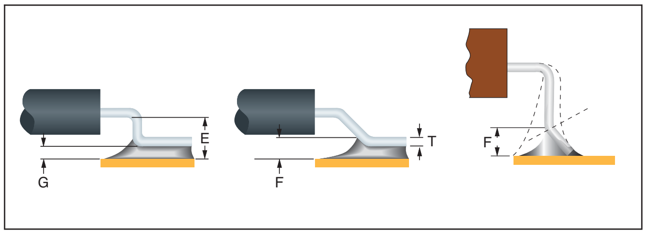


Figure 8-114

Acceptable – Class 1

- A wetted fillet is evident.

Acceptable – Class 2

- Minimum heel fillet height (F) is equal to solder thickness (G) plus 50% thickness of lead at joint side (T).

Acceptable – Class 3

- Minimum heel fillet height (F) is equal to solder thickness (G) plus thickness of lead at joint side (T).

Defect – Class 1

- A wetted fillet is not evident.

Defect – Class 2

- Minimum heel fillet height (F) is less than solder thickness (G) plus 50% thickness of lead at joint side (T).

Defect – Class 3

- Minimum heel fillet height (F) is less than solder thickness (G) plus thickness of lead at joint side (T).

Defect – Class 2,3

- In the case of a toe-down configuration, the minimum heel fillet height (F) does not extend at least to the mid-point of the outside lead bend.

8.3.6.7 Round or Flattened (Coined) Gull Wing Leads – Solder Thickness (G)

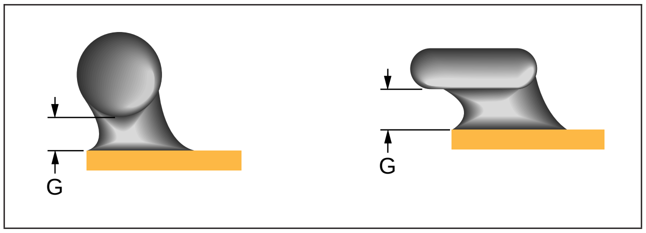


Figure 8-115

Acceptable – Class 1,2,3

- Wetted fillet evident.

Defect – Class 1,2,3

- No wetted fillet.

8.3.6.8 Round or Flattened (Coined) Gull Wing Leads – Minimum Side Joint Height (Q)

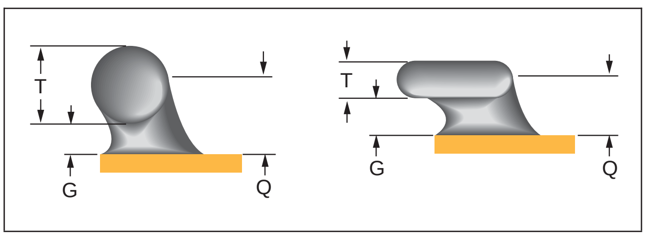


Figure 8-116

Acceptable – Class 1

- A wetted fillet is evident.

Acceptable – Class 2,3

- Minimum side joint height (Q) is equal to or greater than solder thickness (G) plus 50% lead thickness (T).

Defect – Class 1

- A wetted fillet is not evident.

Defect – Class 2,3

- Minimum side joint height (Q) is less than solder thickness (G) plus 50% lead thickness (T).

8.3.6.9 Round or Flattened (Coined) Gull Wing Leads – Coplanarity

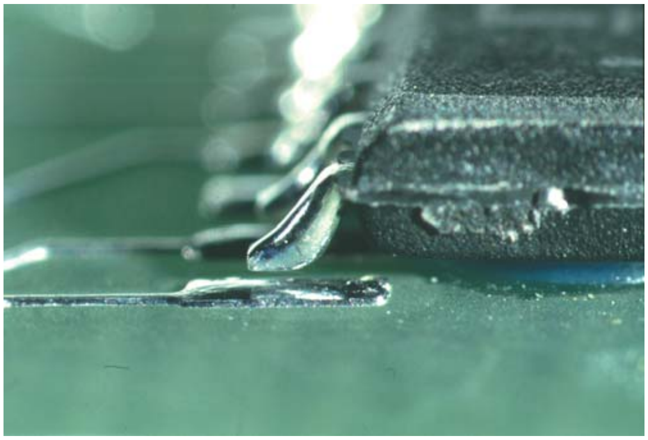


Figure 8-117

Defect – Class 1,2,3

- Component lead(s) out of alignment (coplanarity) preventing the formation of an acceptable solder connection.

8.3.7 J Leads

Connections formed to leads having a J shape **shall** meet the dimensional and fillet requirements in Table 8-7 and 8.3.7.1 through 8.3.7.8.

Table 8-7 Dimensional Criteria – J Leads

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W), Note 1		25% (W), Note 1
Maximum Toe Overhang	B	Note 1		
Minimum End Joint Width	C	50% (W), Note 5		75% (W), Note 5
Minimum Side Joint Length	D	Note 3	150% (W)	
Maximum Heel Fillet Height	E	Note 4		
Minimum Heel Fillet Height	F	(G) + 50% (T)		(G) + (T)
Solder Thickness	G	Note 3		
Lead Thickness	T	Note 2		
Lead Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified dimension, or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. Solder does not touch package body or end seal, see 8.2.1.
Note 5. (C) is measured at the narrowest point of the required fillet.

8.3.7.1 J Leads – Side Overhang (A)

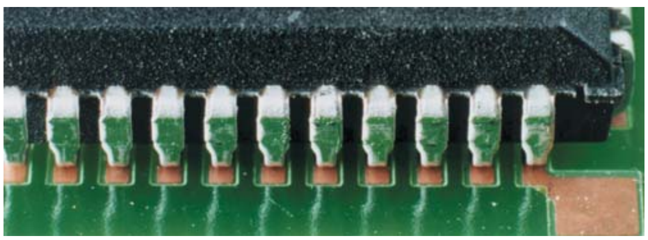


Figure 8-118

Target – Class 1,2,3

- No side overhang.

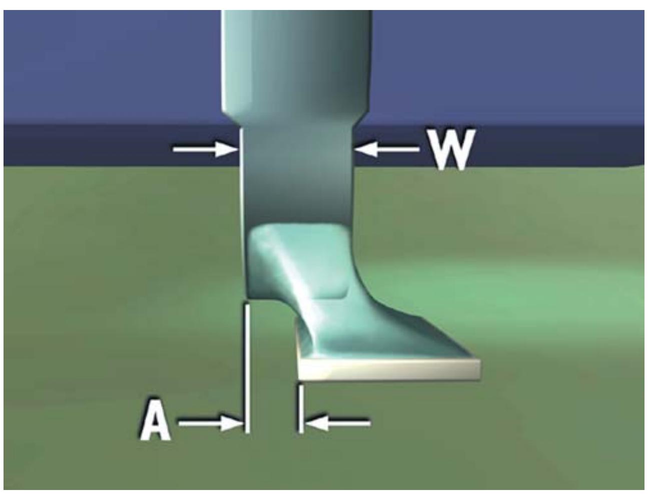


Figure 8-119

Acceptable – Class 1,2

- Side overhang (A) equal to or less than 50% lead width (W).

8.3.7.1 J Leads – Side Overhang (A) (cont.)

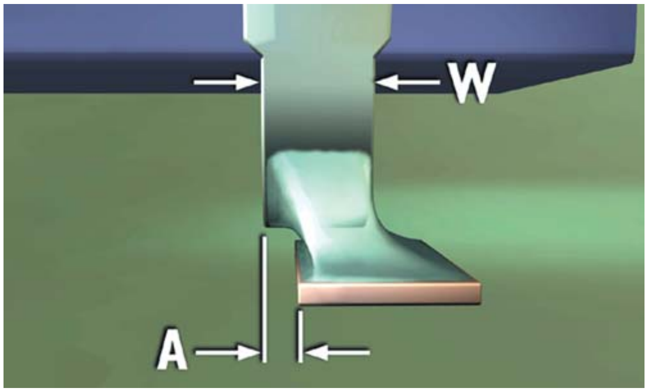


Figure 8-120

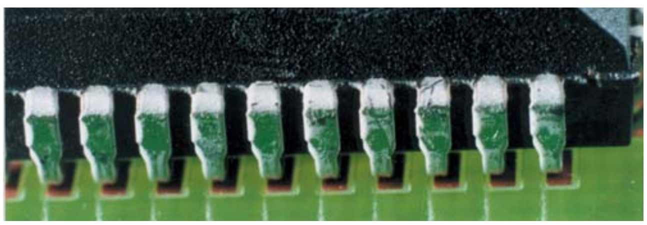


Figure 8-121

Acceptable – Class 3

- Side overhang (A) equal to or less than 25% lead width (W).

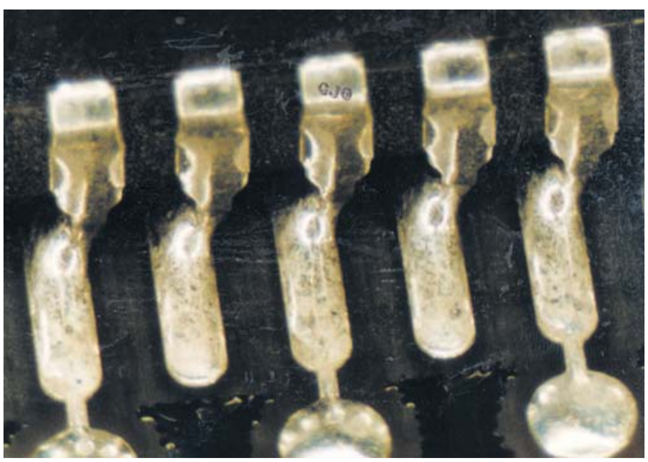


Figure 8-122

Defect – Class 1,2

- Side overhang exceeds 50% lead width (W).

Defect – Class 3

- Side overhang exceeds 25% lead width (W).

8.3.7.2 J Leads – Toe Overhang (B)

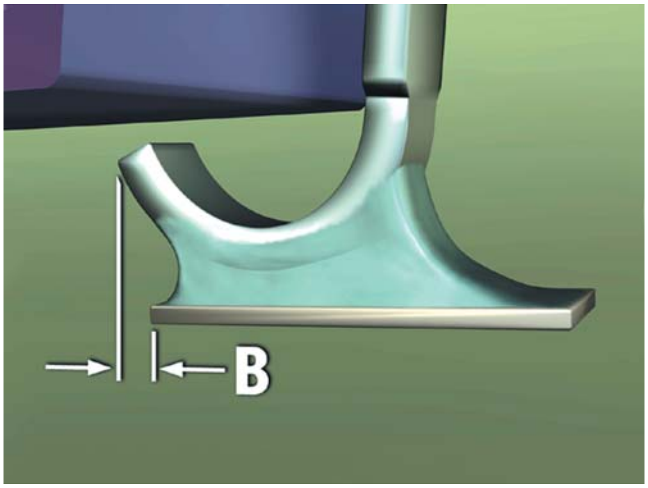


Figure 8-123

Acceptable – Class 1,2,3

- Toe overhang (B) is an unspecified parameter.

8.3.7.3 J Leads – End Joint Width (C)

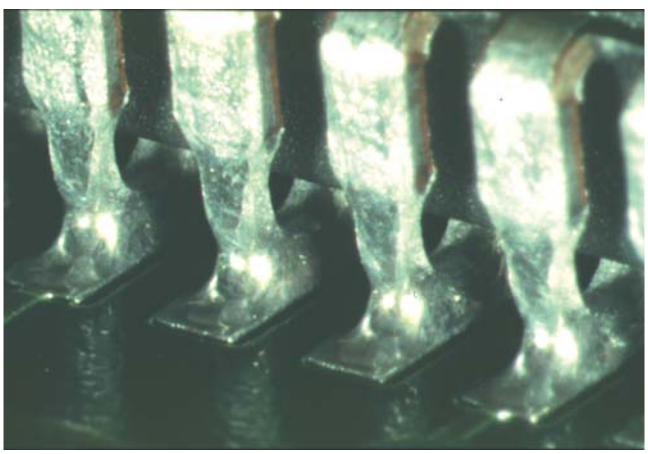


Figure 8-124

Target – Class 1,2,3

- End joint width (C) is equal to lead width (W).

8.3.7.3 J Leads – End Joint Width (C) (cont.)

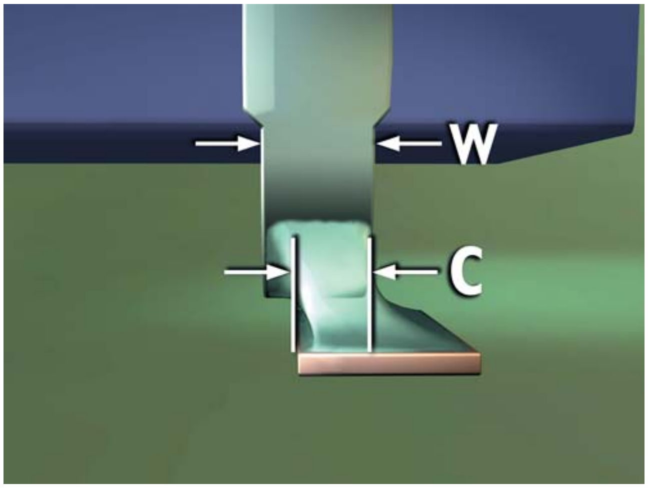


Figure 8-125

Acceptable – Class 1,2

- Minimum end joint width (C) is 50% lead width (W).

Acceptable – Class 3

- Minimum end joint width (C) is 75% lead width (W).

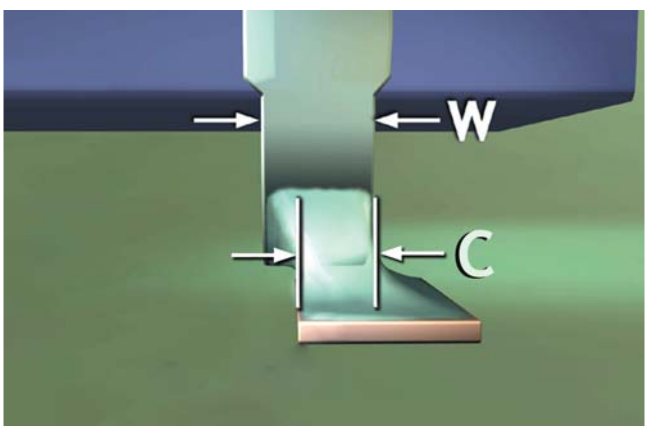


Figure 8-126

Defect – Class 1,2

- Minimum end joint width (C) is less than 50% lead width (W).

Defect – Class 3

- Minimum end joint width (C) is less than 75% lead width (W).

8.3.7.4 J Leads – Side Joint Length (D)

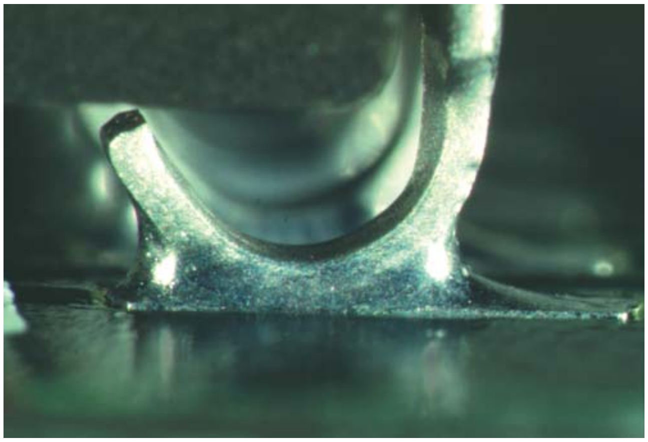


Figure 8-127

Target – Class 1,2,3

• Side joint length (D) is greater than 200% lead width (W).

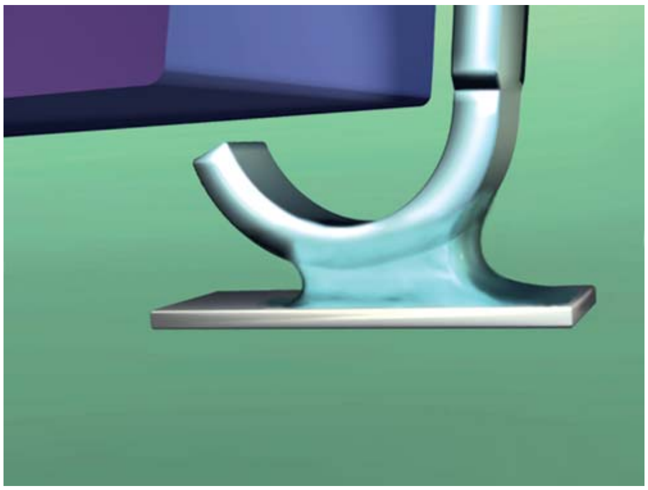


Figure 8-128

Acceptable – Class 1

• Wetted fillet.

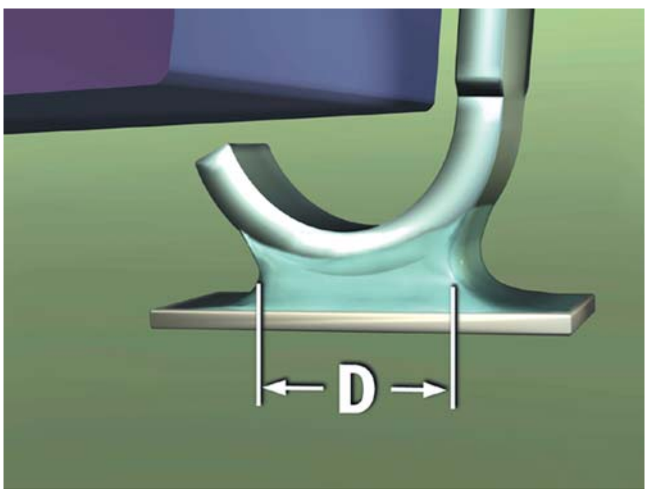


Figure 8-129

Acceptable – Class 2,3

• Side joint length (D) greater than or equal to 150% lead width (W).

Defect – Class 2,3

• Side joint fillet (D) less than 150% lead width (W).

Defect – Class 1,2,3

• A wetted fillet is not evident.

8.3.7.5 J Leads – Maximum Heel Fillet Height (E)

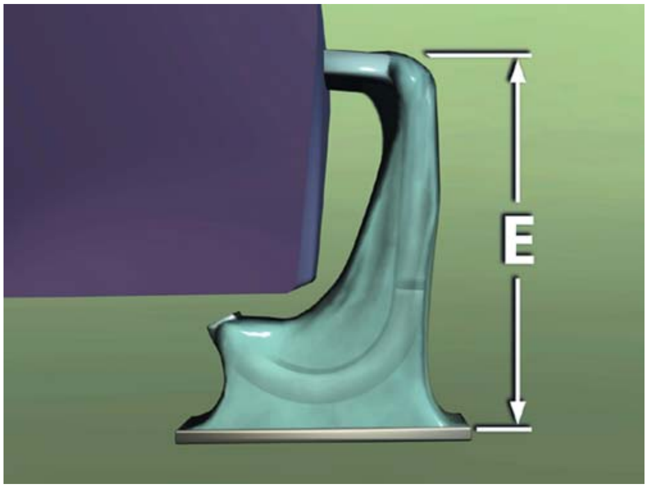


Figure 8-130

Acceptable – Class 1,2,3

- Solder fillet does not touch package body.

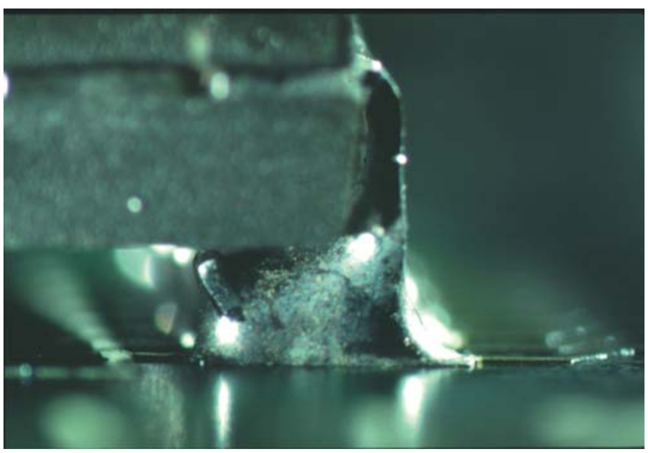


Figure 8-131

Defect – Class 1,2,3

- Solder fillet touches package body, see 8.2.1.

8.3.7.6 J Leads – Minimum Heel Fillet Height (F)

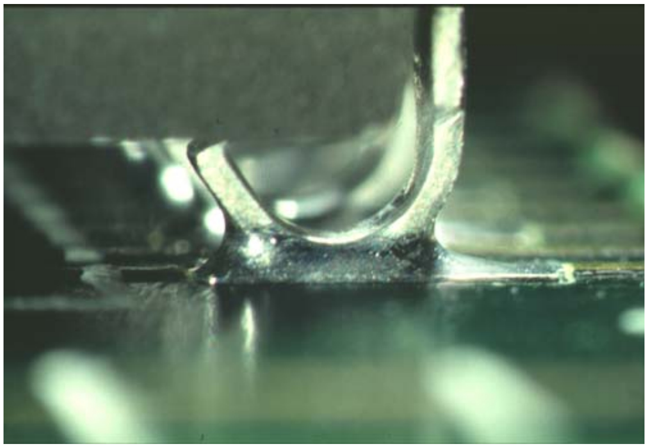


Figure 8-132

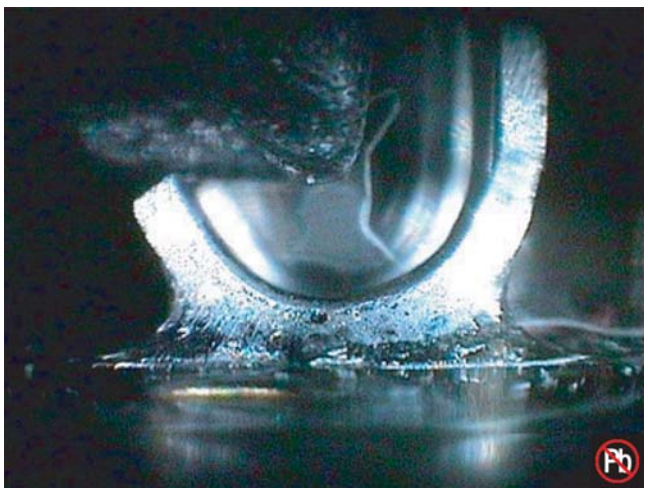


Figure 8-133

Target – Class 1,2,3

- Heel fillet height (F) exceeds lead thickness (T) plus solder thickness (G).

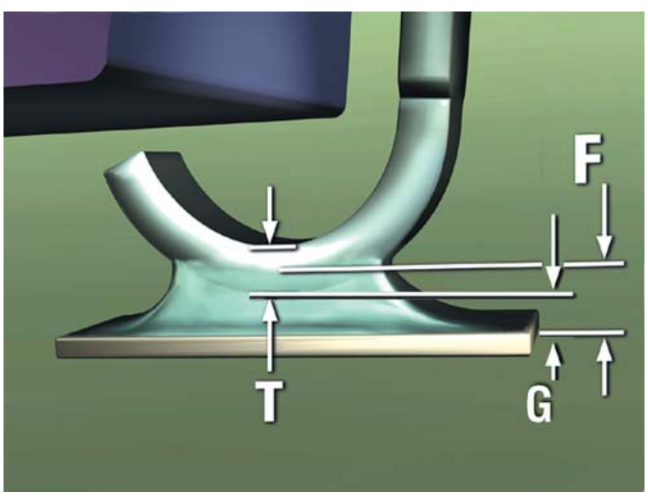


Figure 8-134

Acceptable – Class 1,2

- Heel fillet height (F) is minimum solder thickness (G) plus 50% lead thickness (T).

8.3.7.6 J Leads – Minimum Heel Fillet Height (F) (cont.)

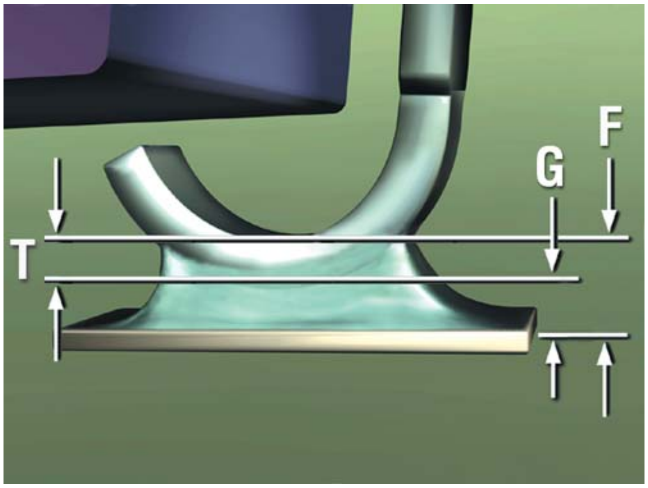


Figure 8-135

Acceptable – Class 3

- Heel fillet height (F) is at least lead thickness (T) plus solder thickness (G).

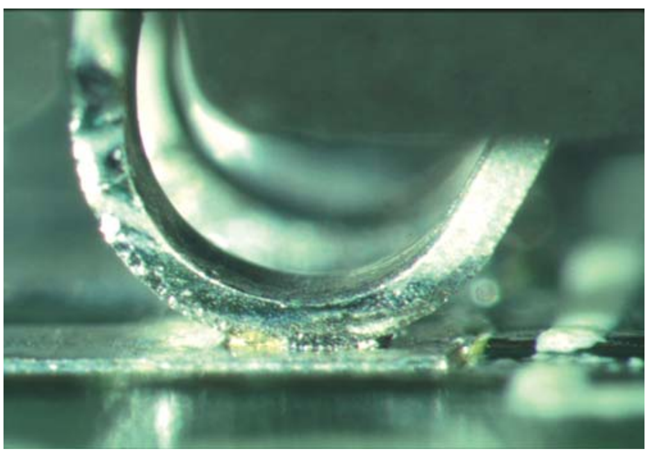


Figure 8-136

Defect – Class 1,2,3

- Heel fillet not wetted.

Defect – Class 1,2

- Heel fillet height (F) less than solder thickness (G) plus 50% lead thickness (T).

Defect – Class 3

- Heel fillet height (F) less than solder thickness (G) plus lead thickness (T).

8.3.7.7 J Leads – Solder Thickness (G)

Figure 8-137

Acceptable – Class 1,2,3

- Wetted fillet evident.

Defect – Class 1,2,3

- No wetted fillet.

8.3.7.8 J Leads – Coplanarity

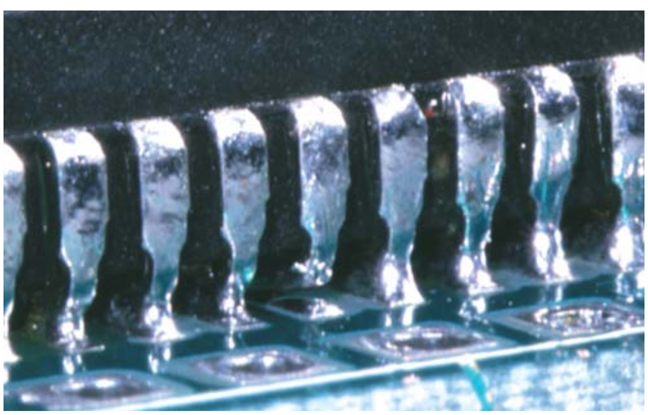


Figure 8-138

Defect – Class 1,2,3

- Component lead(s) out of alignment (coplanarity) preventing the formation of an acceptable solder connection.

8.3.8 Butt/I Connections

Connections formed with leads configured for butt mounting **shall** meet dimensional and solder fillet requirements in Tables 8-8 or 8.9 and 8.3.8.1.1 through 8.3.8.2.4 as applicable.

8.3.8.1 Butt/I Connections – Modified Through-Hole Terminations

Components designed for pin-in-hole application and modified for butt connection attachment, or stiff-leaded dual-inline packages, e.g., Alloy 42, brazed or tempered leads, etc., may be modified for use on Class 1 and 2 products. Butt connections with modified through-hole leads are not permitted for Class 3 products.

Post assembly acceptability evaluations should consider the inherent limitation of this component mounting technique to survive operational environments when compared to footed leads or through-hole mounting.

For Class 1 and 2 product, leads not having wettable sides by design (such as leads stamped or sheared from preplated stock) are not required to have side fillets. However the design should permit easy inspection of wetting to the wettable surfaces.

Table 8-8 Dimensional Criteria – Butt/I Connections – Modified Through-Hole Leads

Feature	Dim.	Class 1	Class 2
Maximum Side Overhang	A	25% (W), Note 1	Not permitted
Toe Overhang	B	Not permitted	
Minimum End Joint Width	C	75% (W), Note 5	
Minimum Side Joint Length	D	Note 3	
Maximum Fillet Height	E	Note 4	
Minimum Fillet Height	F	0.5 mm [0.02 in]	
Solder Thickness	G	Note 3	
Lead Thickness	T	Note 2	
Lead Width	W	Note 2	

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified dimension, or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. Solder does not touch package body.
Note 5. (C) is measured at the narrowest point of the required fillet.

8.3.8.1.1 Butt/I Connections – Modified Through-Hole Terminations – Maximum Side Overhang (A)

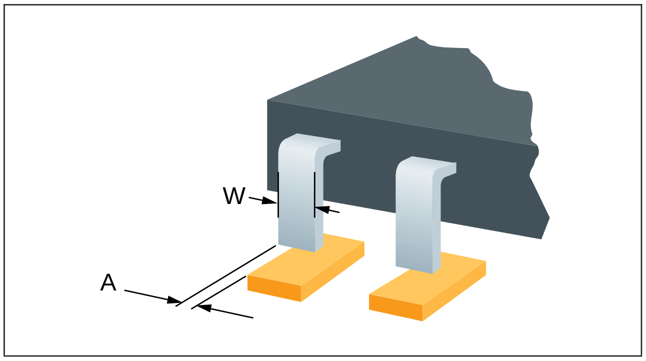


Figure 8-139

Target – Class 1,2

- No side overhang.

Acceptable – Class 1

- Overhang (A) less than 25% lead width (W), see Figure 8-139.

Defect – Class 1

- Overhang (A) exceeds 25% lead width (W).

Defect – Class 2

- Any side overhang (A).

8.3.8.1.2 Butt/I Connections – Modified Through-Hole Terminations – Toe Overhang (B)

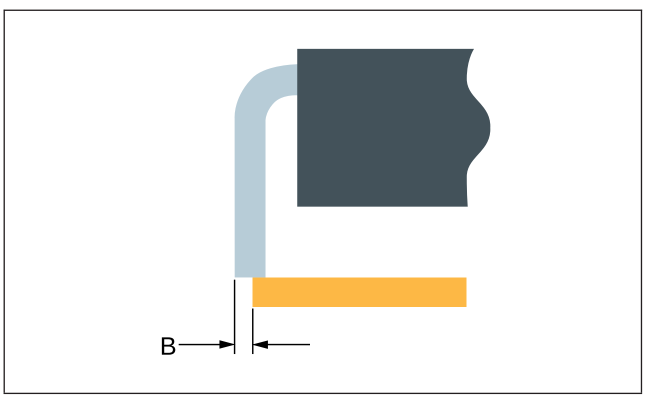


Figure 8-140

Defect – Class 1,2

- Any toe overhang (B).

8.3.8.1.3 Butt/I Connections – Modified Through-Hole Terminations – Minimum End Joint Width (C)

Target – Class 1, 2

- End joint width (C) is 100% of lead width (W).

Acceptable – Class 1, 2

- End joint width (C) is minimum 75% lead width (W).

Defect – Class 1, 2

- End joint width (C) is less than 75% lead width (W).

8.3.8.1.4 Butt/I Connections – Modified Through-Hole Terminations – Minimum Side Joint Length (D)

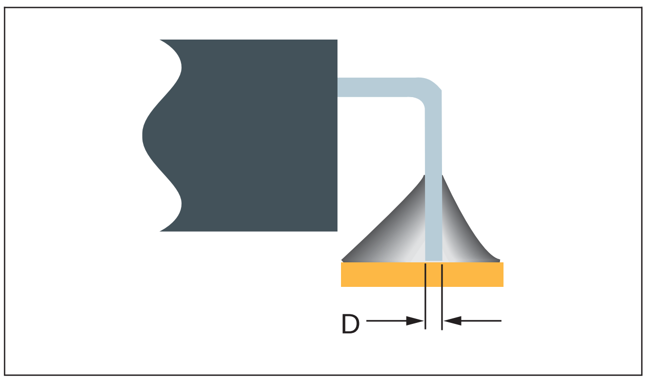


Figure 8-141

Acceptable – Class 1,2

- Wetting is evident.

8.3.8.1.5 Butt/I Connections – Modified Through-Hole Terminations – Maximum Fillet Height (E)

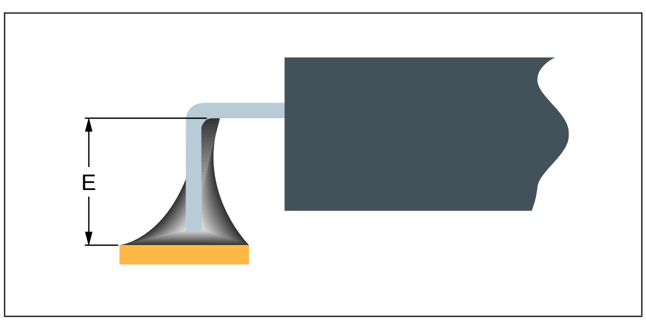


Figure 8-142

Acceptable – Class 1,2

- Wetted fillet evident.

Defect – Class 1,2

- No wetted fillet.
- Solder touches package body.

8.3.8.1.6 Butt/I Connections – Modified Through-Hole Terminations – Minimum Fillet Height (F)

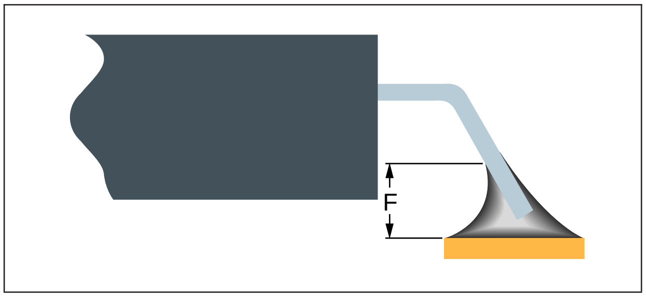


Figure 8-143

Acceptable – Class 1,2

• Fillet height (F) is minimum 0.5 mm [0.02 in].

Defect – Class 1,2

• Fillet height (F) is less than 0.5 mm [0.02 in].

8.3.8.1.7 Butt/I Connections – Modified Through-Hole Terminations – Solder Thickness (G)

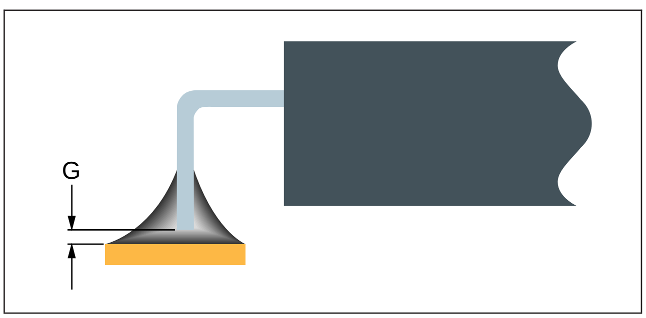


Figure 8-144

Acceptable – Class 1,2

• Wetted fillet evident.

Defect – Class 1,2

• No wetted fillet.

8.3.8.2 Butt/I Connections – Solder Charged Terminations

These criteria are for components designed with a hole or holes in the lead, a bump on the bottom to assure a good (G) fillet thickness across most of the bottom, and an attached solder slug to control the amount of solder, and are applicable to terminations on oval or round land patterns.

The top hole of a solder charged termination with two holes is not required to be filled.

Table 8-9 Dimensional Criteria – Butt/I Connections – Solder Charged Terminations

Feature	Dim.	Class1	Class 2	Class 3
Maximum Side Overhang	A	Not permitted		
Maximum Toe Overhang	B	Not permitted		
Minimum End Joint Width	C	100% of W, Note 2		
Minimum Fillet Height	F	Completely fills bottom hole on the termination		
Lead Width	W	Note 1		
Land Width	P	Note 1		

Note 1. Unspecified parameter or variable in size as determined by design.
Note 2. (C) is measured at the narrowest point of the required fillet.

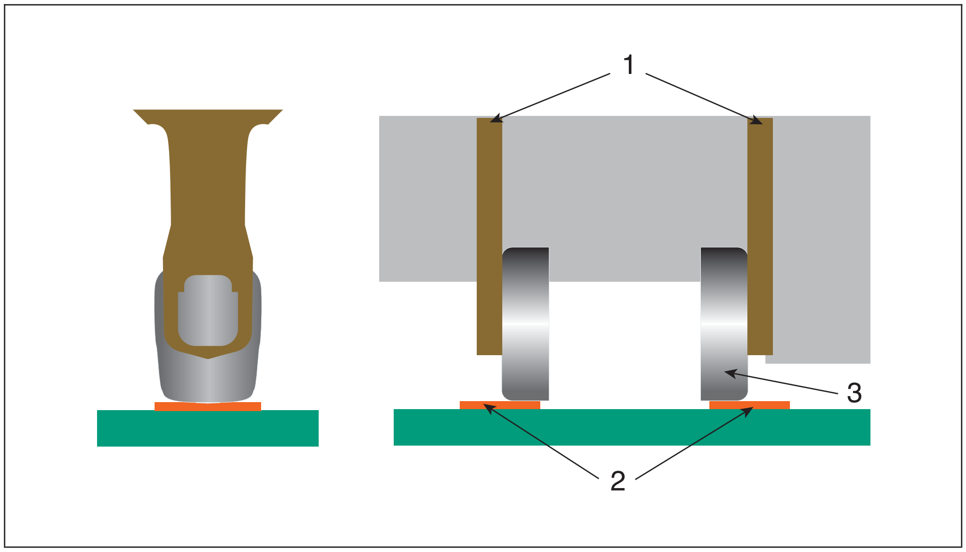


Figure 8-145
1. Connector lead
2. Land
3. Solder charge

8.3.8.2.1 Butt/I Connections – Solder Charged Terminations – Maximum Side Overhang (A)

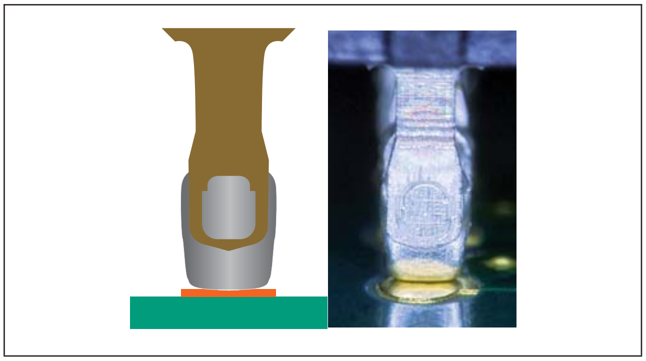


Figure 8-146

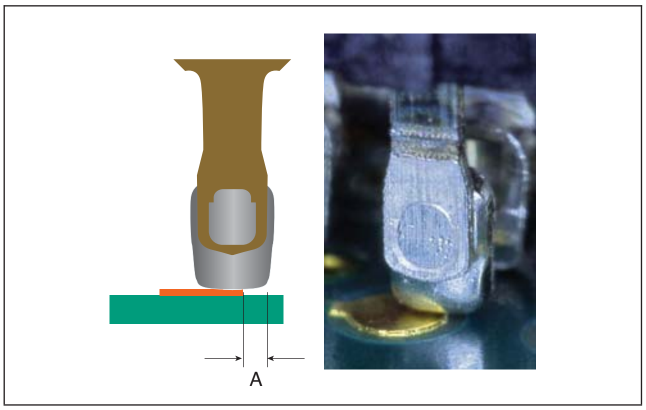


Figure 8-147

Target – Class 1,2,3

- No side overhang.

Defect – Class 1, 2,3

- Any side overhang (A).

8.3.8.2.2 Butt/I Connections – Solder Charged Terminations – Maximum Toe Overhang (B)

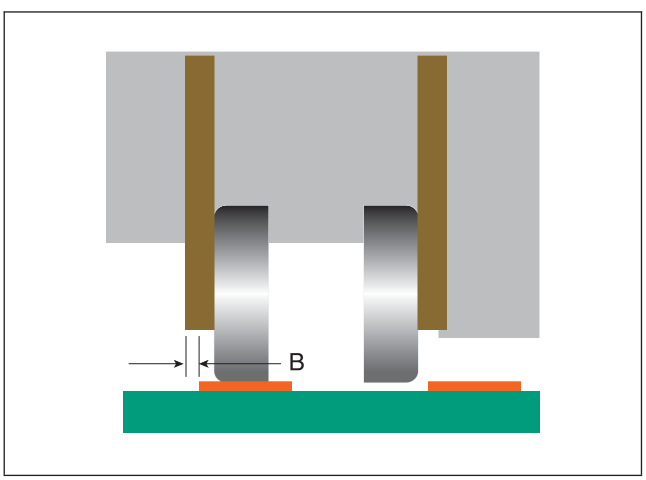


Figure 8-148

Defect – Class 1,2,3

- Any toe overhang (B).

8.3.8.2.3 Butt/I Connections – Solder Charged Terminations – Minimum End Joint Width (C)

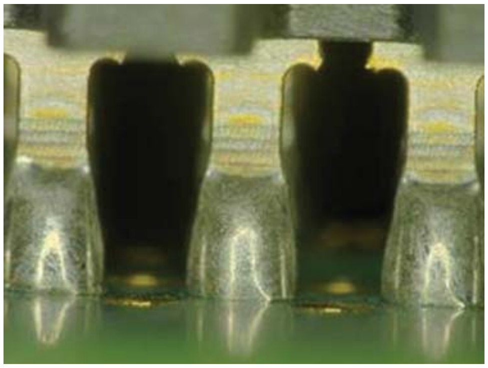


Figure 8-149
1. Lead
2. Land

Acceptable – Class 1,2,3

- End joint width (C) is 100% lead width (W).

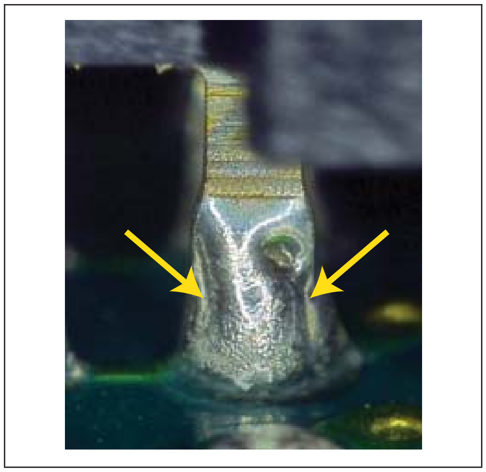


Figure 8-150

Defect – Class 1, 2, 3

- End joint width (C) is less than 100% lead width (W).

8.3.8.2.4 Butt/I Connections – Solder Charged Terminations – Minimum Fillet Height (F)

Acceptable – Class 1,2,3

- For solder charged terminations, the bottom hole is completely filled with solder.

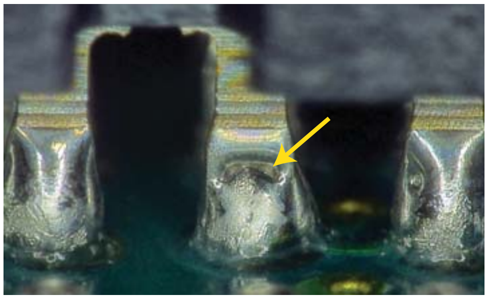


Figure 8-151

Defect – Class 1,2,3

- The bottom hole is not completely filled with solder.

8.3.9 Flat Lug Leads and Flat Unformed Leads

Connections formed to the leads of components with flat lug leads **shall** meet the dimensional requirements of Tables 8-10A and 8-10B, see Figures 8-152, 8-153 and 8-154. The design should permit easy inspection of wetting to the wettable surfaces.

Criteria for components identified as “power dissipating” are defined in Table 8-10A.

Criteria for unformed flat lug lead connections, e.g., flexible circuitry terminations, are defined in Table 8-10B. These criteria would also be used for non-power dissipating components.

The design authority should identify non-power dissipating components. When this characteristic is not identified, the Manufacturer **shall [N1D2D3]** apply the “power dissipating” criteria from Table 8-10A.

Table 8-10A Dimensional Criteria – Flat Lug Leads[5]

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W), Note 1	25% (W), Note 1	Not permitted
Maximum Toe Overhang	B	Note 1	Not permitted	
Minimum End Joint Width	C	50% (W), Note 6	75% (W), Note 6	100% (W), Note 6
Minimum Side Joint Length	D	Note 3	(L)-(M), Note 4	
Maximum Fillet Height	E	Note 2		(G) + (T) + 1 mm [0.04 in]
Minimum Fillet Height	F	Note 3		(G) + (T)
Solder Fillet Thickness	G	Note 3		
Lead Length	L	Note 2		
Gap	M	Notes 1, 2		
Land Width	P	Note 2		
Lead Thickness	T	Note 2		
Lead Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size as determined by design.
Note 3. Wetted fillet is evident.
Note 4. Where the lug is intended to be soldered beneath the component body and the land is designed for the purpose, the lead shows evidence of wetting in the gap (M).
Note 5. Solder does not touch package body or end seal, see 8.2.1.
Note 6. (C) is measured at the narrowest point of the required fillet.

8.3.9 Flat Lug Leads and Flat Unformed Leads (cont.)

Table 8-10B Dimensional Criteria – Flat Unformed Leads[5], e.g., Flexible Circuitry Termination

<table>
<tr><th>Feature</th><th>Dim.</th><th>Class 1</th><th>Class 2</th><th>Class 3</th></tr>
<tr><td>Maximum Side Overhang</td><td>A</td><td>50% (W), Note 1</td><td colspan="2">25% (W), Note 1</td></tr>
<tr><td>Maximum Toe Overhang</td><td>B</td><td>Note 1</td><td colspan="2">Not permitted</td></tr>
<tr><td>Minimum End Joint Width</td><td>C</td><td>50% (W), Note 6</td><td colspan="2">75% (W), Note 6</td></tr>
<tr><td>Minimum Side Joint Length</td><td>D</td><td>Note 3</td><td colspan="2">(L)-(M), Note 4</td></tr>
<tr><td>Maximum Fillet Height</td><td>E</td><td colspan="2">Note 2</td><td>(G) + (T) + 1 mm [0.04 in]</td></tr>
<tr><td>Minimum Fillet Height</td><td>F</td><td colspan="2">Note 3</td><td>(G) + (T)</td></tr>
<tr><td>Solder Fillet Thickness</td><td>G</td><td colspan="3">Note 3</td></tr>
<tr><td>Lead Length</td><td>L</td><td colspan="3">Note 2</td></tr>
<tr><td>Gap</td><td>M</td><td colspan="3">Notes 1, 2</td></tr>
<tr><td>Land Width</td><td>P</td><td colspan="3">Note 2</td></tr>
<tr><td>Lead Thickness</td><td>T</td><td colspan="3">Note 2</td></tr>
<tr><td>Lead Width</td><td>W</td><td colspan="3">Note 2</td></tr>
</table>

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size as determined by design.
Note 3. Wetted is evident.
Note 4. Where the lead is intended to be soldered beneath the flex or the component body and the land is designed for the purpose, wetting is evident.
Note 5. Solder does not touch package body or end seal, see 8.2.1 for exceptions.
Note 6. (C) is measured at the narrowest point of the required fillet.

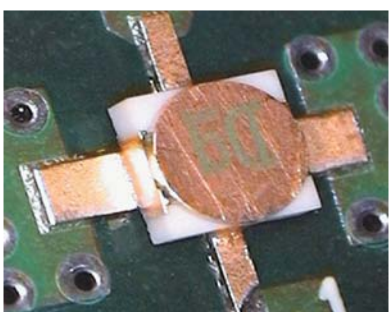


Figure 8-152

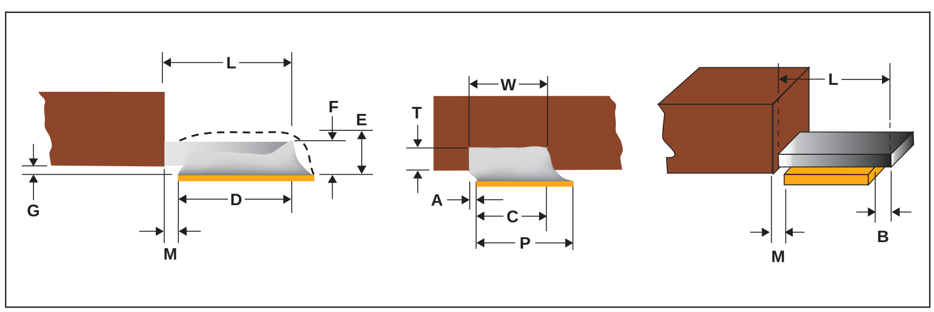


Figure 8-153

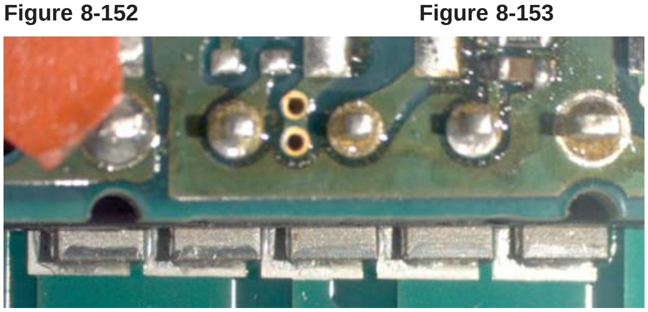


Figure 8-154

8.3.10 Tall Profile Components Having Bottom Only Terminations

Connections formed to the termination areas of tall profile components (component height is more than twice width or thickness, whichever is less) having bottom only terminations **shall** meet the dimensional requirements of Table 8-11, see Figure 8-155.

Table 8-11 Dimensional Criteria – Tall Profile Components Having Bottom Only Terminations

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W), Notes 1, 4	25% (W), Notes 1, 4	Not permitted, Notes 1, 4
Maximum End Overhang	B	Notes 1, 4	Not permitted, Note 4	
Minimum End Joint Width	C	50% (W), Note 5	75% (W), Note 5	(W), Note 5
Minimum Side Joint Length	D	Note 3	50% (R)	75% (R)
Solder Fillet Thickness	G	Note 3		
Termination/Plating Length	R	Note 2		
Land Length	S	Note 2		
Termination Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. As a function of the component design, the termination may not extend to the component edge, and the component body may overhang the PCB land area. It is the component solderable termination area that is not allowed to overhang the PCB land area, except as noted in the table above.
Note 5. (C) is measured at the narrowest point of the required fillet.

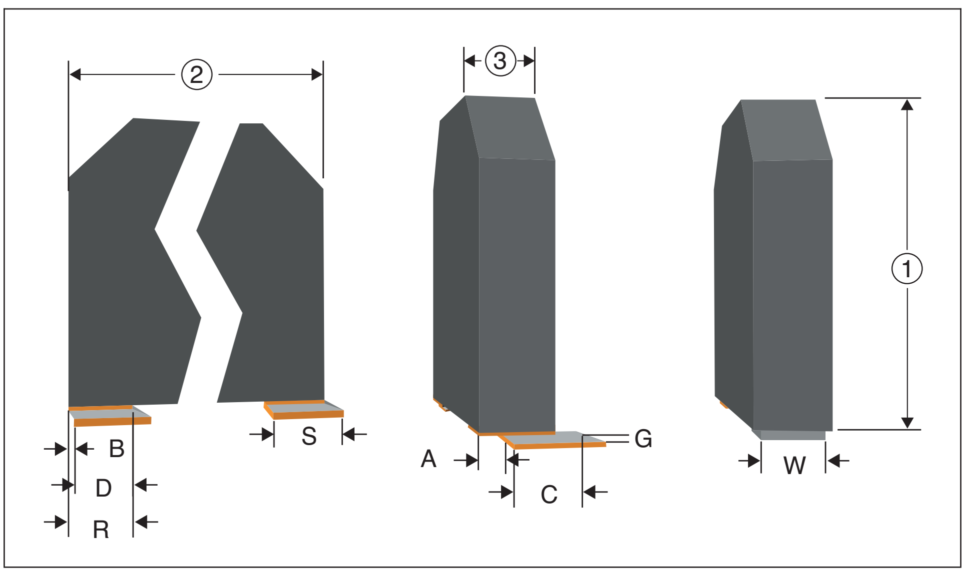


Figure 8-155
1. Component height
2. Component width
3. Component thickness

8.3.11 Inward Formed L-Shaped Ribbon Leads

Connections formed to components having inward formed L-shaped lead terminations **shall** meet the dimensional and solder fillet requirements of Table 8-12, see Figure 8-156. The design should permit easy inspection of wetting to the wettable surfaces.

Table 8-12 Dimensional Criteria – Inward Formed L-Shaped Ribbon Leads[5]

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W), Note 1		25% (W) or 25% (P), whichever is less, Note 1
Maximum Toe Overhang	B	Note 1		
Minimum End Joint Width	C	50% (W), Note 7		75% (W) or 75% (P), whichever is less, Note 7
Minimum Side Joint Length	D	Notes 3, 6	50% (L), Note 6	75% (L), Note 6
Maximum Fillet Height	E	(H) + (G), Note 4		
Minimum Fillet Height, Note 5	F	Wetting is evident on the vertical surface(s) of the component termination.	(G) + 25% (H) or (G) + 0.5 mm [0.02 in], whichever is less	
Solder Fillet Thickness	G	Note 3		
Lead Height	H	Note 2		
Lead Length	L	Note 2		
Land Width	P	Note 2		
Land Length	S	Note 2		
Lead Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. Solder does not contact the component body, see 8.2.1.
Note 5. Where a lead has two prongs, the joint to each prong is to meet all the specified requirements.
Note 6. Not always a visually inspectable attribute.
Note 7. (C) is measured at the narrowest point of the required fillet.

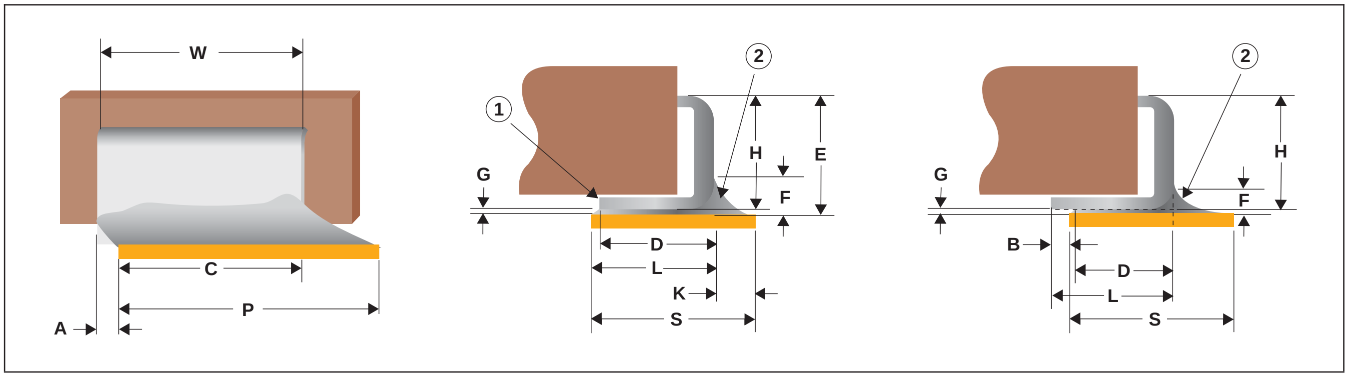


Figure 8-156
1. Toe
2. Heel

8.3.11 Inward Formed L-Shaped Ribbon Leads (cont.)

Figure 8-157

Examples of inward formed L-shaped ribbon lead components.

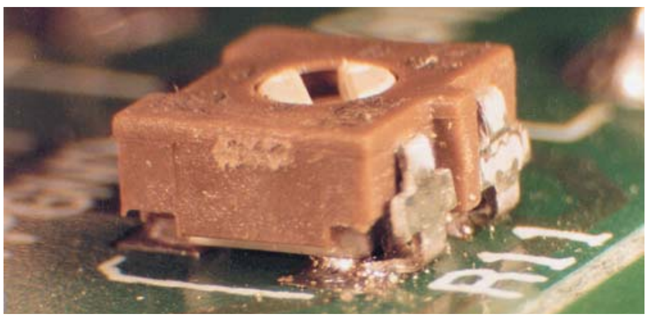


Figure 8-158

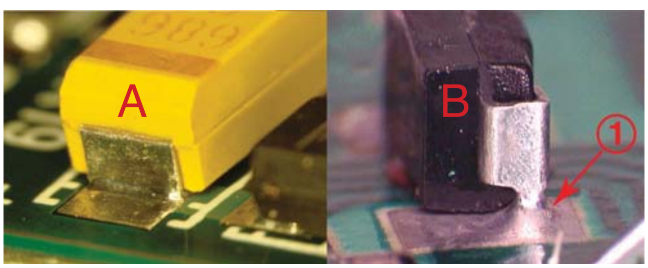


Figure 8-159

Defect – Class 1,2,3

- Insufficient fillet height, see Figure 8-159-A.
- Insufficient end joint width, see Figure 8-159-B, also showing component turned on side preventing formation of required end joint width.

8.3.12 Surface Mount Area Array

Some examples of area array components are BGA, Micro-BGA, Land Grid Array and Column Grid Array.

Area array criteria defined herein assumes an inspection process is established to determine compliance for both X-Ray and normal visual inspection processes. To a limited extent, this may involve visual assessment, but more commonly requires evaluation of X-Ray images to allow assessment of characteristics that cannot be accomplished by normal visual means.

Process development and control is essential for continued success of assembly methods and implementation of materials. Nonconformance to the requirements of Tables 8-13, 8-14 and 8-15 are defects when visual inspection or X-Ray inspection is performed to verify product acceptance. Process validation can be used in lieu of X-Ray/visual inspection provided objective evidence of compliance is available.

Area array process guidance is provided in IPC-7095, which contains recommendations, based from extensive discussion of process development issues.

Note: X-Ray equipment that is not intended for electronic assemblies or not properly set up can damage sensitive components.

Visual inspection requirements:

- When visual inspection is the method used to verify product acceptance the magnification levels of Table 1-2 apply.
- The solder terminations on the outside row (perimeter) of the area array component should be visually inspected whenever practical.
- The area array component needs to align in both X & Y directions with the corner markers on the PCB (if present).

Solder balls or columns **shall not** be absent unless specified by design.

When underfill is required, it **shall** be present and completing cured. Process and acceptance criteria should be agreed upon between the Manufacturer and User.

Voiding criteria for components with noncollapsing balls are not established, see 1.5.1.

Alternative criteria for voiding may be developed, considering special requirements of the end-use environment. Voiding criteria that are less stringent than Table 8-13 **shall** be as agreed between Manufacturer and User.

Table 8-13 Dimensional Criteria – Ball Grid Array Components with Collapsing Balls

Feature	Clause	Classes 1,2,3
Alignment	8.3.12.1	Solder ball offset does not violate minimum electrical clearance.
Solder Ball Clearance (C), see Figure 8-161	8.3.12.2	Solder ball does not violate minimum electrical clearance.
Soldered Connection	8.3.12.3	No solder bridging; BGA solder balls contact and wet to the land forming a continuous elliptical round connection.
Voids	8.3.12.4	30% or less voiding of any ball in the X-Ray image area. Notes 1 and 2

Note 1. Design induced voids, e.g., microvia in land, are excluded from this criteria. In such cases acceptance criteria should be established between the Manufacturer and User.
Note 2. Plating process induced voids, e.g., champagne voids, are excluded from this criteria. In such cases, the acceptance of the voids will need to be established between the Manufacturer and User.

Table 8-14 Ball Grid Array Components with Noncollapsing Balls

Feature	Classes 1,2,3
Alignment	Solder ball offset does not violate minimum electrical clearance.
Soldered Connections	a. Solder connections meet the criteria of 8.3.12.3. b. Solder is wetted to the solder balls and land terminations.
Voids	Voiding criteria is not established.

8.3.12 Surface Mount Area Array (cont.)

Table 8-15 Column Grid Array

Feature	Class 1	Classes 2,3
Alignment	Column offset does not violate minimum electrical clearance.	Column perimeter does not extend beyond the perimeter of the land.
Solder connections	Meet the criteria of 8.3.12.3.	
	Minimum 270° circumferential wetting for the portions of the columns that are visible, see Figure 8-166.	

8.3.12.1 Surface Mount Area Array – Alignment

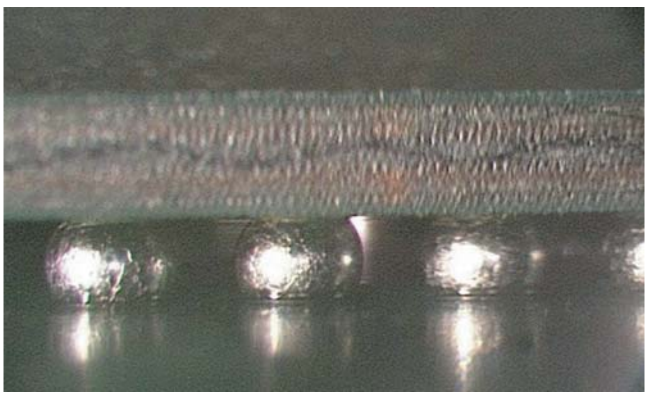


Figure 8-160

Target – Class 1,2,3

- Placement of the BGA solder ball is centered and shows no offset of the ball to land centers.

Defect – Class 1,2,3

- Solder ball offset violates minimum electrical clearance.

8.3.12.2 Surface Mount Area Array – Solder Ball Spacing

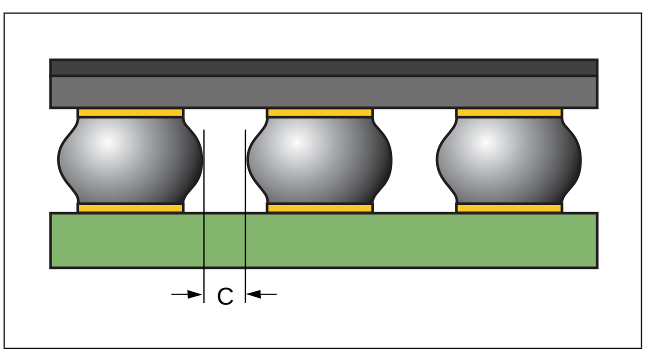


Figure 8-161

Acceptable – Class 1,2,3

- BGA solder balls do not violate minimum electrical clearance, see Figure 8-161-C.

Defect – Class 1,2,3

- BGA solder ball spacing violates minimum electrical clearance.

8.3.12.3 Surface Mount Area Array – Solder Connections

Target – Class 1,2,3

- The BGA solder ball terminations are uniform in size and shape.

Acceptable – Class 1,2,3

- No solder bridging.
- BGA solder balls contact and wet to the land forming a continuous elliptical round connection, see Figure 8-160.

Process Indicator – Class 2,3

- BGA solder ball terminations are not uniform in size, shape, coloration, and color contrast.

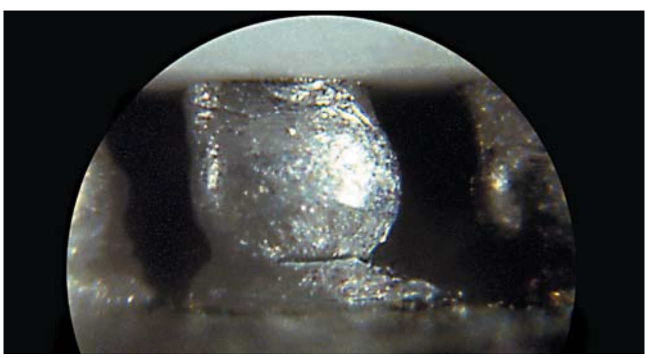


Figure 8-162

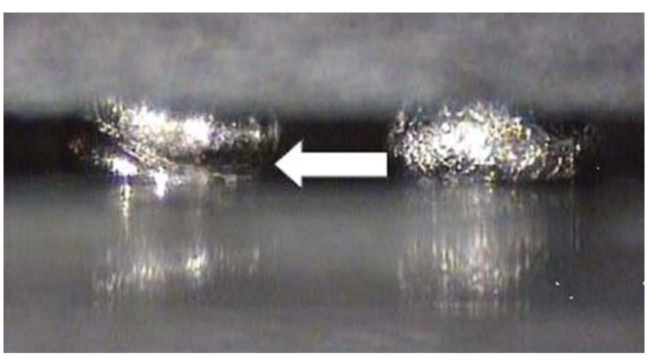


Figure 8-163

Defect – Class 1,2,3

- Fractured solder connection, see Figure 8-162.
- Ball is not wetted to solder (head in pillow/head on pillow), see Figure 8-163.
- Visual or X-Ray evidence of solder bridging, see Figure 8-164.
- A ''waist'' in the solder connection indicating that the solder ball and the attaching solder paste did not flow together, see Figure 8-165.
- Incomplete wetting to the land, see Figures 8-165 and 8-166.
- Solder terminations have incomplete reflow of the solder paste, see Figure 8-167.

8.3.12.3 Surface Mount Area Array – Solder Connections (cont.)

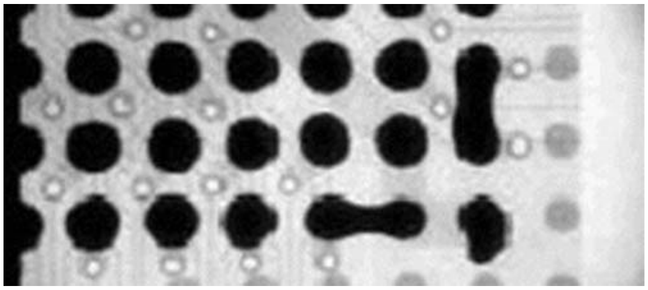


Figure 8-164

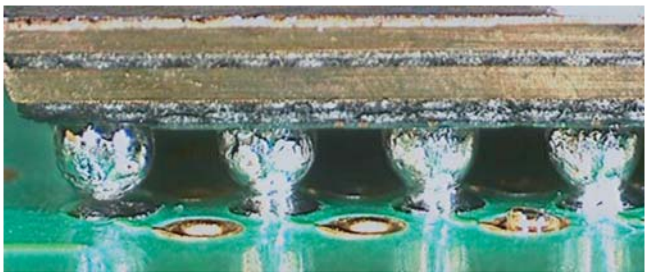


Figure 8-165

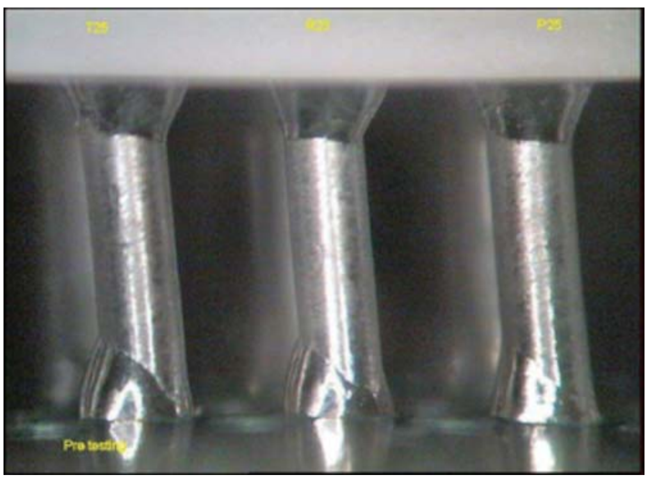


Figure 8-166

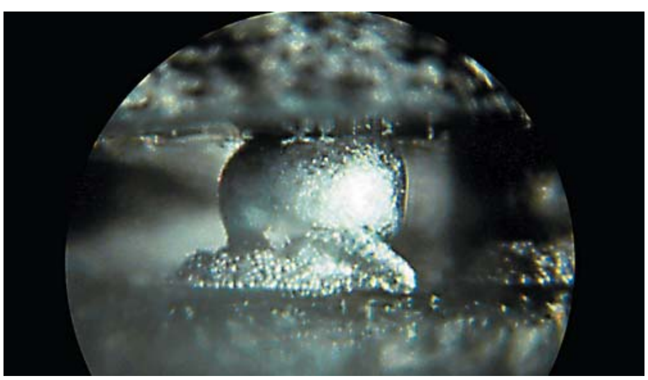


Figure 8-167

8.3.12.4 Surface Mount Area Array – Voids

Design induced voids, e.g., microvia in land, are excluded from this criteria. In such cases acceptance criteria **shall** be established between the Manufacturer and User.

Acceptable – Class 1,2,3

- 30% or less voiding of any ball in the X-Ray image area.

Defect – Class 1,2,3

- More than 30% voiding of any ball in the X-Ray image area.

8.3.12.5 Surface Mount Area Array – Underfill/Staking

Target – Class 1,2,3

- Underfill or staking material does not contact adjacent components.

Acceptable – Class 1,2,3

- When specified, underfill or staking material is present.
- Excess underfill or staking material does not interfere with form, fit, or function of the assembly.
- Underfill or staking material completely cured.

Defect – Class 1,2,3

- When specified, underfill or staking material is not present.
- Excess underfill or staking material interferes with form, fit or function of the assembly.
- Underfill or staking material not fully cured.

8.3.12.6 Surface Mount Area Array – Package on Package

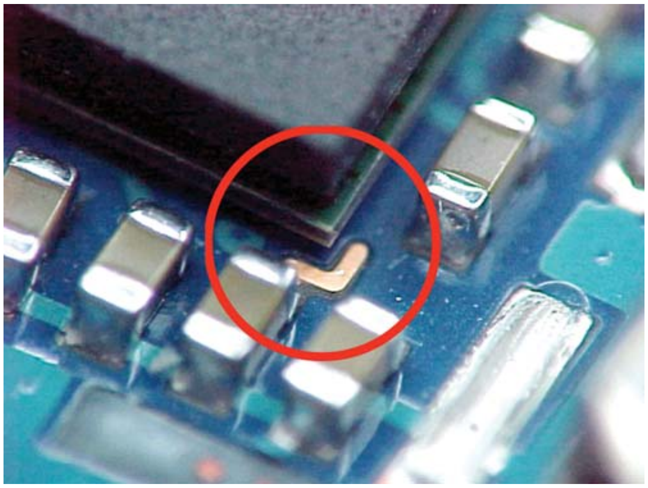


Figure 8-168

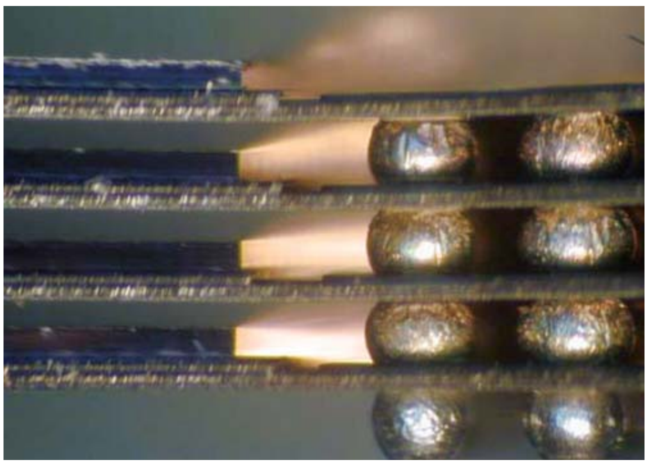


Figure 8-169

Acceptable – Class 1,2,3

- Components aligned to markings on the PCB if provided, see Figure 8-168.
- Ball to land alignment conforms to 8.3.12.1.
- Solder connections conform to 8.3.12.3, see Figure 8-169, and have reflowed showing wetting to the lands on all package levels.
- Package warping or distortion does not interfere with alignment or the formation of solder connections.

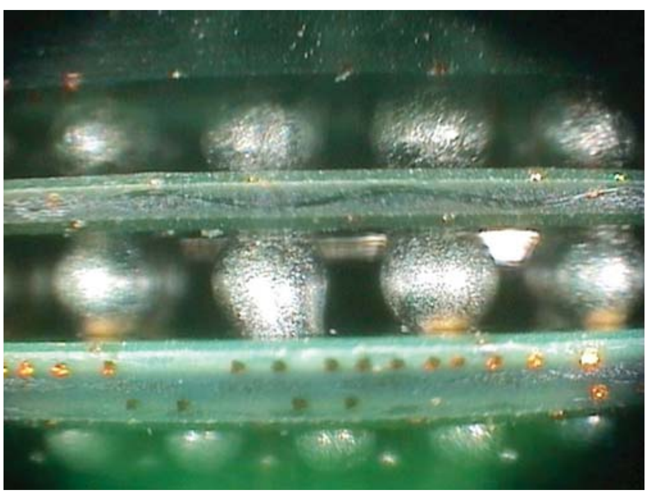


Figure 8-170

Defect – Class 1,2,3

- Ball to land alignment does not conform to 8.3.12.1.
- Solder connections do not conform to 8.3.12.3. See Figure 8-170 shows wetting only to middle ball.
- Missing solder ball(s), see Figure 8-171.
- Package warping or distortion interferes with alignment or the formation of solder connections, see Figures 8-172 and 8-173.

8.3.12.6 Surface Mount Area Array – Package on Package (cont.)

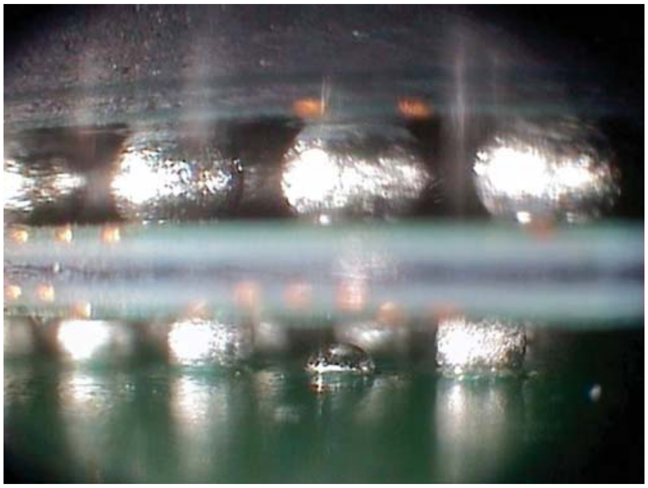


Figure 8-171

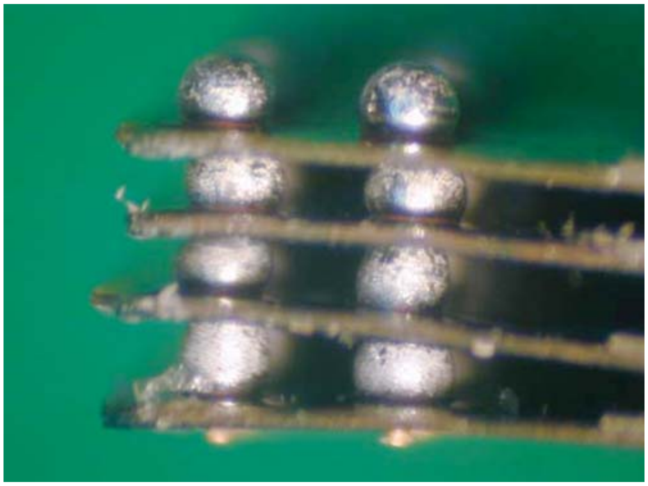


Figure 8-172

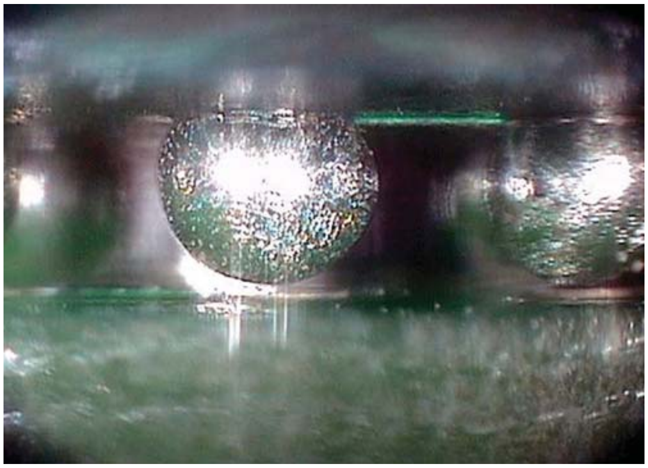


Figure 8-173

8.3.13 Bottom Termination Components (BTC)

Some other names for these devices are Land Grid Array (LGA), Quad Flat No-Lead (QFN), Plastic Quad Flat No-Lead (PQFN), Microlead Frame Packages (MLF), Leadless Plastic Chip Carriers (LPCC), and Quad Flat No-Lead Exposed Pad (QFN-EP), Connections formed to bottom termination components (BTC) **shall** meet dimensional and solder fillet requirements in Table 8-16, see Figures 8-174 and 8-175.

Bottom Termination Component (BTC) process guidance is provided in IPC-7093, which contains recommendations developed from extensive discussion of BTC process development issues.

Process development and control is essential for continued success of assembly methods and implementation of materials. Process validation and control can be used in lieu of X-Ray/visual inspection provided objective evidence of compliance is available.

Thermal plane void criteria **shall** be established between the Manufacturer and User.

Table 8-16 Dimensional Criteria – BTC

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W), Note 1	25% (W), Note 1	
Toe Overhang (outside edge of component termination)	B	Not permitted		
Minimum End Joint Width	C	50% (W), Note 6	75% (W), Note 6	
Minimum Side Joint Length	D	Note 4		
Solder Fillet Thickness	G	Note 3		
Minimum Toe (End) Fillet Height	F	Notes 2, 5		
Termination Height	H	Note 5		
Land Width	P	Note 2		
Termination Width	W	Note 2		

Note 1. Does not violate minimum electrical clearance.
Note 2. Unspecified parameter or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. Not a visually inspectable attribute.
Note 5. (H) = height of solderable surface of lead, if present. Some package configurations do not have a continuous solderable surface on the sides and do not require a toe (end) fillet.
Note 6. (C) is measured at the narrowest point of the required fillet.

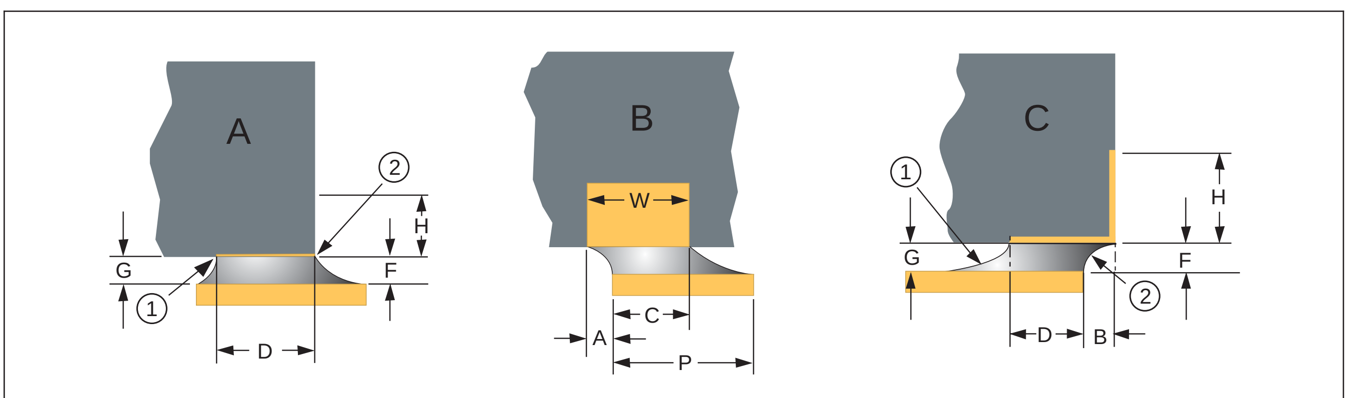


Figure 8-174
1. Heel
2. Toe

A. Side View
B. End View
C. Additional Side View

8.3.13 Bottom Termination Components (BTC) (cont.)

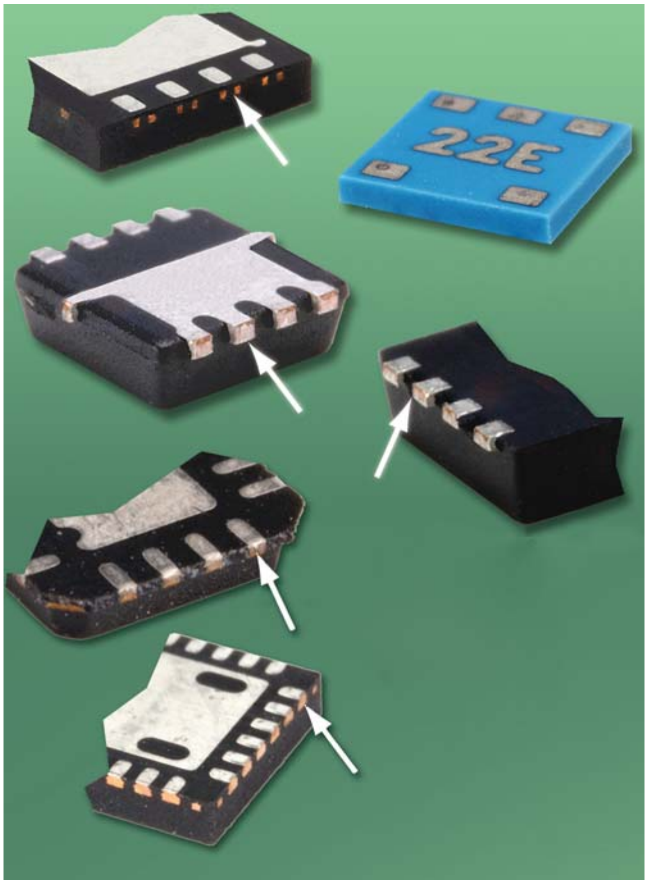


Figure 8-175

There are some package configurations that have no toe exposed or do not have a continuous solderable surface on the exposed toe on the exterior of the package, see Figure 8-175 arrows, and a toe fillet will not form, see Figures 8-176 and 8-177.

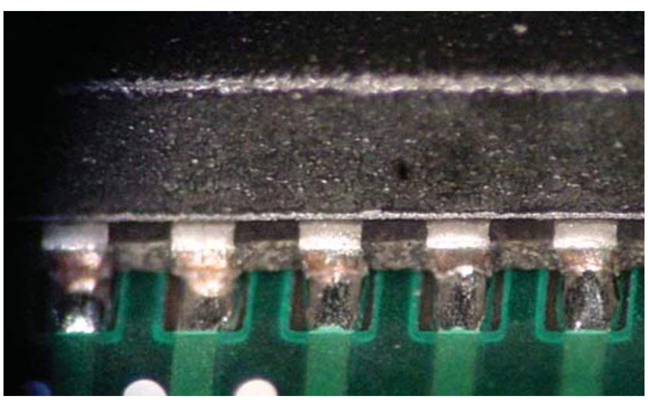


Figure 8-176

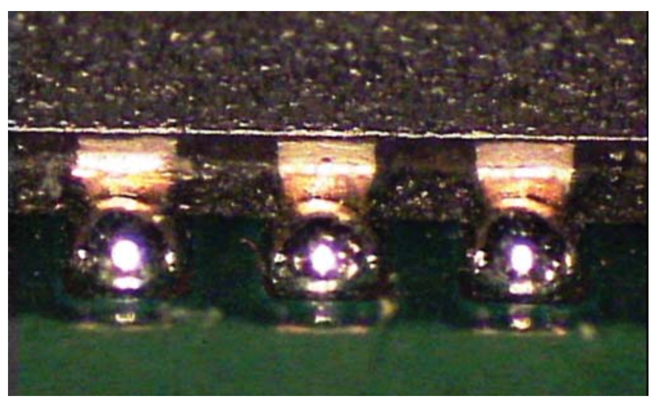


Figure 8-177

8.3.14 Components with Bottom Thermal Plane Terminations

These criteria are specific to any leaded or leadless package that employs a soldered bottom thermal plane. One such example, shown here, is the TO-252 (D-Pak). Connections formed to components with bottom thermal-plane terminations **shall** meet dimensional and solder fillet requirements in Table 8-17.

The mounting and solder requirements for SMT terminations **shall** meet the criteria for the type of lead termination being used.

Criteria for nonvisible thermal plane solder connections are not described in this document and **shall** be established by agreement between the User and the Manufacturer. The thermal transfer plane acceptance criteria are design and process related. Issues to consider include but are not limited to component manufacturer's application notes, solder coverage, voids, solder height, etc. When soldering these types of components voiding in the thermal plane is common.

Table 8-17 Dimensional Criteria – Bottom Thermal Plane Terminations

Feature (all connections except thermal plane)	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	Criteria for the type of lead termination being used. Note 4		
Toe Overhang	B			
Minimum End Joint Width	C			
Minimum Side Joint Length	D			
Maximum Heel Fillet Height	E			
Minimum Heel Fillet Height	F			
Solder Fillet Thickness	G			
Lead Thickness	T			
Feature (only for the thermal plane connection)		**Class 1,2,3**		
Thermal Plane Side Overhang		Not greater than 25% of termination width.		
Thermal Plane End Overhang		No overhang, (not shown).		
Thermal Plane End Joint Width, Notes 2, 4		100% wetting to land in the end-joint contact area, (not shown).		
Thermal Plane Side Joint Length	D	Note 1		
Thermal Plane Solder Fillet Thickness	G	Wetting is evident when a fillet is present.		
Thermal Plane Void Criteria		Note 1		
Thermal Plane Termination Width	W	Note 2		
Thermal Plane Land Width	P	Note 3		

Note 1: Acceptance criteria will need to be established between the Manufacturer and User.
Note 2: Solder wetting is not required on trimmed edges of a thermal plane that expose non-wettable vertical surfaces.
Note 3: Unspecified parameter or variable in size, as determined by design.
Note 4. (C) is measured at the narrowest point of the required fillet.

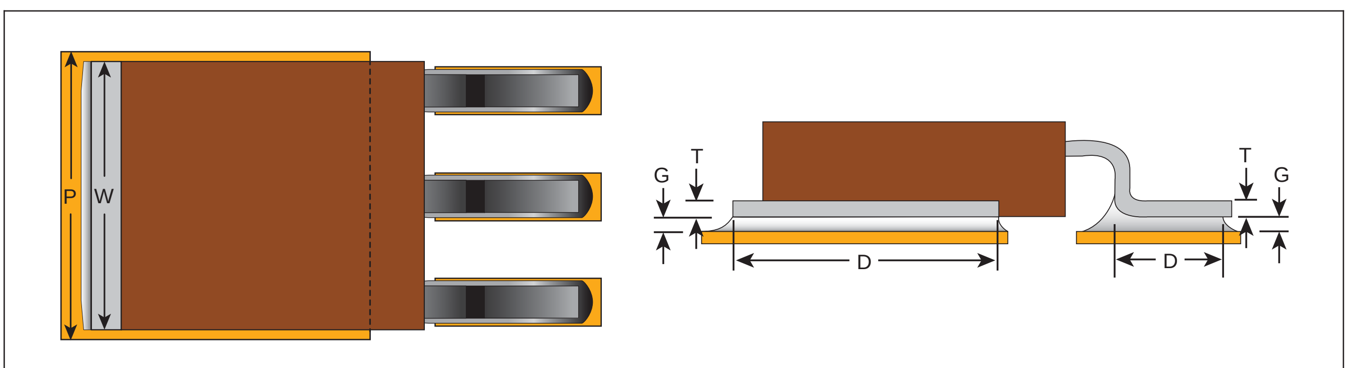


Figure 8-178

8.3.14 Components with Bottom Thermal Plane Terminations (cont.)

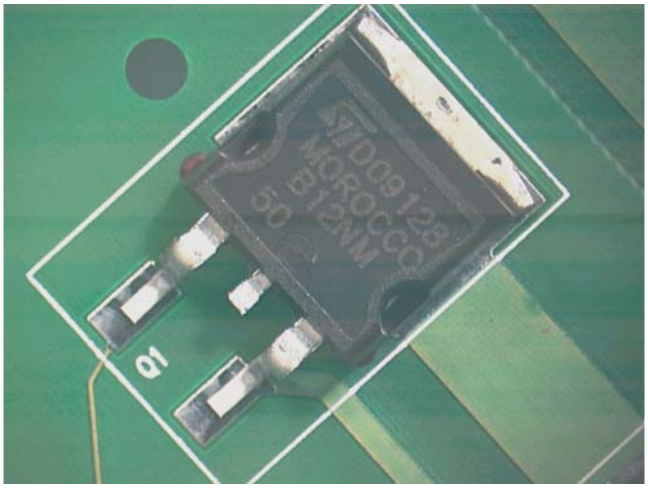


Figure 8-179

Target – Class 1,2,3

- No thermal plane side overhang.
- Thermal plane termination edges have 100% wetting.

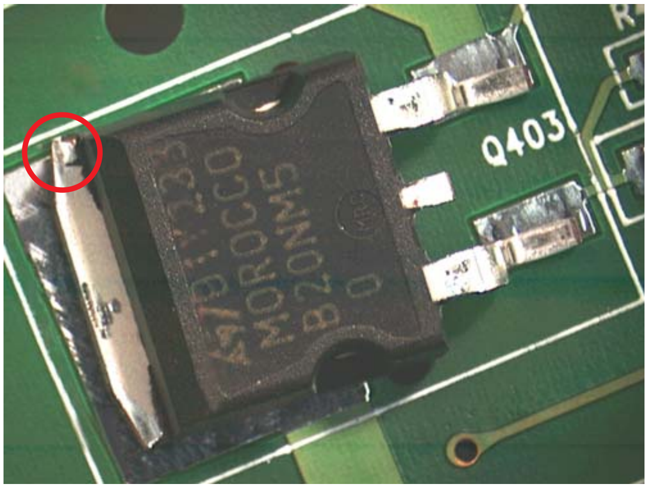


Figure 8-180

Acceptable – Class 1,2,3

- Thermal plane termination side overhang is not greater than 25% of termination width, see Figure 8-180.
- End joint width of the thermal plane end termination has 100% wetting to land in the contact area.

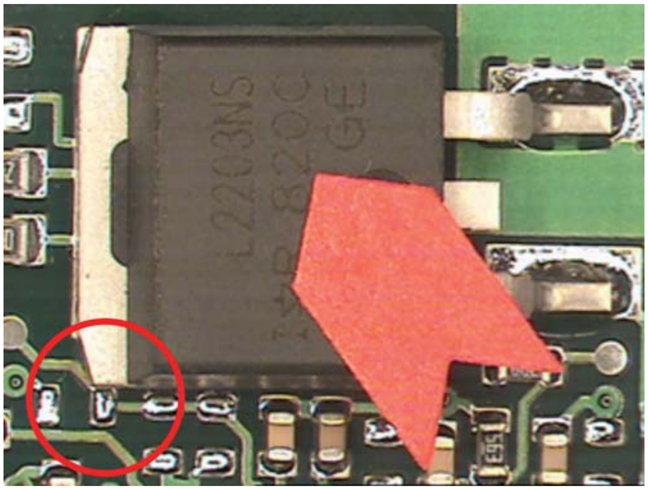


Figure 8-181

Defect – Class 1,2,3

- Side overhang of thermal plane termination is greater than 25% of termination width.
- End of thermal plane termination overhangs land.
- End joint width of the thermal plane end termination has less than 100% wetting to land in the contact area.
- Thermal plane overhang violates minimum electrical clearance, see Figure 8-181.

8.3.15 Flattened Post Connections

This termination style is sometimes referred to as nail-head pin.

Criteria have not been established for Class 3 for this termination style. Process development and control is essential for continued success of assembly methods and implementation of materials. Connections formed to flattened post terminations **shall** meet dimensional and solder fillet requirements in Table 8-18 and 8.3.15.1 through 8.3.15.3.

Table 8-18 Dimensional Criteria Flattened Post Connections

Feature	Class1	Class 2	Class 3
Maximum Termination Overhang, Square Solder Land	75% Termination Width (W), Notes 1, 2	50% Termination Width (W), Notes 1, 2	Criteria not established
Maximum Termination Overhang, Round Solder Land	50% Termination Width (W), Notes 1, 2	25% Termination Width (W), Notes 1, 2	
Maximum Fillet Height	Note 4		
Minimum Fillet Height	Note 3		

Note 1. Does not violate minimum electrical clearance.
Note 2. Lead diameter is less than diameter or side length of the solder land.
Note 3. Wetting is evident.
Note 4. Solder does not touch package body.

8.3.15.1 Flattened Post Connections – Maximum Termination Overhang – Square Solder Land

Target – Class 1,2

• No overhang.

Acceptable – Class 1

• Overhang less than 75%.

Acceptable – Class 2

• Overhang less than 50%.

Defect – Class 1

• Overhang exceeds 75%.

Defect – Class 2

• Overhang exceeds 50%.

8.3.15.2 Flattened Post Connections – Maximum Termination Overhang – Round Solder Land

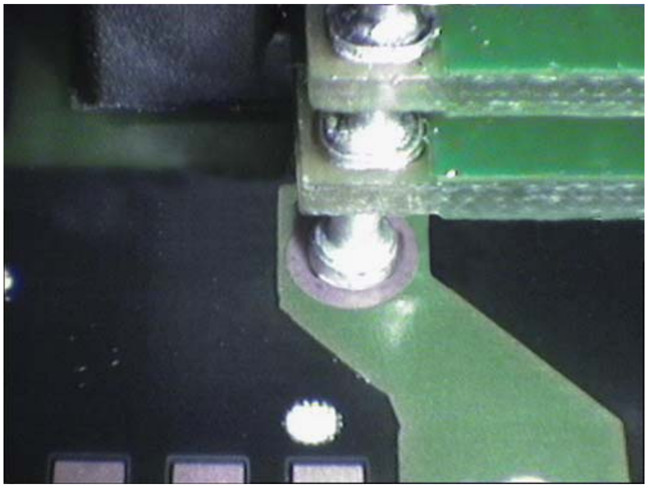


Figure 8-182

Target – Class 1,2

• No overhang.

Acceptable – Class 1

• Overhang less than 50%.

Acceptable – Class 2

• Overhang less than 25%.

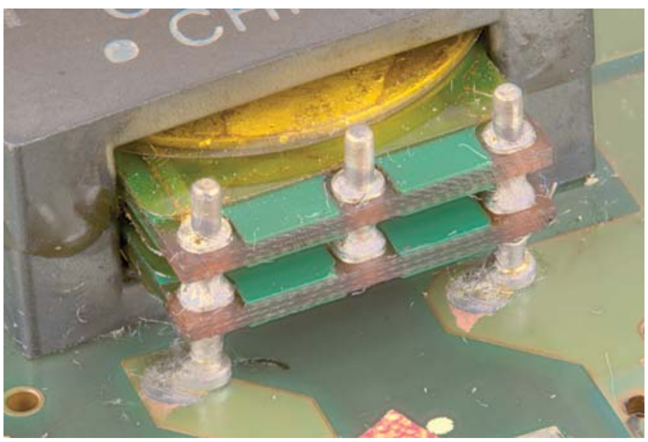


Figure 8-183

Defect – Class 1

• Overhang exceeds 50%.

Defect – Class 2

• Overhang exceeds 25%.

8.3.15.3 Flattened Post Connections – Maximum Fillet Height

Acceptable – Class 1,2

• Wetted fillet evident.

Defect – Class 1,2

• No wetted fillet.

• Solder touches package body.

8.3.16 P-Style Connections

Connections formed to components having the P-Style termination, see Figure 8-184, **shall** meet the dimensional and solder fillet requirements of Table 8-19 and 8.3.16.1 through 8.3.16.5. This termination style is typically found on edge mounted connectors that will be soldered on both sides of the board.

Table 8-19 Dimensional Criteria –- P-Style Terminations

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W)	25% (W)	Not permitted
Maximum Toe Overhang	B	Note 1		
Minimum End Joint Width	C	50% (W), Note 4	75% (W), Note 4	100% (W), Note 4
Minimum Side Joint Length	D	100% (W)	150% (W)	
Minimum Fillet Height - Heel and Toe	F	Note 2	25% (H)	
Solder Fillet Thickness	G	Note 3		
Termination Height	H	Note 3		
Minimum Side Fillet Height	Q	Note 2		
Termination Length	L	Note 3		
Termination Width	W	Note 3		

Note 1: No part of the (L) portion of the termination extends beyond the land.
Note 2: Unspecified parameter or variable in size, determined by design.
Note 3: Wetting is evident.
Note 4. (C) is measured at the narrowest point of the required fillet.

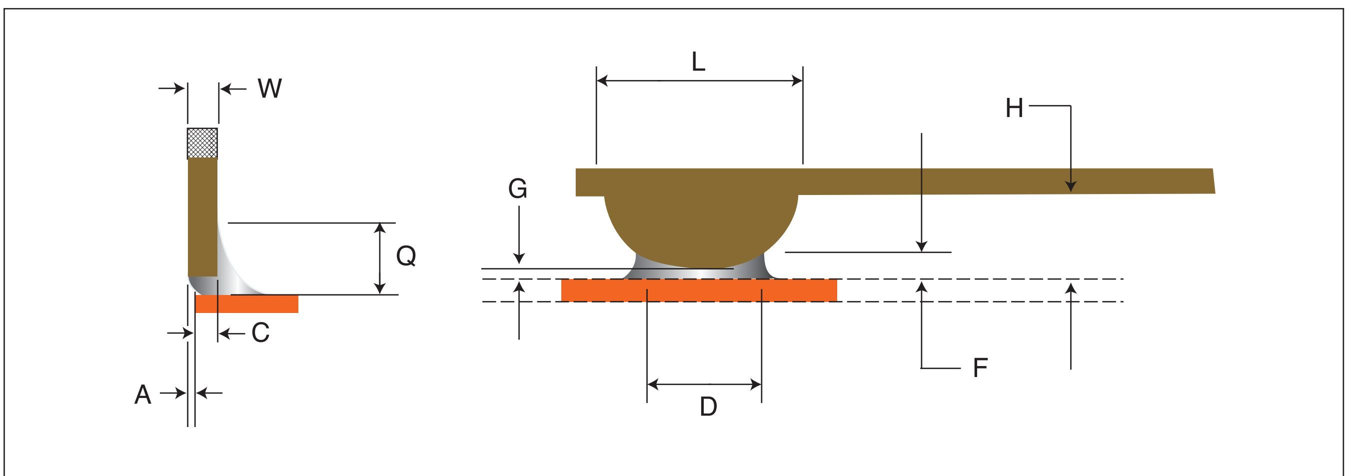


Figure 8-184 P-Style Termination

8.3.16.1 P-Style Connections – Maximum Side Overhang (A)

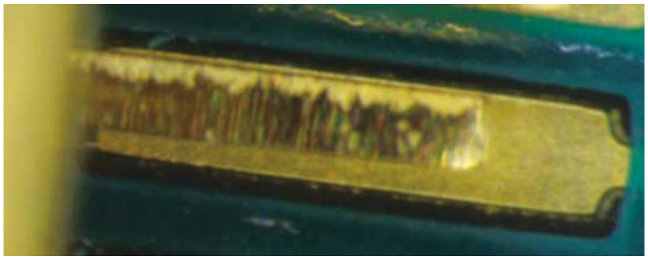


Figure 8-185

Target – Class 1,2,3

- No overhang.

Acceptable – Class 1

- Overhang equal to or less than 50% termination width (W).

Acceptable – Class 2

- Overhang equal to or less than 25% termination width (W).

Acceptable – Class 3

- No side overhang.

Defect – Class 1

- Overhang exceeds 50% termination width (W).

Defect – Class 2

- Overhang exceeds 25% termination width (W).

Defect – Class 3

- Any side overhang.

8.3.16.2 P-Style Connections – Maximum Toe Overhang (B)

Acceptable – Class 1,2,3

- No portion of the termination length (L) extends beyond the land length (S).

Defect – Class 1,2,3

- Any portion of the termination length (L) extends beyond the land length (S).

8.3.16.3 P-Style Connections – Minimum End Joint Width (C)

Target – Class 1,2,3

• End joint width (C) is 100% termination width (W).

Acceptable – Class 1

• End joint width (C) is 50% termination width (W).

Acceptable – Class 2

• End joint width (C) is 75% termination width (W).

Defect – Class 1

• End joint width (C) is less than 50% termination width (W).

Defect – Class 2

• End joint width (C) is less than 75% termination width (W).

Defect – Class 3

• End joint width (C) is less than 100% termination width (W).

8.3.16.4 P-Style Connections – Minimum Side Joint Length (D)

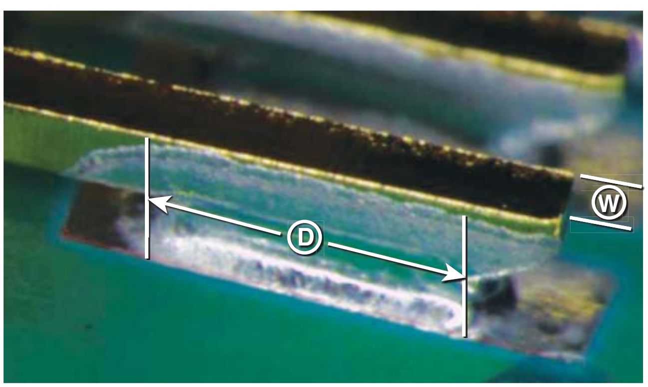


Figure 8-186

Target – Class 1,2,3

• Side joint length (D) is 100% termination length (L).

Acceptable – Class 1

• Side joint length (D) is 100% termination width (W).

Acceptable – Class 2,3

• Side joint length (D) is 150% termination width (W).

Defect – Class 1

• Side joint length (D) is less than 100% termination width (W).

Defect – Class 2,3

• Side joint length (D) is less than 150% termination width (W).

8.3.16.5 P-Style Connections – Minimum Fillet Height (F)

These criteria are applicable to both the toe and heel regions of the connection.

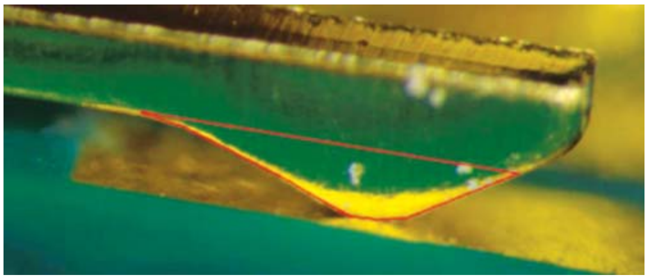


Figure 8-187

Target – Class 1,2,3

- Fillet height (F) is 100% termination height (H), see Figures 8-186 and 8-187 red line.

Acceptable – Class 1

- Wetting is evident.

Acceptable – Class 2,3

- Fillet height (F) is 25% termination height (H).

Acceptable – Class 1
Defect – Class 2,3

- Fillet height (F) is less than 25% termination height (H).

8.4 Specialized SMT Terminations

The IPC committee that maintains this standard has received requests to include a number of specialized SMT termination styles such as shown in Figures 8-188, 8-189 and 8-190. Often these termination styles are unique to a particular component or are specially made for a limited number of users. Before acceptance criteria can be developed there needs to be significant use so that a history of failure data can be captured from multiple users. Clause 1.5.1.7 of this standard is repeated here.

> ***1.5.1.7 Specialized Designs*** *IPC-A-610, as an industry consensus document, cannot address all of the possible components and product design combinations. Where uncommon or specialized technologies are used, it may be necessary to develop unique acceptance criteria. However, where similar characteristics exist, this document may provide guidance for product acceptance criteria. Often, unique definition is necessary to consider the specialized characteristics while considering product performance criteria. The development should include customer involvement or consent and for Classes 2 and 3 the criteria **shall** include agreed definition of product acceptance.*
>
> *Whenever possible these criteria should be submitted to the IPC Technical Committee to be considered for inclusion in upcoming revisions of this standard.*

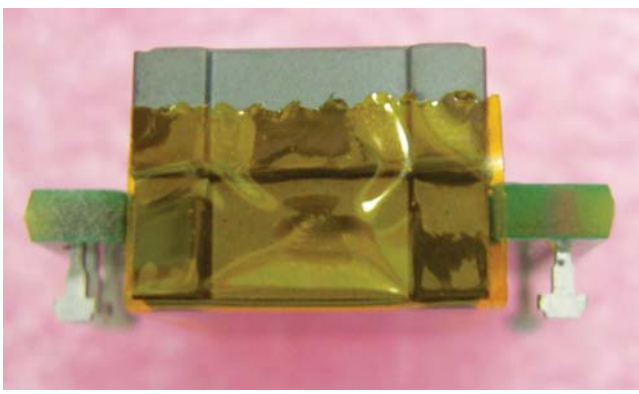


Figure 8-188

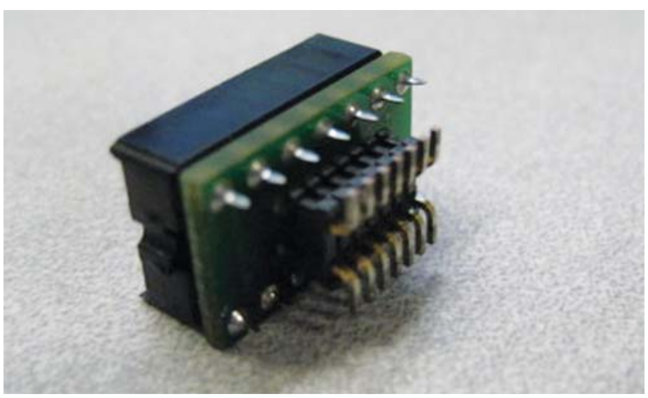


Figure 8-189

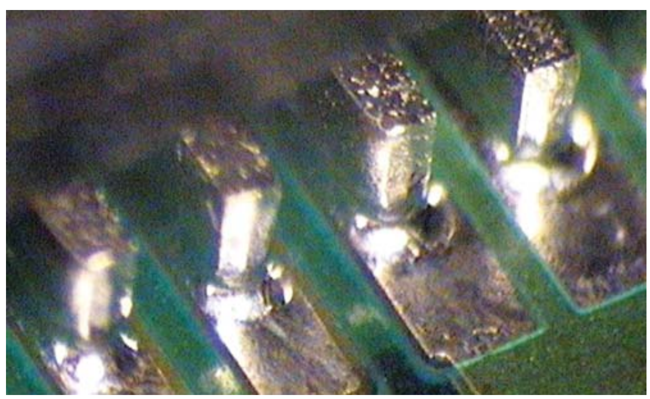


Figure 8-190

8.5 Surface Mount Connectors

These criteria apply to soldered connectors. For connector damage criteria see 9.5. The mounting and solder requirements for SMT connectors **shall** meet the criteria for the type of lead termination being used. There are no illustrations for these criteria.

Target – Class 1,2,3

- Connector is flush with board.

Acceptable – Class 1,2,3

- Back edge of connector is flush; entering edge of connector does not violate component height.
- Board lock is fully inserted/snapped through the board.
- Any tilt, provided:
  - Maximum height requirements are not exceeded.
  - Mates correctly.

Defect – Class 1,2,3

- Will not mate when used in application due to angle.
- Component violates height requirements.
- Boardlock is not fully inserted/snapped into board.

Note: Connectors need to meet form, fit and function requirements. A trial mating of connector to connector or to assembly may be required for final acceptance.

8.6 Jumper Wires

These criteria do not constitute authority for repair to assemblies without prior customer consent, see 1.1. This section establishes visual acceptability criteria for the installation of discrete wires (jumper wires, etc.) used to interconnect components where there is no continuous printed circuit.

Information concerning rework and repair can be found in IPC-7711/7721.

Wire selection (7.5.1), wire routing (7.5.2) and adhesive staking of wire (7.5.3) criteria are applicable to SMT jumper wires.

They may be terminated in plated holes, and/or to terminal standoffs, conductor lands, and component leads.

Jumper wires are considered as components and are covered by an engineering instruction document for routing, termination, staking and wire type.

Keep jumper wires as short as practical and unless otherwise documented do not route over or under other replaceable components. Design constraints such as real estate availability and minimum electrical clearance need to be taken into consideration when routing or staking wires. A jumper wire 25 mm [1 in] maximum in length whose path does not pass over conductive areas and do not violate the designed spacing requirements may be uninsulated. Insulation, when required on the jumper wires, **shall** be compatible with conformal coating when conformal coating is required.

Acceptable – Class 1,2,3

- The insulation is in contact with the solder but does not interfere with formation of an acceptable connection.

Defect – Class 1,2,3

- Insulation interfers with formation of the solder connection.

8.6.1 Jumper Wires – SMT

There is no adhesive on component bodies, leads or lands. Adhesive deposits do not obscure or interfere with solder connections.

For all lap solder connections described in this section the following conditions are acceptable:

- Insulation clearance does not permit shorting to noncommon conductors or violate minimum electrical clearance.
- Evidence of wetting of jumper wire and lead or the land.
- Wire contour or end is discernible in the solder connection.
- No fractures in solder connection.
- Wire overhang does not violate minimum electrical clearance.

8.6.1.1 Jumper Wires – SMT – Chip and Cylindrical End Cap Components

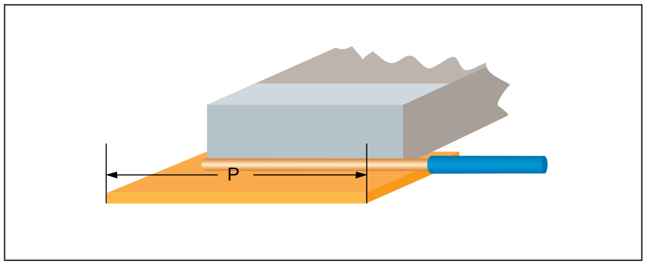


Figure 8-191

Target – Class 1,2,3

- Lead is positioned parallel to longest dimension of the land.
- Solder fillet length equal to land width (P).

Acceptable – Class 1,2,3

- Wire to component termination-land solder connection length is at least 50% of land width (P) or twice the conductor diameter, whichever is greater.

Defect – Class 1,2,3

- Wire to component termination-land solder connection length is less than 50% of land width (P) or twice the conductor diameter, whichever is greater.
- Wire soldered on top of chip component termination.

8.6.1.2 Jumper Wires – SMT – Gull Wing

These criteria are applicable to jumpers attached to leads. See 8.6.1.5 for jumpers attached to lands.

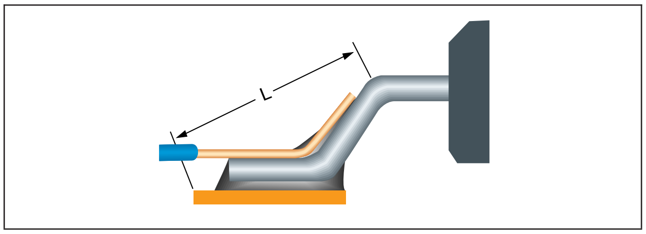


Figure 8-192

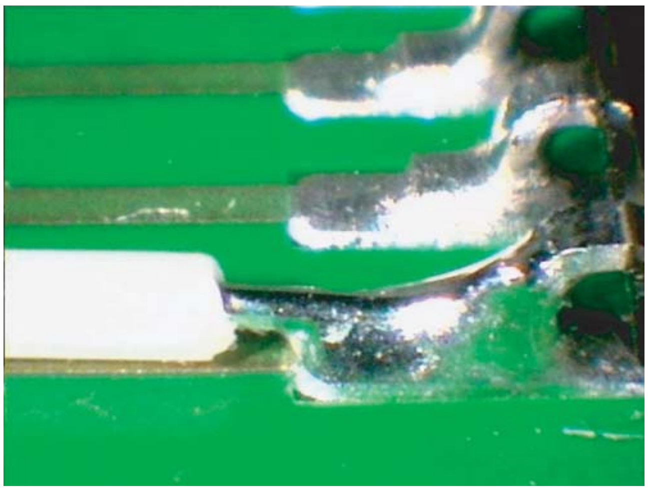


Figure 8-193

Acceptable – Class 1,2,3

- Wire length and solder wetting are equal to or greater than 75% from edge of land to knee of lead (L).
- The wire end does not extend past the lead knee bend.
- Wire does not violate minimum electrical clearance.

Figure 8-194

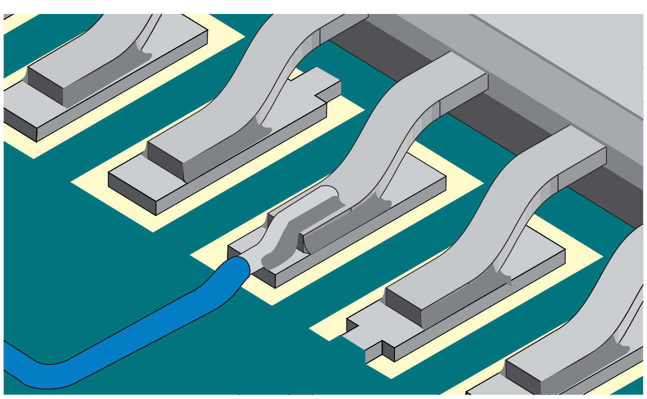


Figure 8-195

Defect – Class 1,2,3

- Wire length and solder wetting is less than 75% from edge of land to knee of lead (L).
- Wire end extends past knee of bend.
- Wire violates minimum electrical clearance.

8.6.1.3 Jumper Wires – SMT – J Lead

These criteria are applicable to jumpers attached to leads. See 8.6.1.5 for jumpers attached to lands.

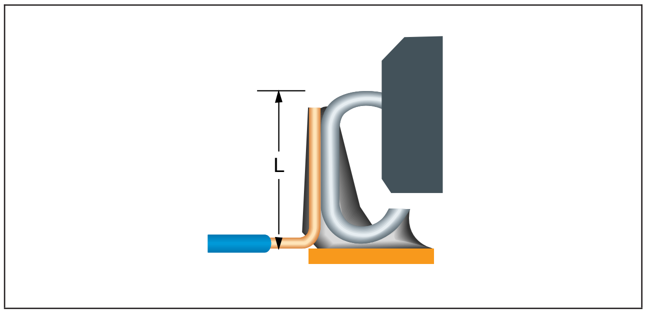


Figure 8-196

Target – Class 1,2,3

- Wire to lead-land interface solder connection is equal to (L).

Acceptable – Class 1,2,3

- Wire length and solder wetting is equal to or more than 75% height of the J lead (L).
- The wire end does not extend past the knee of the component lead.

Defect – Class 1,2,3

- Wire length and solder wetting is less than 75% height of the J lead (L).
- The wire end extends past the knee of the component lead.
- Wire violates minimum electrical clearance.

8.6.1.4 Jumper Wires – SMT – Castellations

These criteria are applicable to jumpers attached to castellations. See 8.6.1.5 for jumpers attached to lands.

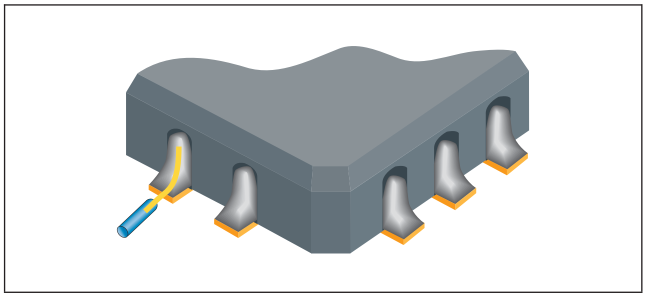


Figure 8-197

Acceptable – Class 1,2,3

- Wire length and solder wetting is at least 75% top of land to top of castellation.
- Wire is placed against the back of the castellation.
- Wire does not extend above the top of the castellation.

Defect – Class 1,2,3

- Wire length and solder wetting is less than 75% top of land to top of castellation.
- Wire end extends past top of castellation.
- Wire violates minimum electrical clearance.

8.6.1.5 Jumper Wires – SMT – Land

These criteria are applicable to vacant lands.

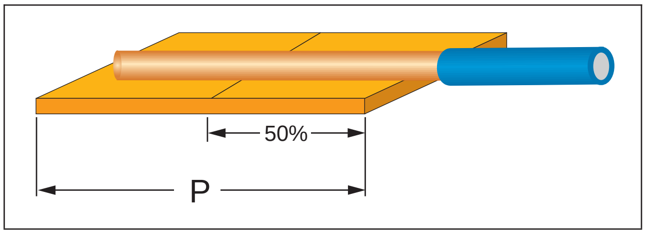


Figure 8-198

Target – Class 1,2,3

- Wire is positioned parallel to longest dimension of the land.
- Wire length and solder fillet equal to (P).

Acceptable – Class 1,2,3

- For a land width (P) that is 6 mm [0.25 in] or larger, the wetted wire to land interface is at least two conductor diameters.
- For a land width (P) less than 6 mm [0.25 in], the wetted wire to land interface is at least 50% of the land width or two conductor diameters, whichever is greater.
- Conductor discernible in solder connection.

Defect – Class 1,2,3

- For a land width (P) that is 6 mm [0.25 in] or larger, the wetted wire to land interface is less than two conductor diameters.
- For a land width (P) less than 6 mm [0.25 in], the wetted wire to land interface is less than 50% of the land width or two conductor diameters, whichever is greater.
- Conductor is not discernible in the solder connection.

9 Component Damage

The following topics are addressed in this section:

9.1 Loss of Metallization

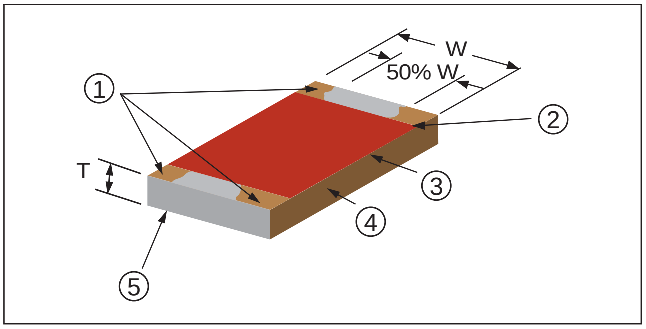


Figure 9-1
1. **Metallization missing**
2. **Adhesive coating**
3. **Resistive element**
4. **Substrate (ceramic/alumina)**
5. **Terminal end**

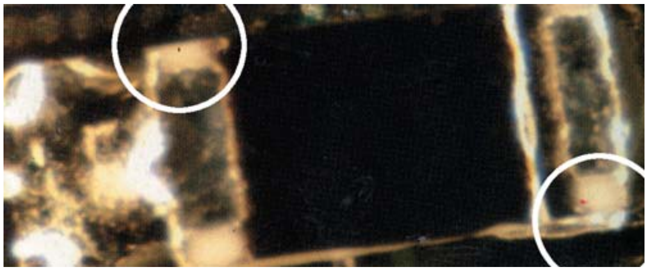


Figure 9-2

Acceptable – Class 1,2,3

- Metallization loss on any termination side (not the end face) of a five-sided termination component, up to 25% of the component width (W) or the component thickness (T).
- Maximum of 50% of metallization loss of top metallization area (for each terminal end) of a three-sided termination component, see Figures 9-1 and 9-2.

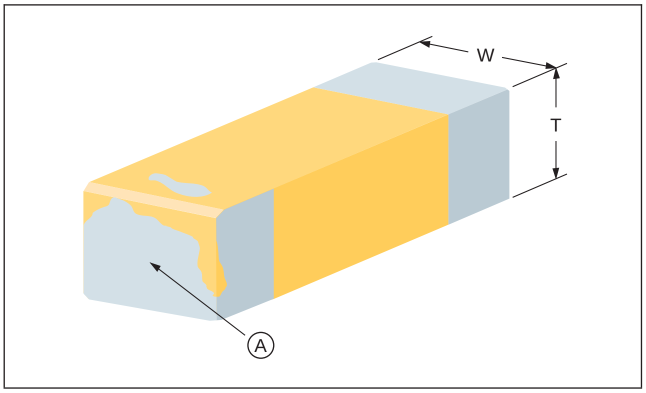


Figure 9-3

Defect – Class 1,2,3

- Metallization loss on the terminal end face exposing the ceramic, see Figure 9-3-A.
- Metallization loss on any termination side (not the end face) on a five-sided termination component greater than 25% of component width (W) or component thickness (T), see Figures 9-4 and 9-5.
- Metallization loss greater than 50% of the top area on a three-sided termination component, see Figures 9-5 and 9-6.
- Irregular shapes exceeding maximum or minimum dimensions for that component type.

9.1 Loss of Metallization (cont.)

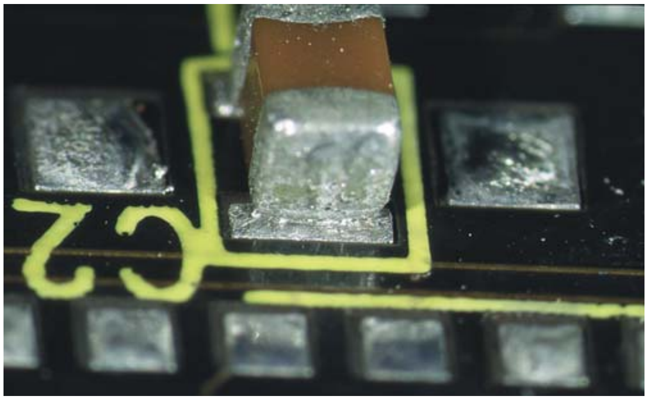


Figure 9-4

Figure 9-5


Figure 9-6

9.2 Chip Resistor Element

Figure 9-7

Acceptable – Class 1,2,3

- No damage to the resistive element or glass coating.
- No exposure of the resistive element.

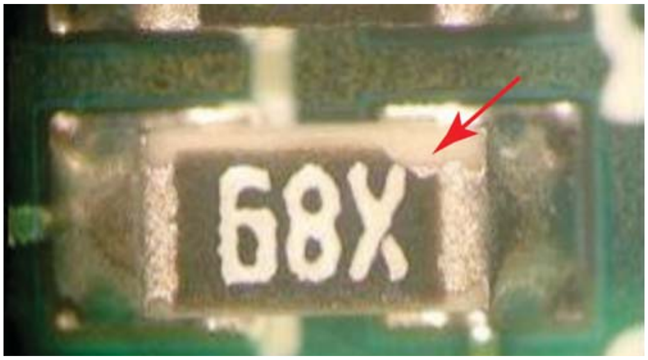


Figure 9-8

Defect – Class 1,2,3

- Damage to glass coating.
- Damage or exposure of the resistive element.

9.3 Leaded/Leadless Devices

These criteria are applicable to leaded and leadless devices.

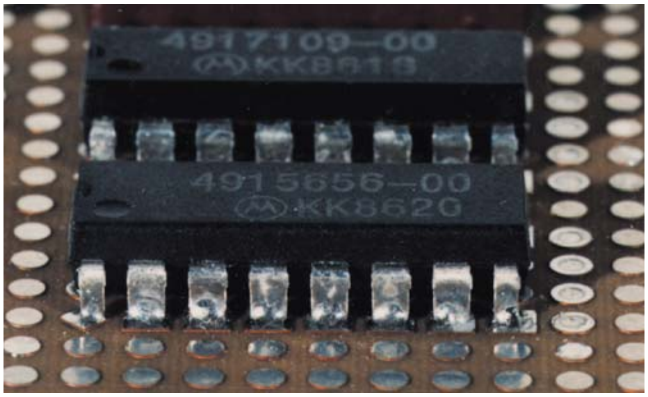


Figure 9-9

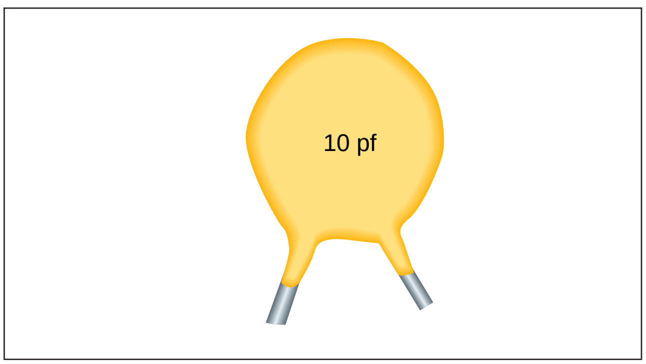


Figure 9-10

Target – Class 1,2,3

- Finish not damaged.
- Component bodies are free of scratches, cracks, chips and crazing.
- ID markings are legible.

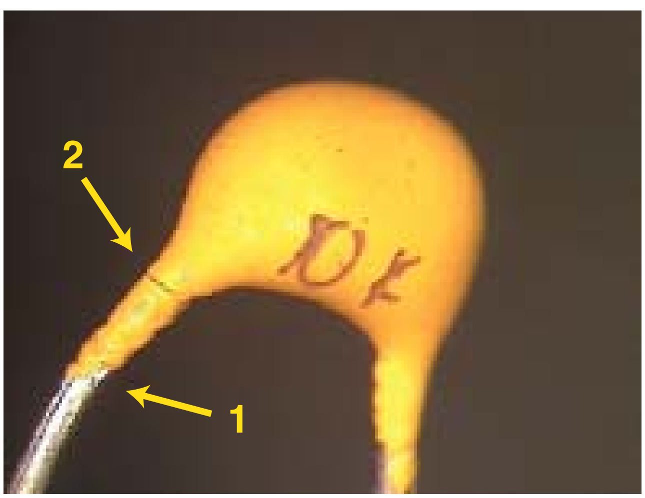


Figure 9-11
1. Chip
2. Crack

Acceptable – Class 1,2,3

- Chips or scratches that do not expose the component substrate or active element, or affect structural integrity, form, fit or function.
- Chips or cracks in component meniscus that do not expose the component substrate or active element, or affect structural integrity, form, fit or function.
- No evidence of cracks or damage to the lid or lead seals of a component.
- Dents, scratches do not affect form, fit and function and do not exceed manufacturer's specifications.
- No burned, charred components.

9.3 Leaded/Leadless Devices (cont.)

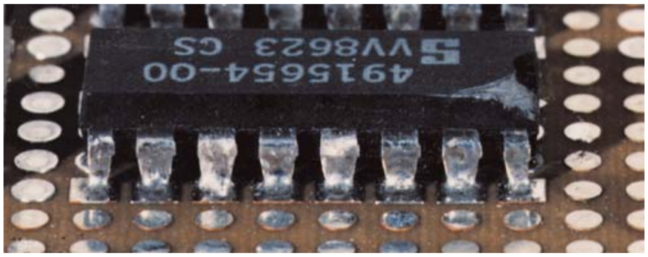


Figure 9-12

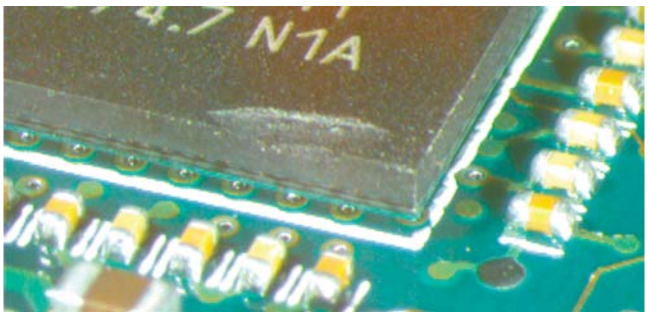


Figure 9-13

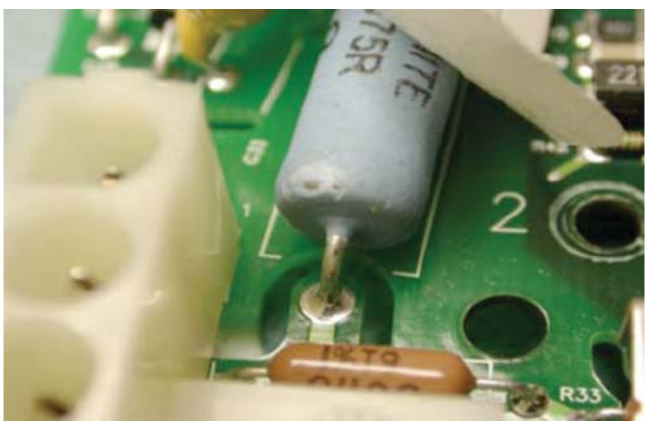


Figure 9-14

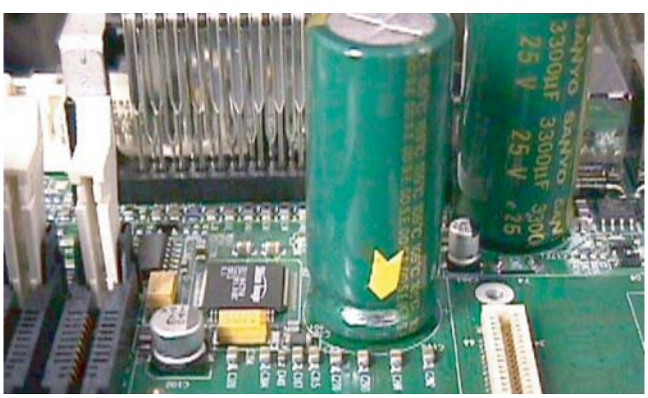


Figure 9-15

Acceptable – Class 1
Process Indicator – Class 2,3

- Indentations or chipouts on plastic body components do not enter lead seal or lid seals or expose an internal functional element, see Figures 9-12, 9-13 and 9-14.
- Component damage has not removed required identification.
- Component insulation/sleeving has damage provided that:
  - Damaged area shows no evidence of increasing, e.g., rounded edges of the damage with no cracks, sharp corners or brittle material from heat damage, etc., see Figures 9-13 and 9-14.
  - Exposed component conductive surface provides no danger of shorting to adjacent components or circuitry, see Figure 9-15.

9.3 Leaded/Leadless Devices (cont.)

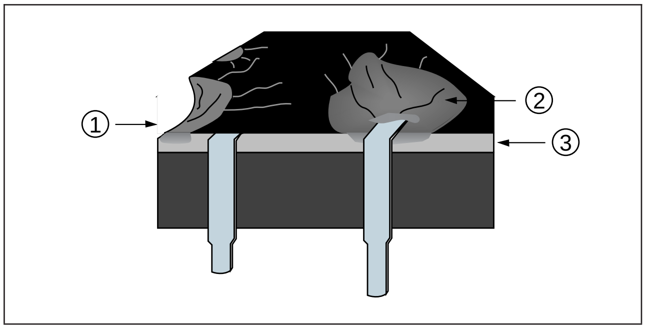


Figure 9-16
1. Chip enters seal
2. Exposed lead
3. Seal

Figure 9-17

Defect – Class 1,2,3

- Chip out or crack that enters into the seal, see Figure 9-16.
- There are cracks leading from the chipout on a ceramic body component, see Figure 9-16.
- Chip or crack that exposes the component substrate or active element, or affects hermeticity, integrity, form, fit or function, see Figure 9-17.
- Chips or cracks in glass body beyond the part specification, see Figure 9-18.
- Cracked or damaged glass bead beyond part specification (not shown).
- Required identification is missing due to component damage (not shown).
- The insulating coating is damaged to the extent that the internal functional element is exposed or the component shape is deformed (not shown).
- Damaged area shows evidence of increasing, for instance from cracks, sharp corners, brittle material from heat, etc., see Figure 9-19.
- Damage permits potential shorting to adjacent components or circuitry.
- Flaking, peeling, or blistering of plating.
- Burned, charred components (the charred surface on a component has black, dark brown appearance due to excessive heat), see Figure 9-20.
- Dents, scratches in the component body that affect form, fit and function or exceed component manufacturer's specifications, see Figure 9-21.
- Cracks in shield material, see Figure 9-22.
- Component body delaminates from substrate, see Figure 9-23.

9.3 Leaded/Leadless Devices (cont.)

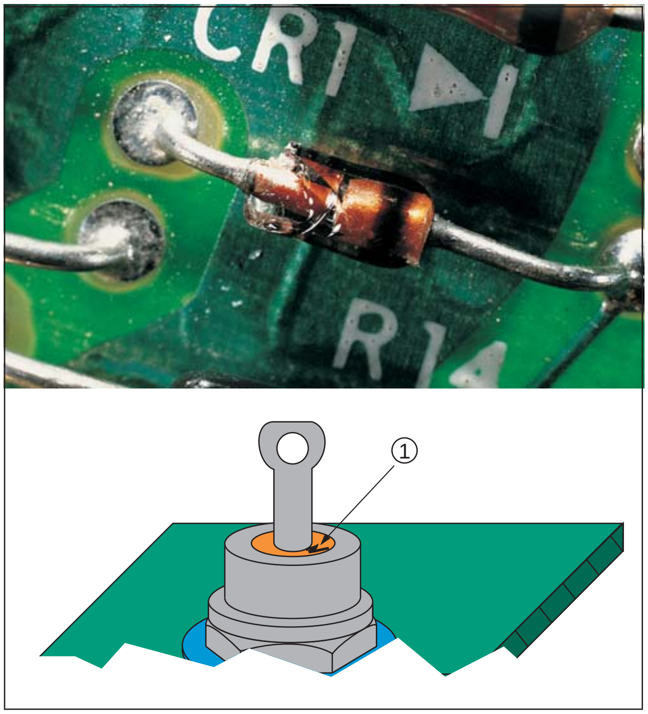


Figure 9-18

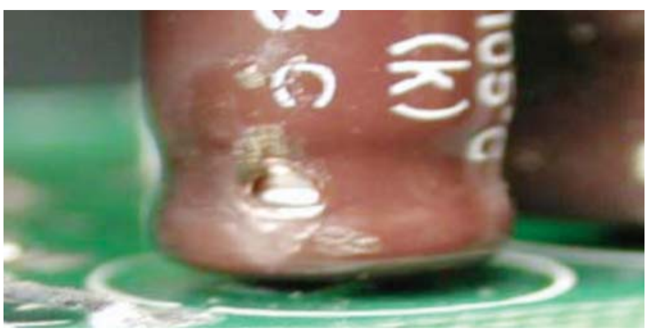


Figure 9-19

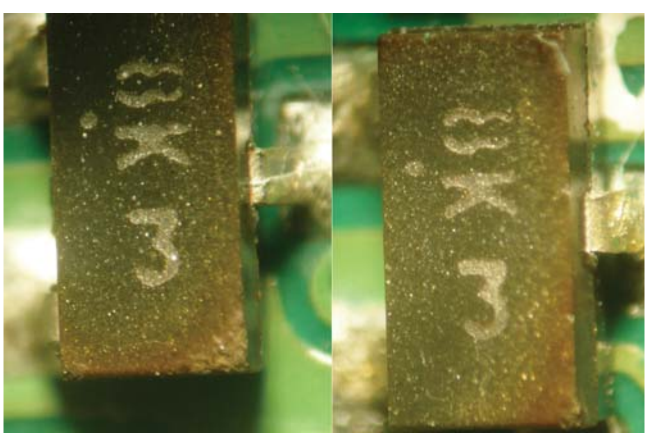


Figure 9-20

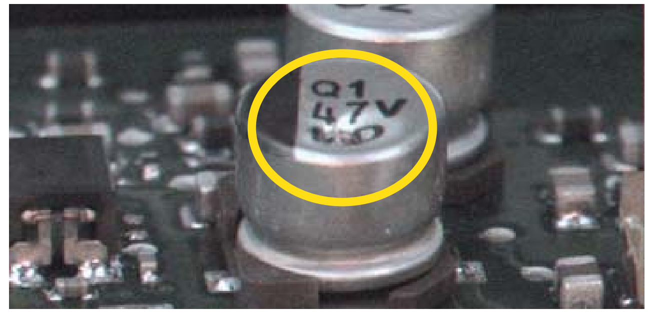


Figure 9-21

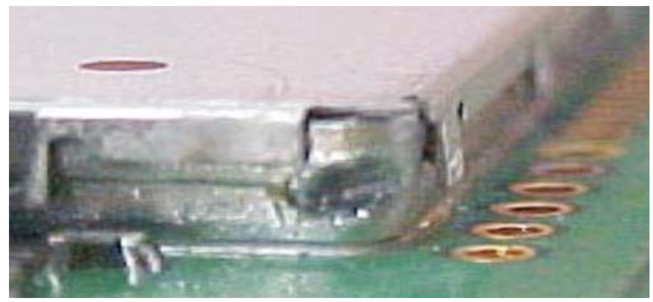


Figure 9-22

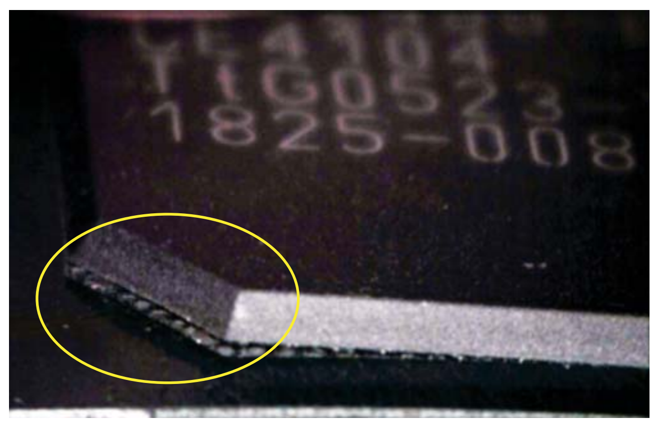


Figure 9-23

9.4 Ceramic Chip Capacitors

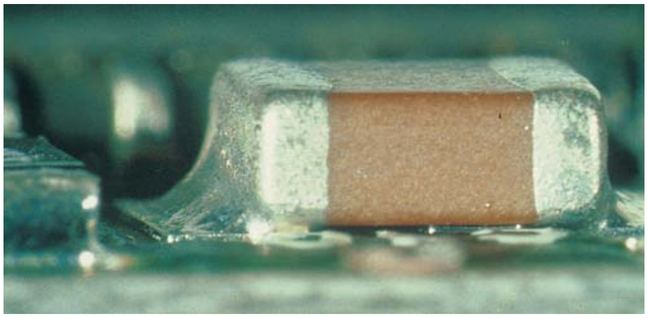


Figure 9-24

Target – Class 1,2,3

• No nicks, cracks, or stress fractures.

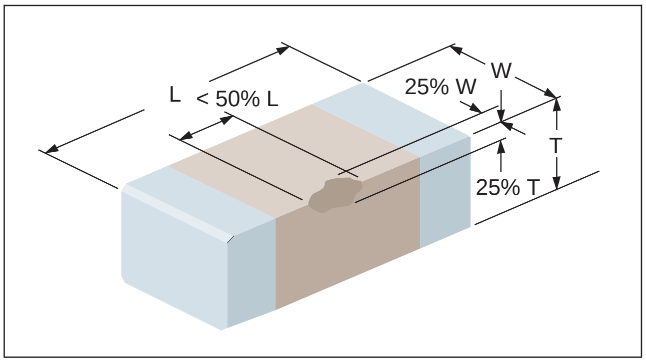


Figure 9-25

Acceptable – Class 1,2,3

• Nicks or chip-outs not greater than dimensions stated in Table 9-1, each considered separately.

Table 9-1 Chip-Out Criteria

(T)	25% of the thickness
(W)	25% of the width
(L)	50% of the length

Acceptable – Class 1,2,3

• Component color change due to thermal exposure in the reflow process.

9.4 Ceramic Chip Capacitors (cont.)

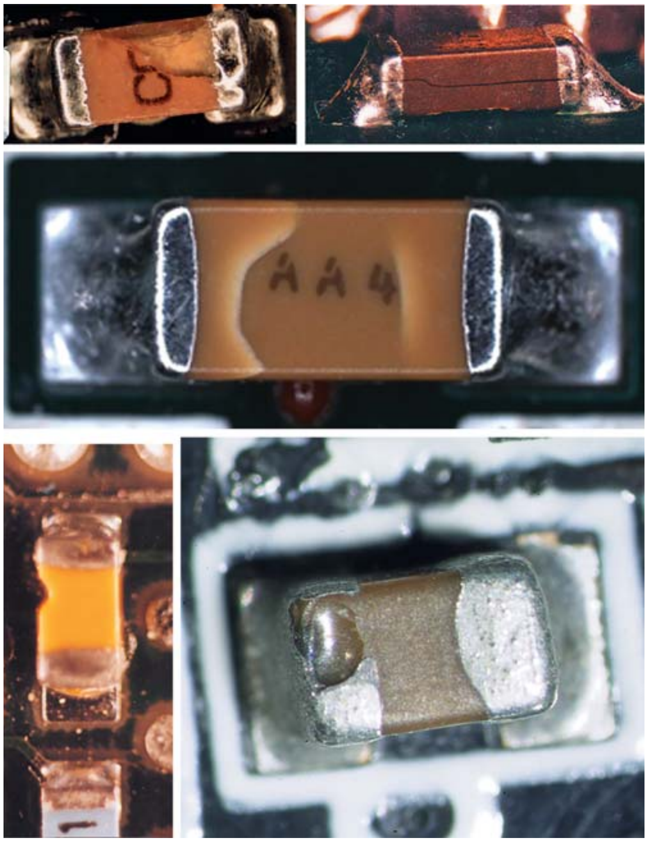


Figure 9-26

Defect – Class 1,2,3

- Any nick or chip-out in the termination area, or exposing an electrode.
- Any cracks or stress fractures.
- Damage in excess of Table 9-1.

9.5 Connectors

These criteria cover the plastic molded housings/shrouds which are used primarily as a guide for the mating connector. Connector pins are typically held by interference fit in a housing. Visual inspection of housings and shrouds includes physical damage such as cracks and deformation.

Target – Class 1,2,3

- No discernable physical damage.
- No burrs on housing/shroud.
- No cracks in housing/shroud.
- Connector/header pins are straight.

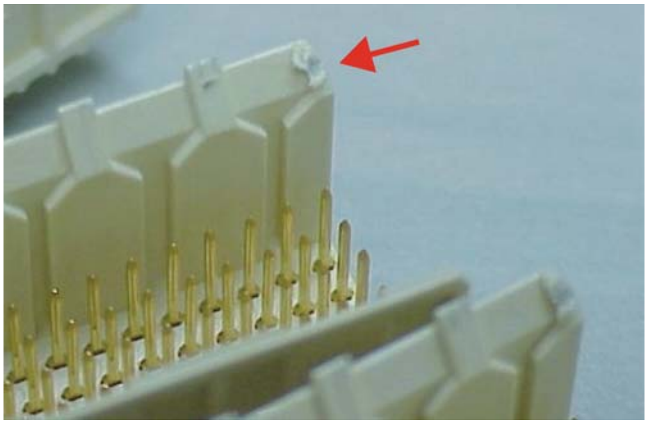


Figure 9-27

Acceptable – Class 1,2,3

- Burrs on housing but still attached (have not broken loose) and do not affect form, fit or function.
- Cracks in noncritical areas (do not impact integrity of the housing/shroud).
- Minor scratches, chips, or thermal deformation that do not compromise protection of the contacts or interfere with proper mating.
- Pins are bent off center by 25% pin thickness/diameter or less.

9.5 Connectors (cont.)

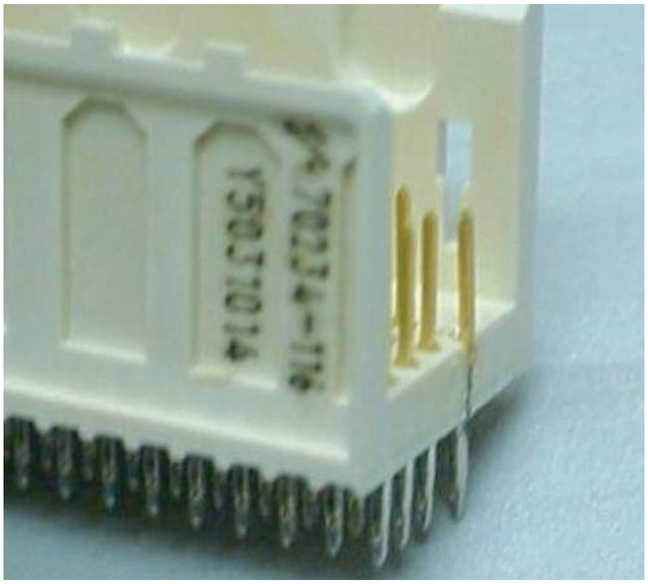


Figure 9-28

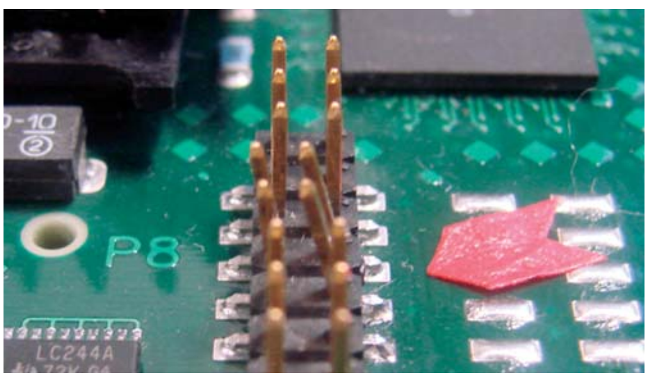


Figure 9-29

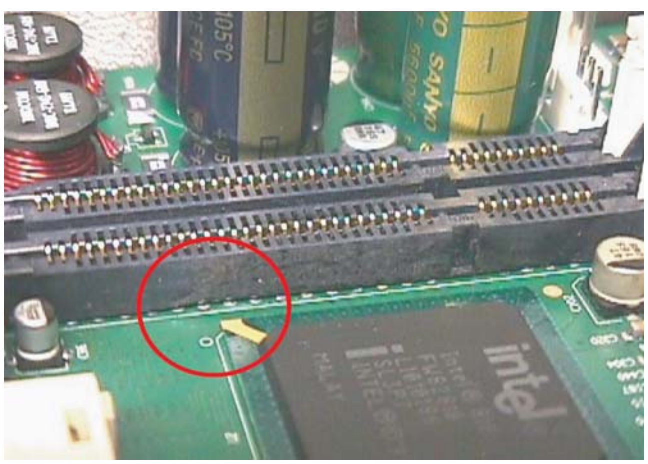


Figure 9-30

Defect – Class 1,2,3

- Burrs, cracks or other deformations that impact the mechanical integrity or functionality of the housing.
- Pins are bent off center by more than 25% pin thickness/ diameter.

Acceptable – Class 1,2,3

- No evidence of burn or char.
- Minor chips, scrapes, scratches or melting that does not affect form, fit or function.

Process Indicator – Class 2,3

- Slight discoloration.

9.5 Connectors (cont.)

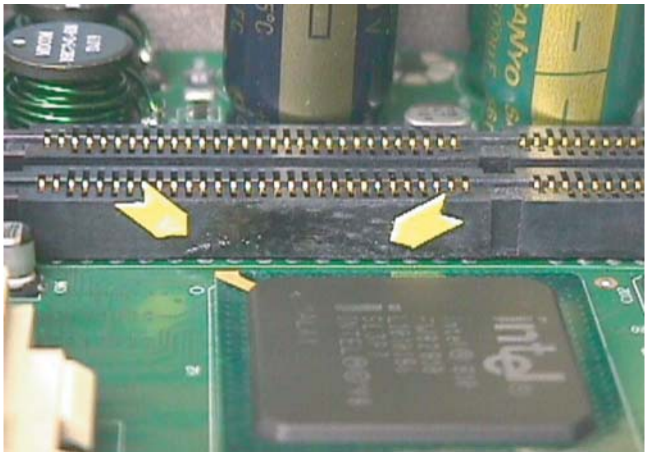


Figure 9-31

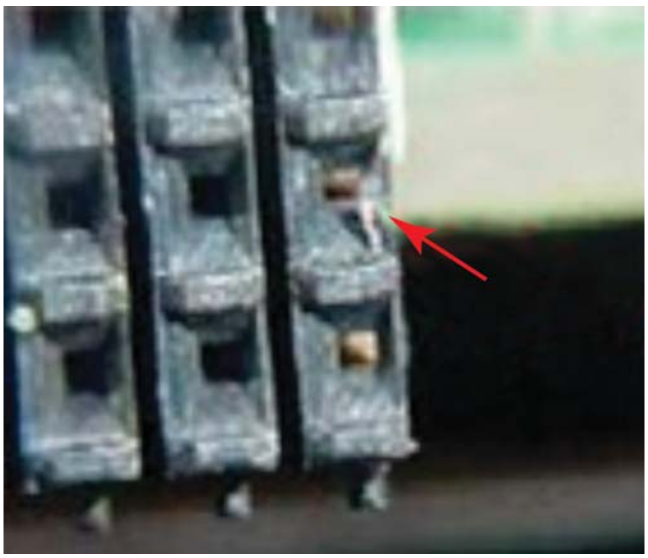


Figure 9-32

Defect – Class 1,2,3

- Evidence of burning or charring.
- Changes in shape, chips, scrapes, scratches, melting or other damage that affect form, fit or function.

9.6 Relays

Acceptable – Class 1,2,3

- Minor scratches, cuts, chips, or other imperfections that do not penetrate the case or affect the seal (not shown).

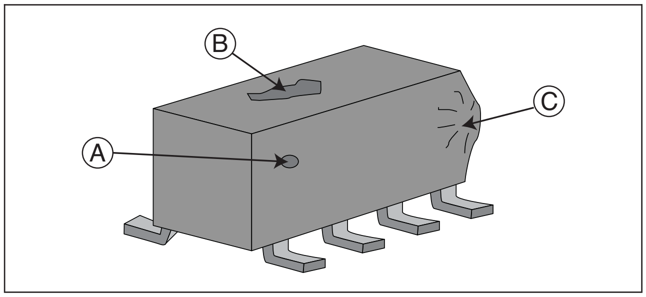


Figure 9-33

Defect – Class 1,2,3

- Scratches, cuts, chips, or other imperfections that penetrate the case or affect the seal, see Figure 9-33-A and Figure 9-33-B.
- The case is bulging or swollen, see Figure 9-33-C.

9.7 Magnetic Components

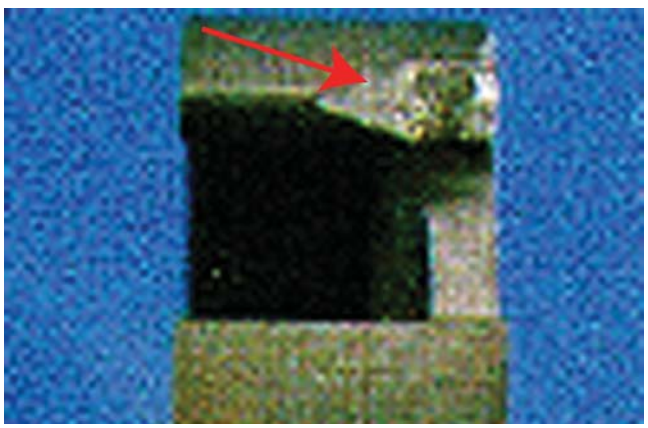


Figure 9-34

Acceptable – Class 1,2,3

- Chips and/or scratches on exterior edges of core are permissible, providing they do not extend into core mating surfaces and do not exceed 1/2 the thickness of the core.

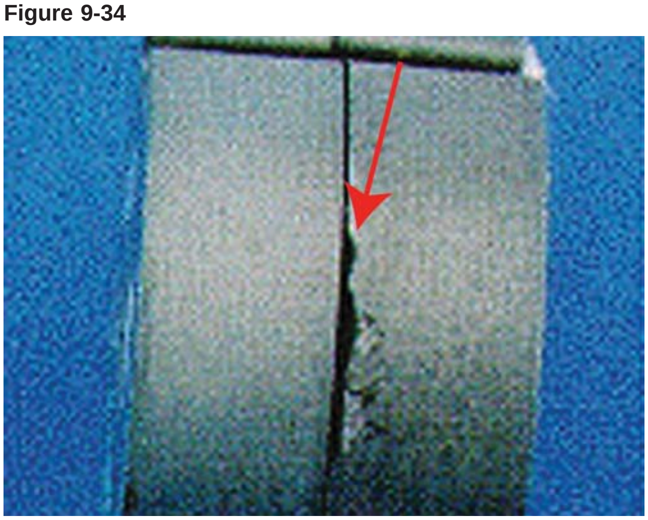


Figure 9-35

Defect – Class 1,2,3

- Chip in the core material is located on mating surface (arrow).
- Chip extending greater than 50% of the core thickness.
- Cracks in the core material.

9.8 Connectors, Handles, Extractors, Latches

This section shows some of the many different types of hardware mounted devices, e.g., connectors, handles, extractors and plastic molded parts.

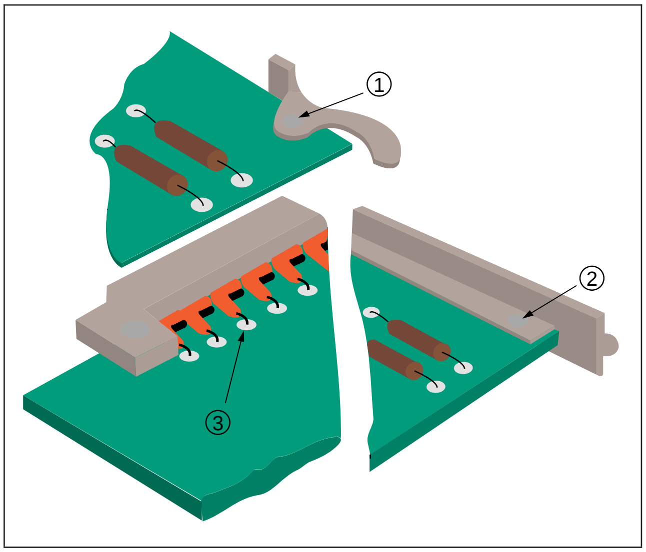


Figure 9-36
1. Extractor
2. Securing hardware
3. Component lead

Target – Class 1,2,3

- No damage to part, printed board or securing hardware (rivets, screws, etc.).

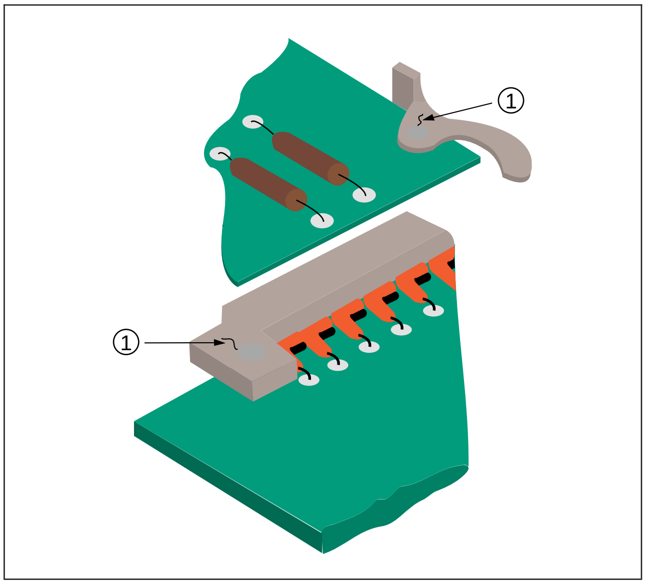


Figure 9-37
1. Crack

Acceptable – Class 1

- Cracks in the mounted part extend no more than 50% of the distance between a mounting hole and a formed edge.

Defect – Class 1

- Cracks in the mounted part extend more than 50% of the distance between a mounting hole and a formed edge.

Defect – Class 2,3

- Cracks in mounted part.

Defect – Class 1,2,3

- Crack connects a mounting hole to an edge.
- Damage/stress to connector lead pins.

9.9 Edge Connector Pins

Acceptable – Class 1,2,3

- Contact is not broken or twisted.

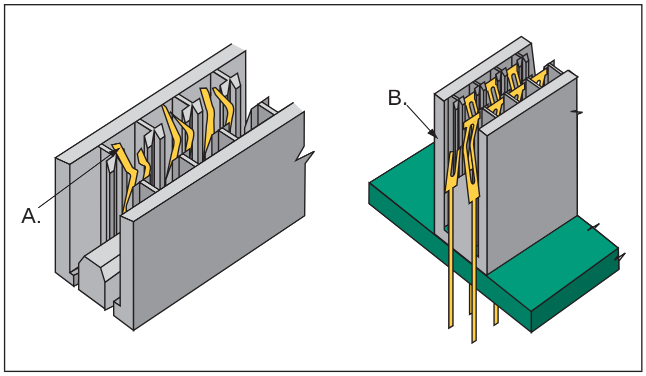


Figure 9-38

Defect – Class 1,2,3

- Contacts are twisted or otherwise deformed, see Figure 9-38-A.
- Contact is broken, see Figure 9-38-B.

9.10 Press Fit Pins

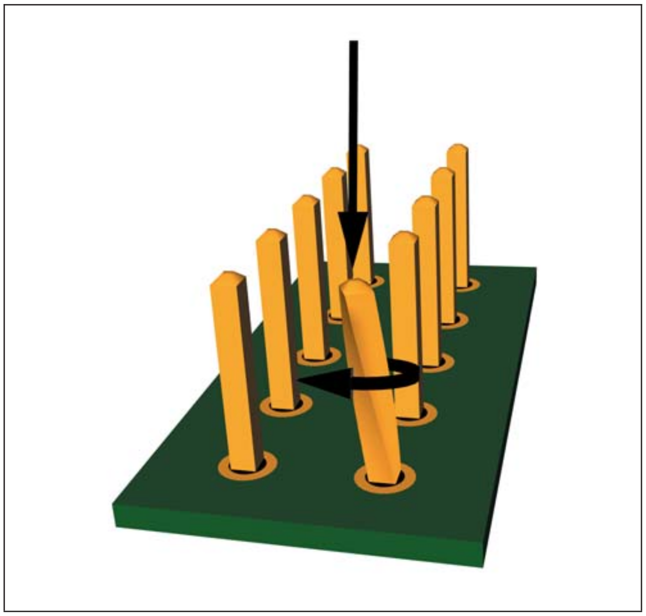


Figure 9-39

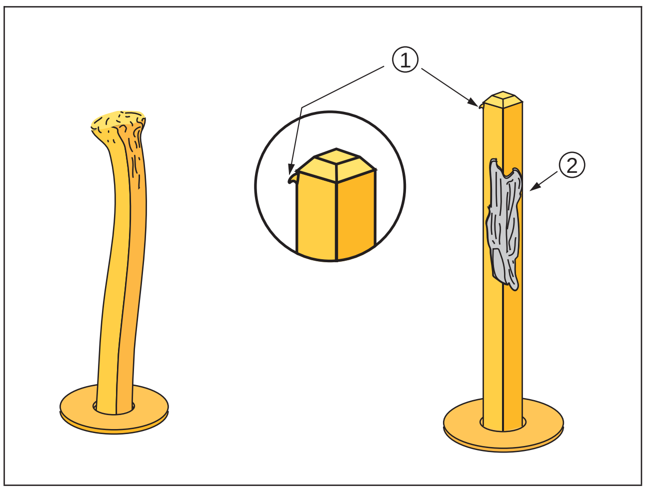


Figure 9-40
1. Burr
2. Plating missing

Defect – Class 1,2,3

- Damaged pin as a result of handling or insertion.
  - Twisted
  - Mushroomed
  - Bent, see 4.3.2
  - Exposed basis metal
  - Burr

9.11 Backplane Connector Pins

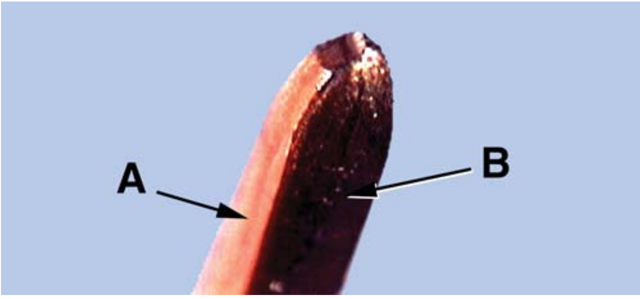


Figure 9-41
A. Sheared/nonmating surface of connector pin
B. Coined/mating surface of connector pin

Acceptable – Class 1,2,3

- Chip on nonmating surface of separable connector pin.
- Burnish on mating surface of separable connector pin, providing that plating has not been removed.
- Chip that encroaches the mating surface of separable connector pin which will not be in the mating connector contact wear path.

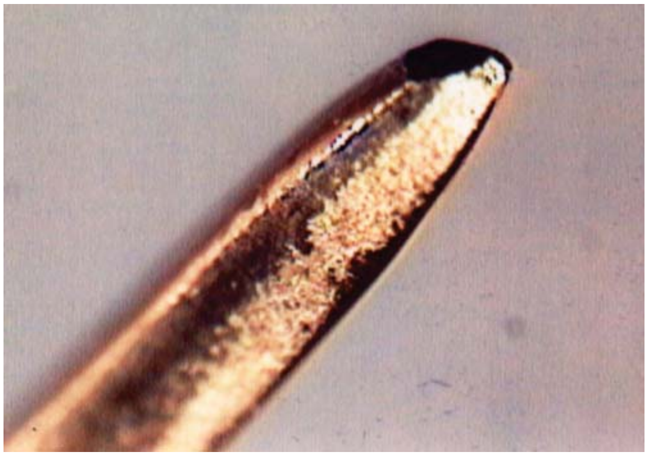


Figure 9-42

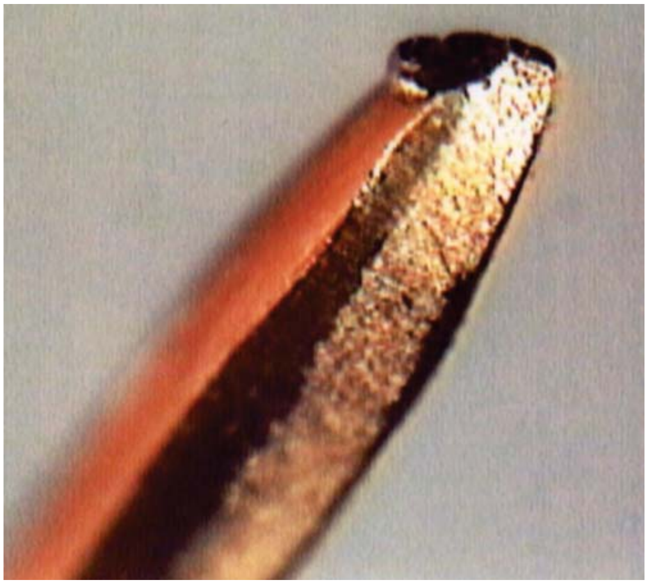


Figure 9-43

Defect – Class 1,2,3

- Chipped pin on mating surface of separable connector, see Figure 9-42.
- Scratched pin that exposes nonprecious plating or basis metal.
- Missing plating on required areas.
- Burr on pin, see Figure 9-43.
- Cracked PCB substrate.
- Pushed out barrel as indicated by copper protruding from bottom side of PCB.

9.12 Heat Sink Hardware

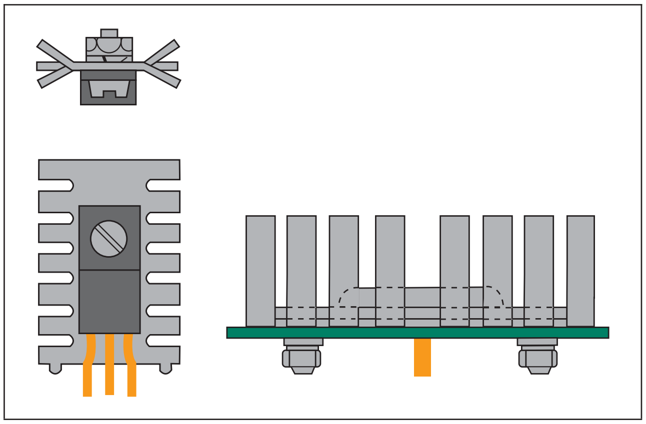


Figure 9-44
1. Heatsink

Acceptable – Class 1,2,3

- No damage or stress on heat sink hardware.

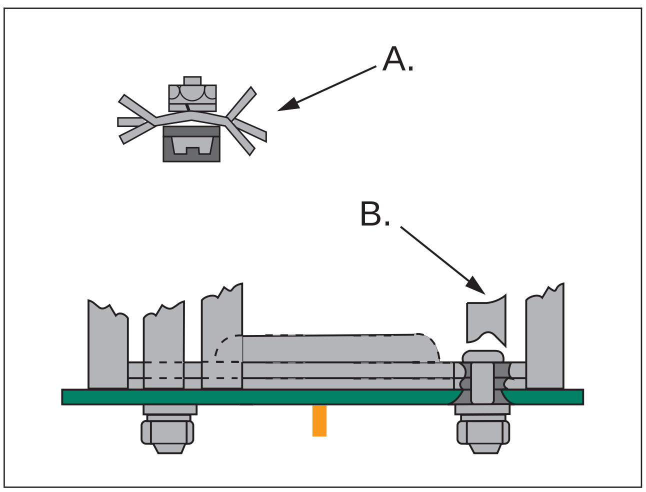


Figure 9-45

Defect – Class 1,2,3

- Bent heatsink, see Figure 9-45-A.
- Missing fins on heatsink, see Figure 9-45-B.
- Damage or stress to heat sink hardware.

9.13 Threaded Items and Hardware

Defect – Class 1,2,3

- Evidence of damage resulting from over-tightening of the threaded item.

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10 Printed Circuit Boards and Assemblies

For PCB anomalies not related to assembly caused damage refer to the applicable bare board specification criteria, e.g., IPC-6010-FAM, IPC-A-600, etc.

The following topics are addressed in this section:

10.1 Non-Soldered Contact Areas

These criteria are applicable to contacts that will mate in connectors.

See IPC-A-600 and IPC-6010-FAM for further criteria on gold fingers, gold pins or any gold surface contact area.

Inspection is typically accomplished without magnification or lighting aids. However, there may be instances where these aids are needed, e.g., pore corrosion, surface contamination.

Critical contact area (the portion that contacts the mating surface of the connector) is dependent upon the connector system scheme being used by the manufacturer. The documentation should identify those particular dimensions.

10.1.1 Non-Soldered Contact Area – Contamination

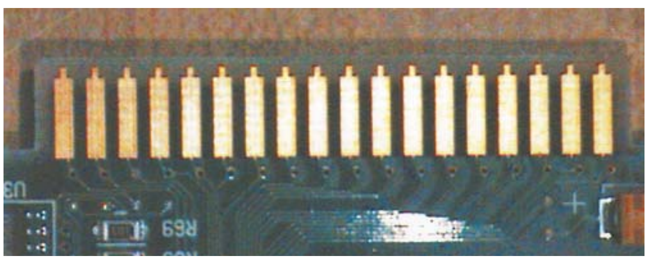

Figure 10-1

Target – Class 1,2,3

- No contamination on surface contact areas.

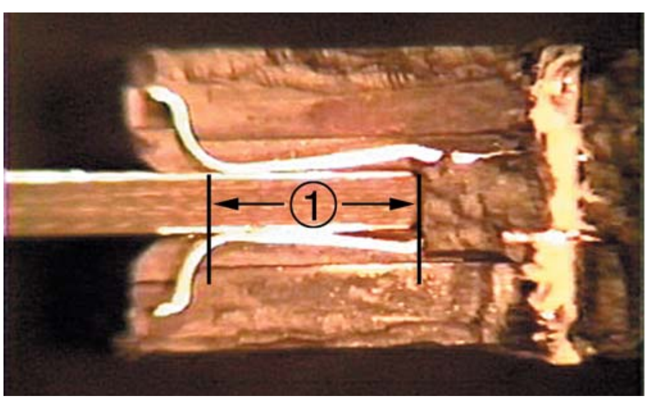

Figure 10-2
1. Critical contact area of edge fingers in contact with spring contact.

Acceptable – Class 1,2,3

- Solder is allowed in noncontact areas.

10.1.1 Non-Soldered Contact Area – Contamination (cont.)

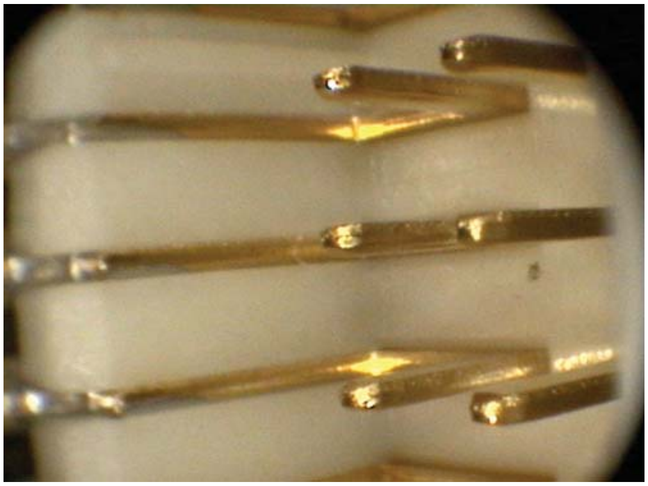

Figure 10-3

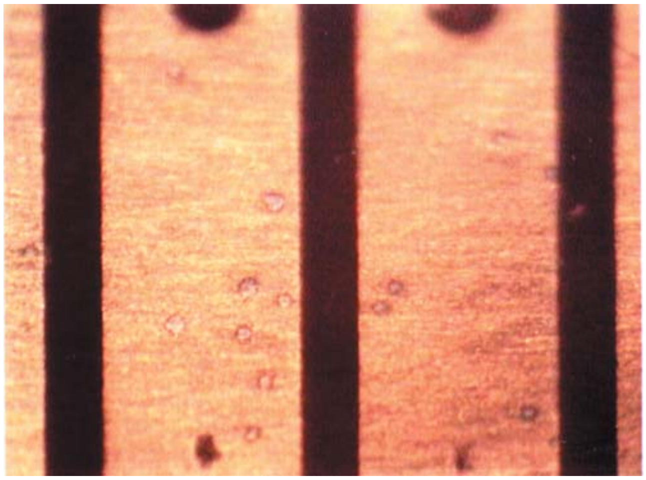

Figure 10-4

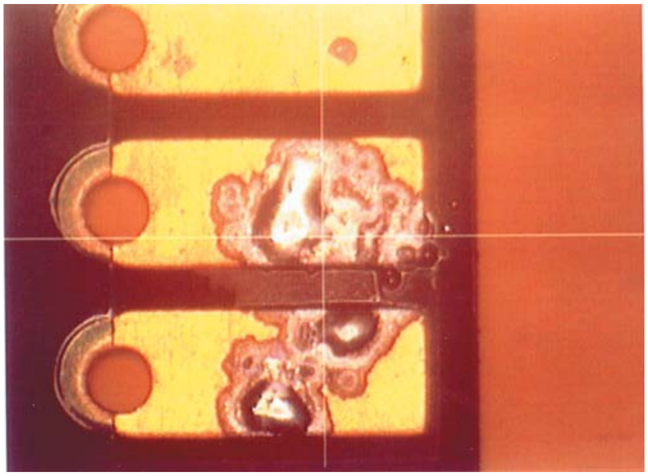

Figure 10-5

Defect – Class 1,2,3

- Solder or any other contamination in the critical contact area.

10.1.2 Non-Soldered Contact Area – Damage

Defect – Class 1,2,3

- Any surface defect in the critical contact area that exposes basis metal.

10.2 Laminate Conditions

The purpose of this section is to help the reader better understand the problem of recognizing laminate defects. In addition to providing detailed drawings and photographs to help identify common laminate defects, this section also provides acceptance criteria for the presence of measles on the board assembly.

The identification of laminate defects can be confusing. To help identify defect conditions, please refer to the following pages where definitions, illustrations and photographs have been provided that define and identify the following conditions and establish acceptance criteria:

- Measling
- Crazing
- Blistering
- Delamination
- Weave texture
- Weave exposure
- Haloing
- Edge nicks and crazing

It is important to note that laminate defect conditions may become apparent when the fabricator receives the material from the laminator, or during the fabrication or assembly of the printed board.

10.2.1 Laminate Conditions – Measling and Crazing

These are inherent conditions in the laminate caused during processing the board or assembly.

Measling or crazing that occurs as a result of an assembly process, e.g., use of press fit pins, reflow soldering, etc., will usually not increase.

Where measles are present that violate minimum electrical clearance, additional performance testing or dielectric resistance measurements may be required considering the product performance envelope, e.g., moisture environments, low atmosphere.

Where the substrate includes embedded components additional criteria may need to be defined.

Measling – An internal condition occurring in laminated base material in which the glass fibers are separated from the resin at the weave intersection. This condition manifests itself in the form of discrete white spots or crosses below the surface of the base material, and is usually related to thermally induced stress.

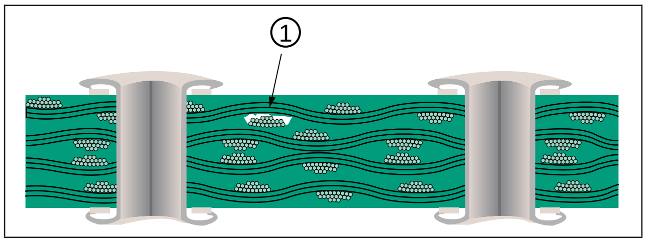

Figure 10-6
1. Measling

Figure 10-7

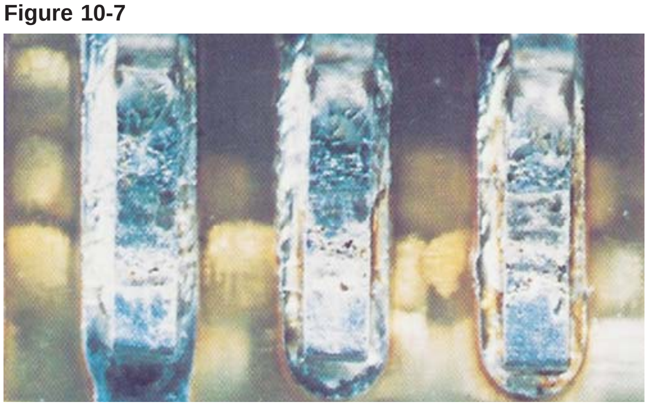

Figure 10-8

Target – Class 1,2,3

• No evidence of measling.

Acceptable – Class 1,2

• The criteria for measling are that the assembly is functional.

Process Indicator – Class 3

• Measled areas in laminate substrates exceed 50% of the physical spacing between internal conductors.

Note: There are no defect criteria for measles. Measling is an internal condition which may not propagate under thermal stress and has not been conclusively shown to be a catalyst for conductive anodic filament CAF growth. Delamination is an internal condition which may propagate under thermal stress and may be a catalyst for CAF growth. The IPC-9691 user's guide for CAF resistance testing and IPC-TM-650, Method 2.6.25, provide additional information for determining laminate performance regarding CAF growth.

10.2.1 Laminate Conditions – Measling and Crazing (cont.)

Crazing – An internal condition occurring in laminated base material in which the glass fibers are separated from the resin at the weave intersections. This condition manifests itself in the form of connected white spots or crosses below the surface of the base material and is usually related to mechanically induced stress.

See 10.2.5 for edge crazing criteria.

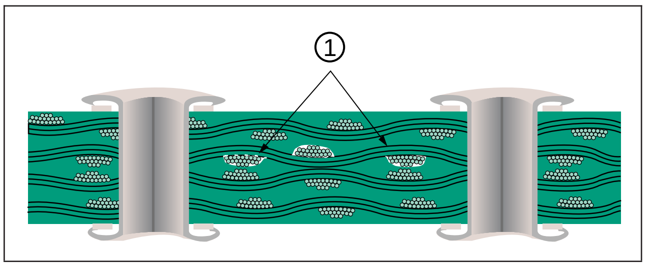

Figure 10-9
1. Crazing

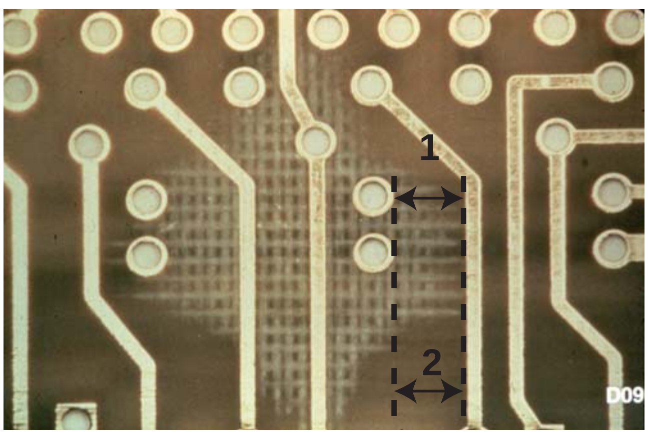

Figure 10-10
1. Crazing distance between noncommon conductors
2. Spacing between noncommom conductors

Target – Class 1,2,3

- No evidence of crazing.

Acceptable – Class 1

- The criteria for crazing are that the assembly is functional.

Acceptable – Class 2,3

- Crazed areas in laminate substrates do not exceed 50% of the physical spacing between noncommon conductors.
- Crazing does not reduce spacing below minimum electrical clearance.
- Crazing at the edge of the board does not reduce the minimum defined distance between board edge and conductive pattern. If the minimum distance is not specified not more than 50% or 2.5 mm [0.1 in], whichever is less.

Defect – Class 2,3

- Crazed areas in laminate substrates exceed 50% of the physical spacing between noncommon conductors, see Figure 10-10.
- Unless otherwise defined, crazing at the edge of the board reduces the distance between board edge and conductive pattern more than 50% or 2.5 mm [0.1 in], whichever is less.

Defect – Class 1,2,3

- Spacing is reduced below minimum electrical clearance.

10.2.2 Laminate Conditions – Blistering and Delamination

In general, delamination and blistering occurs as a result of an inherent weakness of the material or process. Delamination or blistering between nonfunctional areas and functional areas may be acceptable provided that the imperfections are nonconductive and that other criteria are met.

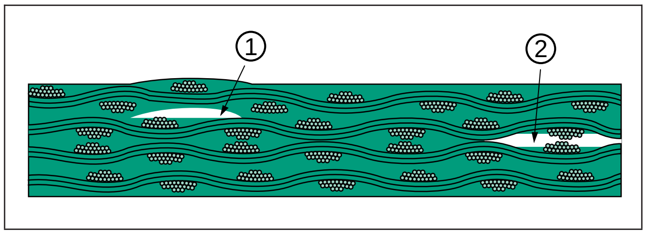

Figure 10-11

1. Blistering
2. Delamination

Blistering – Delamination in the form of a localized swelling and separation between any of the layers of a lamination base material, or between base material and conductive foil or protective coating.

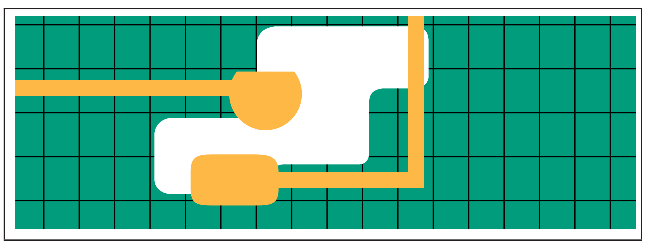

Figure 10-12

Delamination – A separation between plies within a base material, between a base material and a conductive foil or any other planar separation with a printed board.

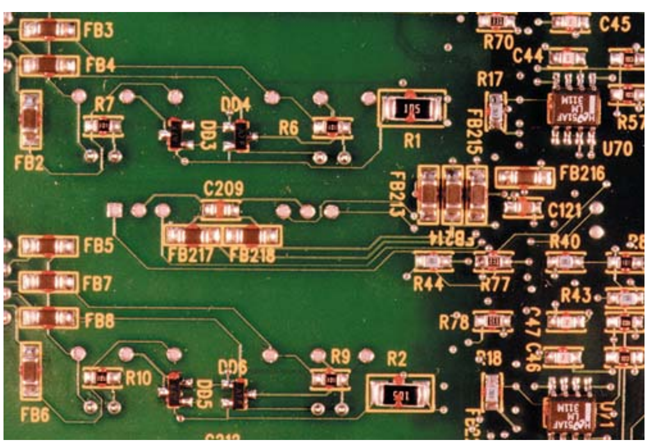

Figure 10-13

Target – Class 1,2,3

- No blistering or delamination.

Acceptable – Class 1

- The blister or delamination spans more than 25% of the distance between conductors, but does not reduce the space between internal conductor patterns below the minimum conductor spacing.

Acceptable – Class 2,3

- The blister or delamination does not span more than 25% of the distance between adjacent conductive patterns.

10.2.2 Laminate Conditions – Blistering and Delamination (cont.)

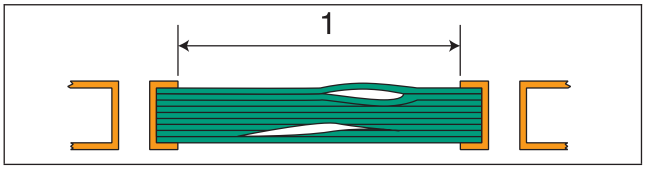

Figure 10-14
1. Spacing between noncommon conductors

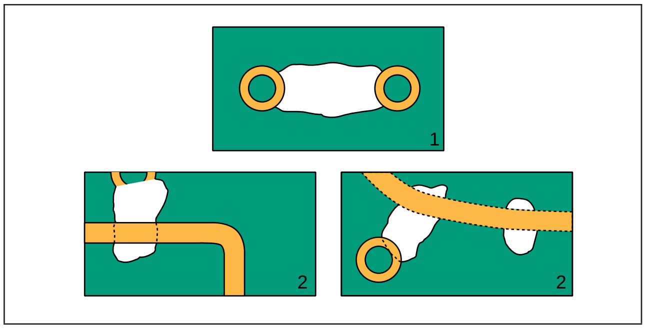

Figure 10-15

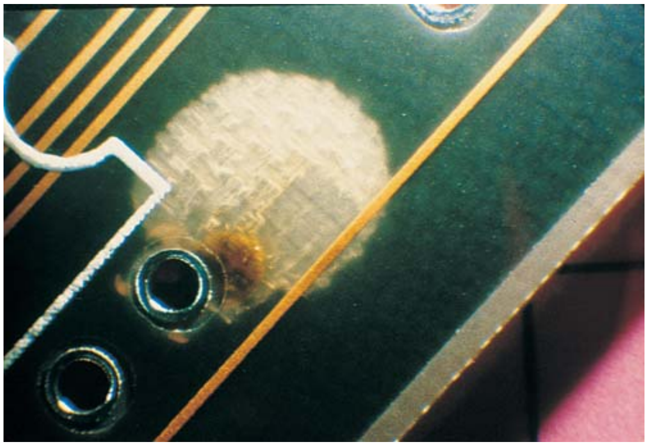

Figure 10-16

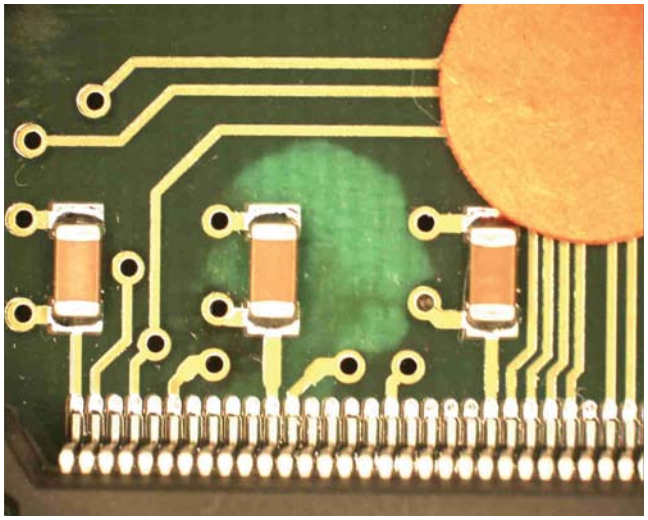

Figure 10-17

Defect – Class 2,3

- Blister/delamination exceeds 25% of the distance between plated through-holes or internal conductors.

Defect – Class 1,2,3

- Blistering/delamination reduce the space between conductive patterns below the minimum electrical clearance.

Note: Blisters or delamination areas may increase during assembly or operation. Separate criteria may need to be established.

10.2.3 Laminate Conditions – Weave Texture/Weave Exposure

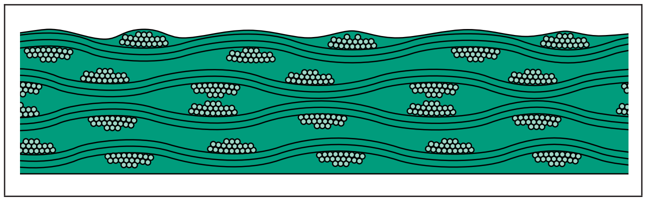
Figure 10-18

Weave Texture – A surface condition of base material in which a weave pattern of glass cloth is apparent although the unbroken fibers are completely covered with resin.

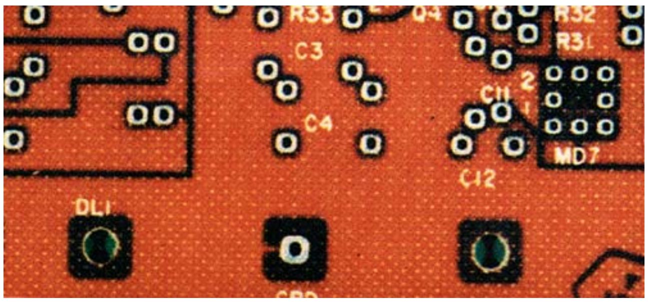

Figure 10-19

Acceptable – Class 1,2,3

- Weave texture is an acceptable condition in all classes but is confused with weave exposure because of similar appearance.

Note: Microsection may be used as a reference for this condition.

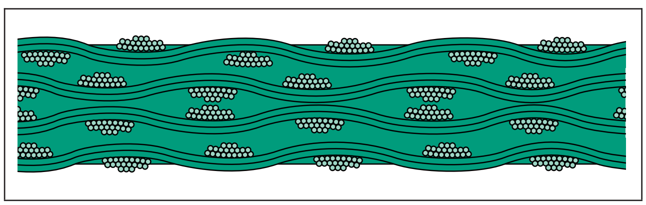
Figure 10-20

Weave Exposure – A surface condition of base material in which the unbroken fibers of woven glass cloth are not completely covered by resin.

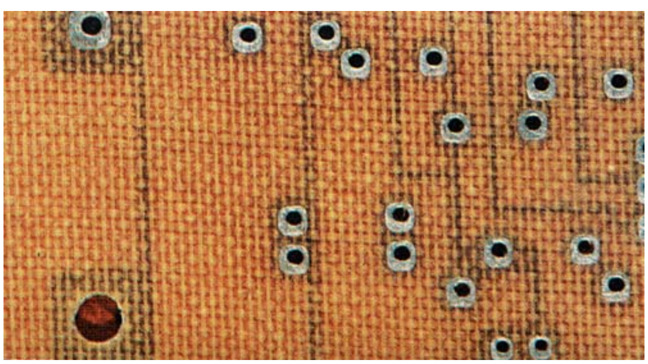
Figure 10-21

Target – Class 1,2,3

- No weave exposure.

Acceptable – Class 1,2,3

- Weave exposure does not reduce the spacing between conductive patterns below specification minimums.

Acceptable – Class 1
Defect – Class 2,3

- Surface damage that cuts into laminate fibers.

Defect – Class 1,2,3

- Weave exposure reduces the spacing between conductive patterns to less than the minimum electrical clearance.

10.2.4 Laminate Conditions – Haloing

Haloing – A condition existing in the base material in the form of a light area around holes or other machined areas on or below the surface of the base material. Mechanically induced fracturing or delamination on or below the surface of the base material; a light area around the holes, other machined areas or both are usually indications of haloing.

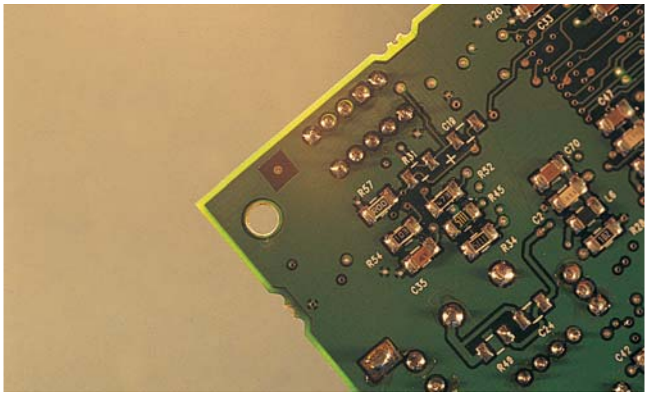

Figure 10-22

Target – Class 1,2,3

- No haloing.

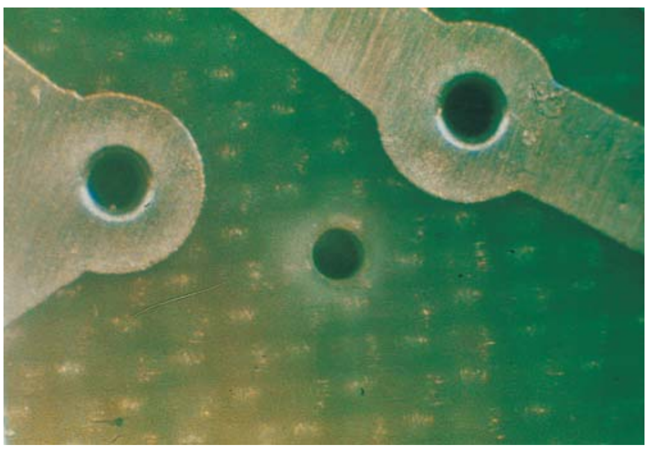

Figure 10-23

Acceptable – Class 1,2,3

- The distance between the haloing penetration and the nearest conductive feature is not less than the minimum lateral conductor spacing, or 0.1 mm [0.004 in] when the minimum lateral conductor spacing is not specified.

Figure 10-24

10.2.4 Laminate Conditions – Haloing (cont.)

Figure 10-25

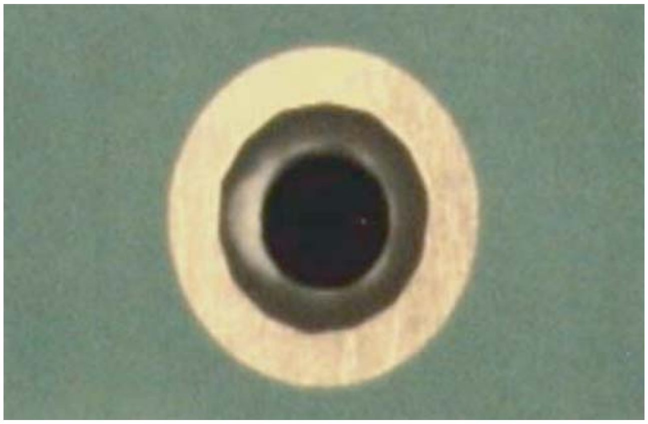

Figure 10-26

Defect – Class 1,2,3

- The distance between the haloing penetration and the nearest conductive feature is less than the minimum lateral conductor spacing, or less than 0.1 mm [0.004 in] when the minimum lateral conductor spacing is not specified.

10.2.5 Laminate Conditions – Edge Delamination, Nicks and Crazing

Delamination – A separation between plies within a base material, between a base material and a conductive foil, or any other planar separation within a printed board.

10.2.1 has additional crazing criteria.

Target – Class 1,2,3

- No edge delamination.
- No nicks, crazing or damage on smooth board edges.

Acceptable – Class 1,2,3

- Nicks do not exceed 50% of the distance from the printed board edge to the nearest conductor or 2.5 mm [0.1 in], whichever is less.
- Delamination or crazing at the edge of the printed board does not reduce spacing to the nearest conductor to less than the specified minimum distance or less than 2.5 mm [0.1 in] if not specified.
- Board edges are rough but not frayed.

10.2.5 Laminate Conditions – Edge Delamination, Nicks and Crazing (cont.)

Figure 10-27

Figure 10-28

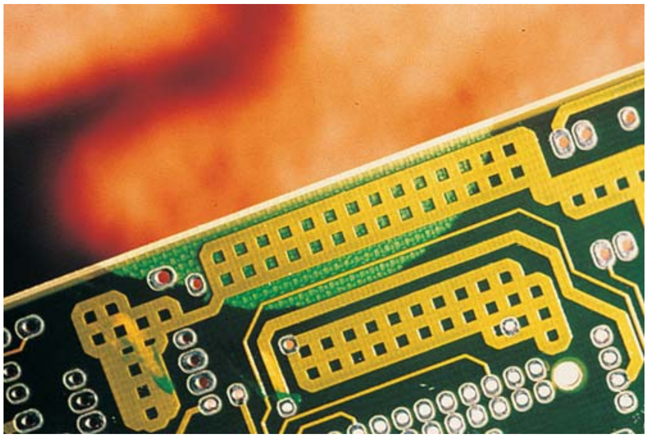

Figure 10-29

Defect – Class 1,2,3

- Nicks exceed 50% of the distance from the printed board edge to the nearest conductor or 2.5 mm [0.1 in], whichever is less, see Figure 10-27.
- Delamination or crazing at the edge of the printed board reduces spacing to the nearest conductor to less than the specified minimum distance or less than 2.5 mm [0.1 in] if not specified.
- Cracks in the laminate, see Figure 10-28 arrow.

10.2.6 Laminate Conditions – Burns

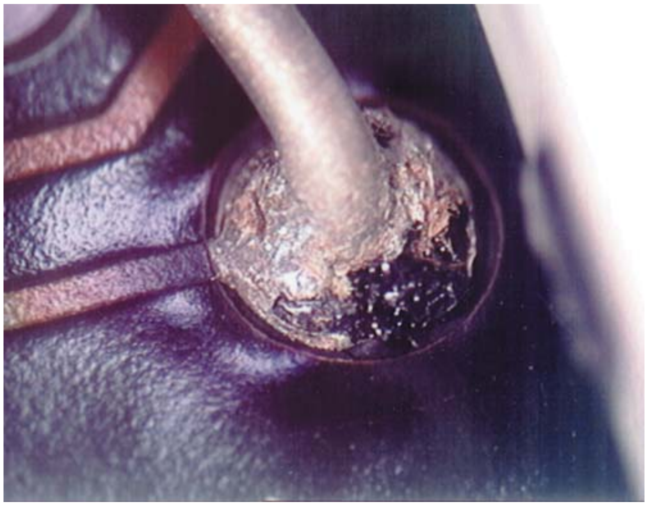

Figure 10-30

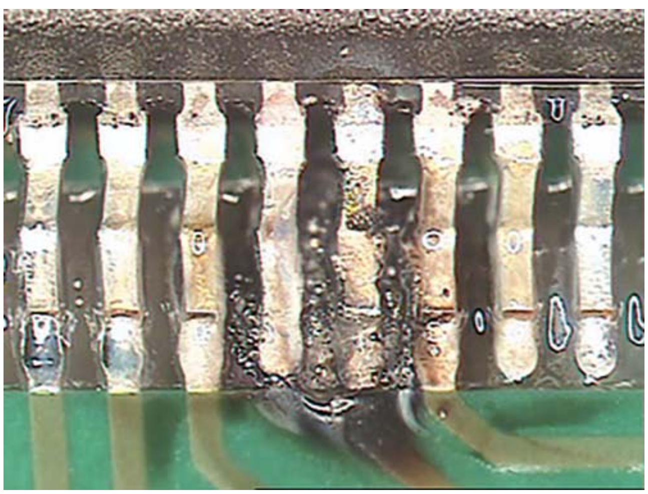

Figure 10-31

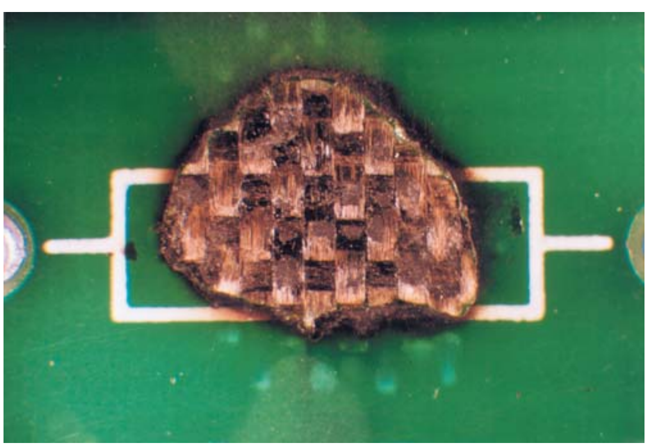

Figure 10-32

Defect – Class 1,2,3

- Burns that physically damage surface or the assembly.

10.2.7 Laminate Conditions – Bow and Twist

Figure 10-33 is an example of bow.

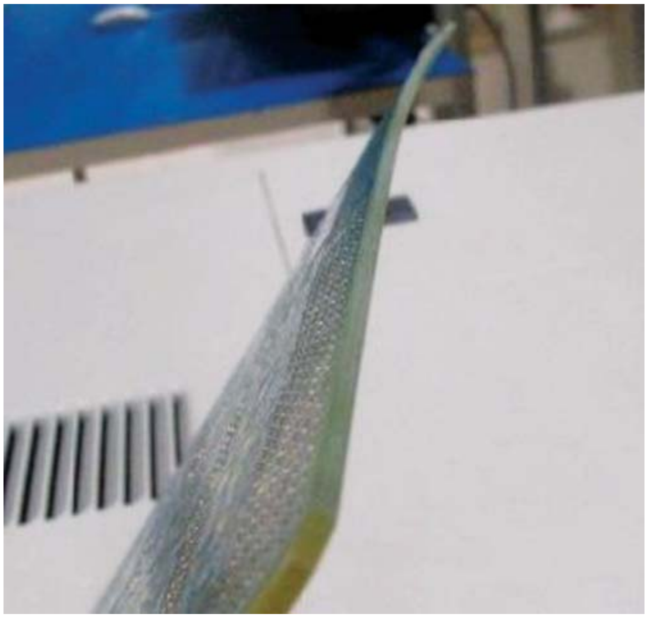

Figure 10-33

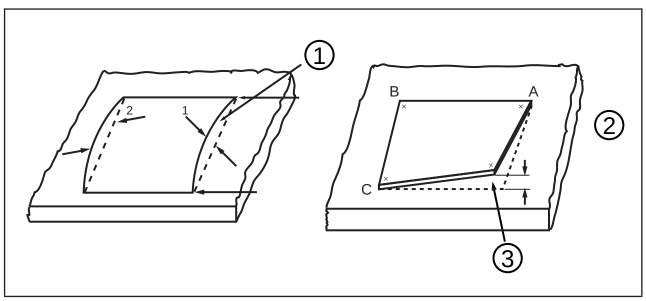

Figure 10-34
1. **Bow**
2. **Points A, B and C are touching base**
3. **Twist**

Acceptable – Class 1,2,3

- Bow and twist does not cause damage during post solder assembly operations or end use. Consider ''Form, Fit and Function'' and product reliability.

Defect – Class 1,2,3

- Bow and twists causes damage during post solder assembly operations or end use or affects form, fit or function.

Note: Bow and twist after solder should not exceed 1.5% for through-hole and 0.75% for surface mount printed board applications. IPC-TM-650 has Test Method 2.4.22 but this is specifically for bare boards. Component size and placement on assemblies often precludes use of that test method for populated assemblies. It may be necessary to confirm through testing that bow and twist has not created stress that will result in solder connection fracture, component damage or will otherwise cause damage during post solder assembly operations or use.

10.2.8 Laminate Conditions – Depanelization

These criteria are applicable to PCAs with or without breakaway tabs. IPC-A-600 provides additional criteria for depanelization of bare boards.

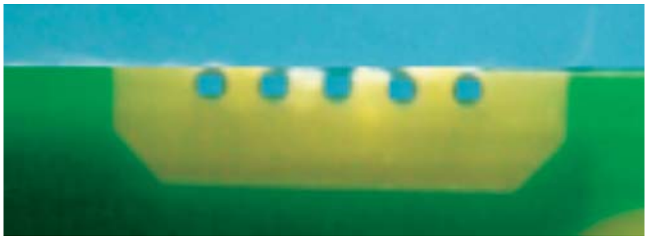

Figure 10-35

Figure 10-36

Target – Class 1,2,3

- Edges are smooth with no burrs, nicks or haloing.

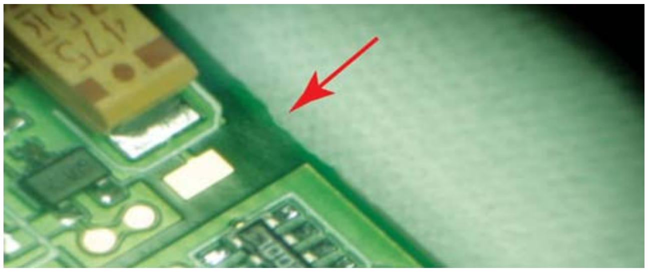

Figure 10-37

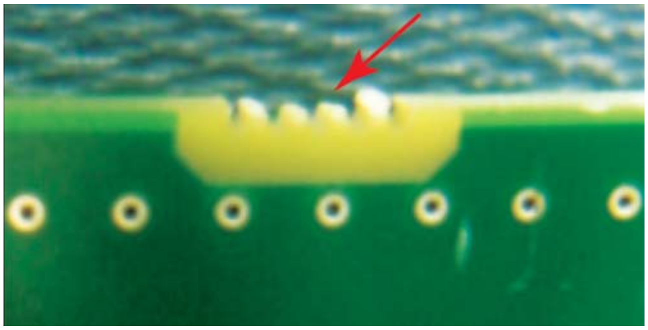

Figure 10-38

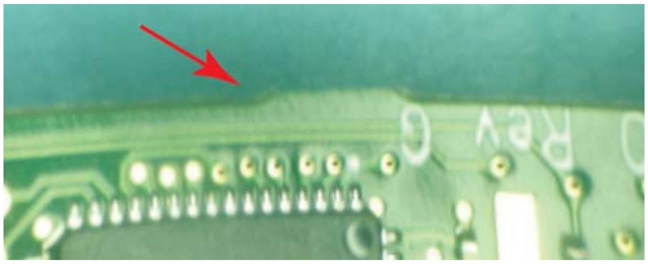

Figure 10-39

Acceptable – Class 1,2,3

- Edges are rough but not frayed.
- Nicks or routing do not exceed 50% of the distance from the board edge to the nearest conductor or 2.5 mm [0.1 in], whichever is less. See 10.2.4 for haloing and 10.2.1 for crazing.
- Loose burrs do not affect fit, form or function.

10.2.8 Laminate Conditions – Depanelization (cont.)

Figure 10-40

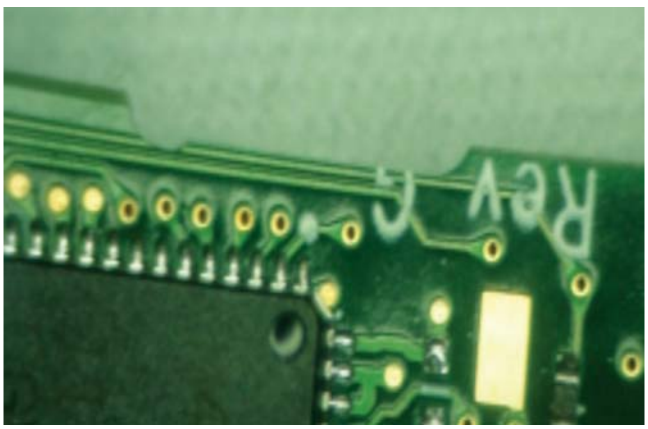

Figure 10-41

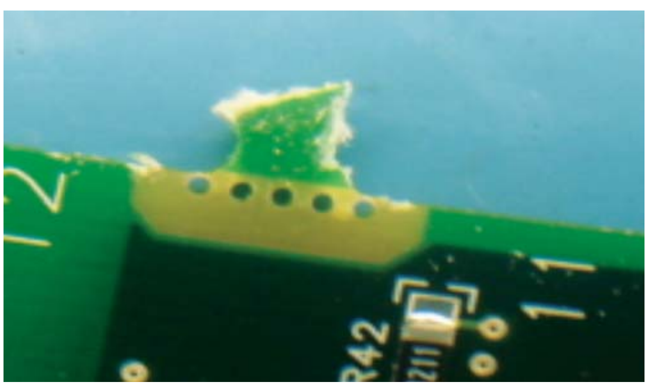

Figure 10-42

Defect – Class 1,2,3

- Edges are frayed.
- Nicks or routing exceed 50% of the distance from the board edge to the nearest conductor or 2.5 mm [0.1 in], whichever is less. See 10.2.4 for haloing and 10.2.1 for crazing.
- Loose burrs affect fit, form or function.

10.3 Conductors/Lands

10.3.1 Conductors/Lands – Reduction

These criteria are applicable to conductors and lands on rigid, flex and rigid-flex circuitry.

IPC-6010-FAM provides the requirements for conductor width and thickness reduction.

Conductor – The physical geometry of a conductor is defined by its width x thickness x length.

Conductor Width Reduction – Reduction of the conductor width (specified or derived) due to individual defects, i.e., edge roughness, nicks, pinholes and scratches.

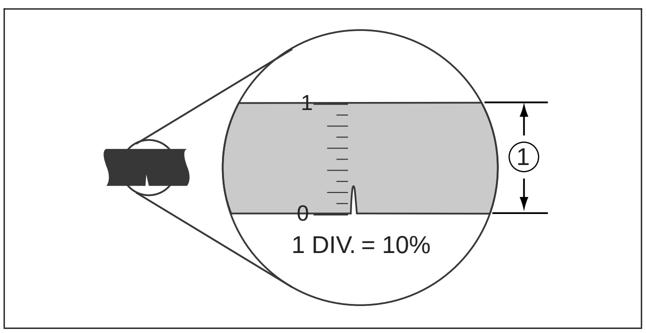

Figure 10-43
1. Minimum conductor width

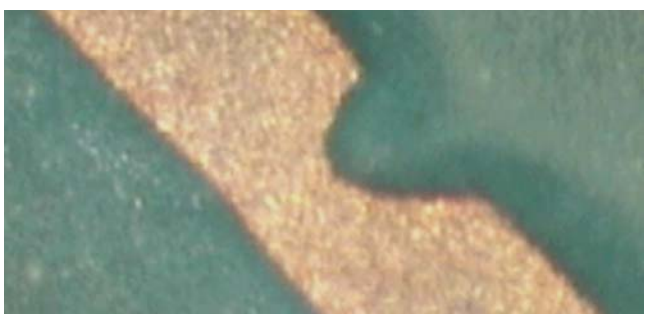

Figure 10-44

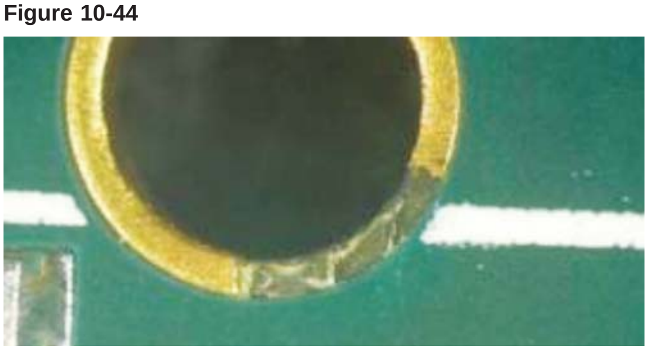

Figure 10-45

Defect – Class 1

- Reduction in width of printed conductors by more than 30%.
- Reduction in width or length of lands by more than 30%.

Defect – Class 2,3

- Reduction in width of printed conductors by more than 20%.
- Reduction in width or length of lands by more than 20%.

Note: Even small changes in cross-sectional area can have a large impact on impedance of RF circuitry. Alternate criteria may need to be developed.

10.3.2 Conductors/Lands – Lifted

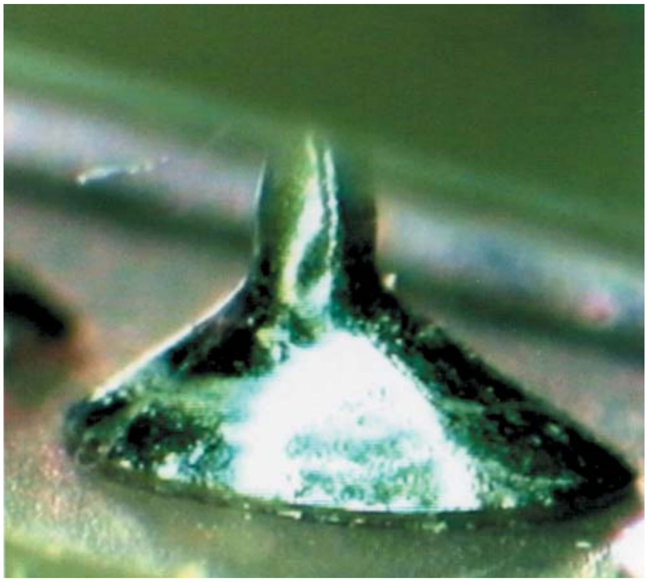

Figure 10-46

Target – Class 1,2,3

- No separation between conductor or land and the laminate surface.

Figure 10-47

Process Indicator – Class 1,2,3

- Separation between outer edge or land and laminate surface is less than one land thickness.

Note: Lifted and/or separated land area(s) is typically a result of the soldering process that warrants immediate investigation to determine root cause. Efforts to eliminate and/or prevent this condition should be made.

10.3.2 Conductors/Lands – Lifted (cont.)

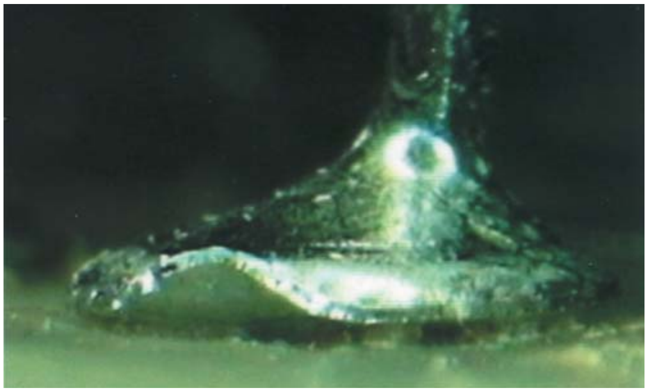

Figure 10-48

Defect – Class 1,2,3

- Separation between land and laminate surface is greater than one land thickness.
- Any separation of circuit conductor (trace) from the laminate surface.

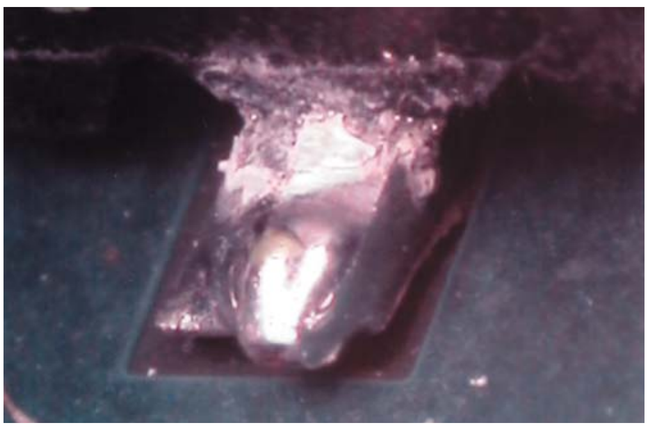

Figure 10-49

Defect – Class 3

- Any lifting of a surface mount land if there is a via in the land.

Figure 10-50

10.3.3 Conductors/Lands – Mechanical Damage

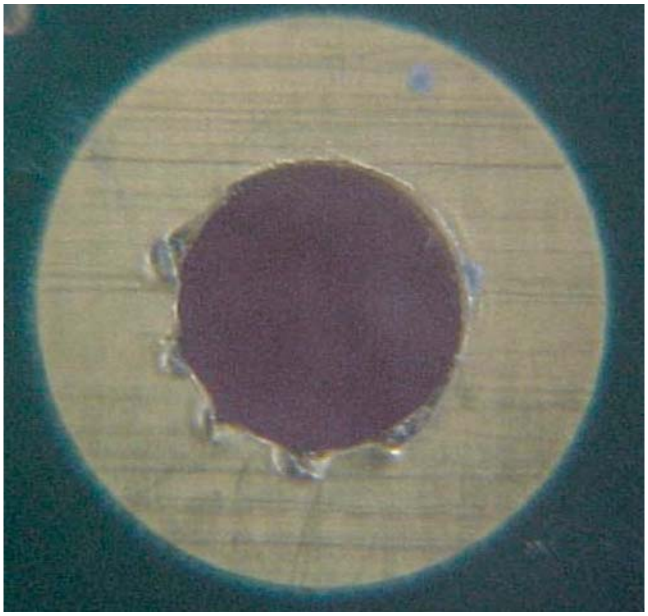

Figure 10-51

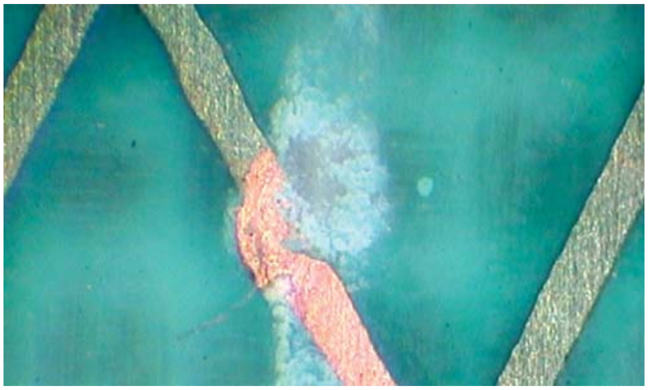

Figure 10-52

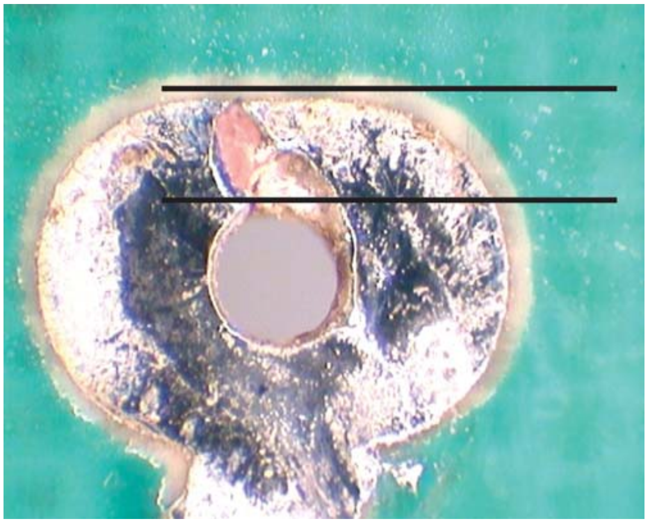

Figure 10-53

Defect – Class 1,2,3

- Damage to functional conductors or lands that affects form, fit or function.

10.4 Flexible and Rigid-Flex Printed Circuitry

10.4.1 Flexible and Rigid-Flex Printed Circuitry – Damage

The trimmed edge of the flexible printed circuit or the flexible section rigid-flex printed circuit is free of burrs, nicks, delamination or tears in excess of that allowed in the procurement documentation.

Cuts, nicks, gouges, tears or other physical damage affecting the flex material thickness **shall not** result in exposed circuitry.

Note: Mechanically created indentations caused by contact between the coverlayer of flexible printed circuit boards or assemblies and molten solder are not rejectable. Additionally, care should be taken to avoid bending or flexing conductors during inspection.

The deformation of a stiffener board should conform to the master drawing or the individual specification. See 10.2.4 and 10.2.5.

Note: For SMT or through-hole component mounting, placement, soldering, cleanliness criteria on flex assemblies, etc., follow the applicable sections of this Standard.

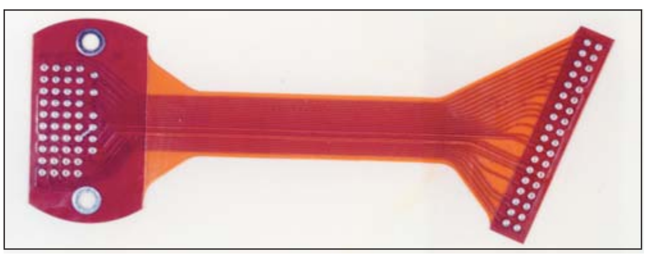

Figure 10-54

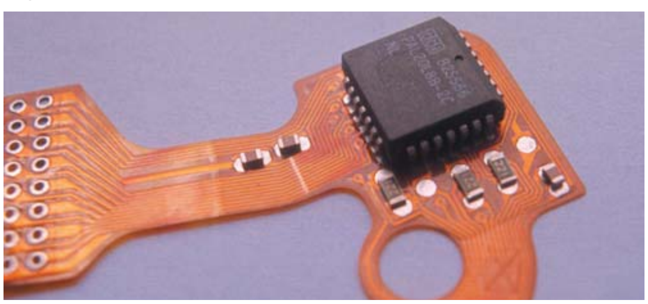

Figure 10-55

Target – Class 1,2,3

- Free of nicks, tears, burns, charring or melting. Minimum edge to conductor spacing maintained.
- The trimmed edge of the flexible printed circuitry or the flexible section of finished rigid-flex printed circuitry is free of burrs, nicks, delamination and tears.

Acceptable – Class 1

- Nicks or damage along the edges of the flexible printed circuitry and cutouts, providing the penetration does not exceed 50% of the distance from the edge to the nearest conductor or 2.5 mm [0.1 in], whichever is less.

Acceptable – Class 2,3

- No nicks, tears or imperfections along the flexible edges of the flexible printed circuity.

10.4.1 Flexible and Rigid-Flex Printed Circuitry – Damage (cont.)

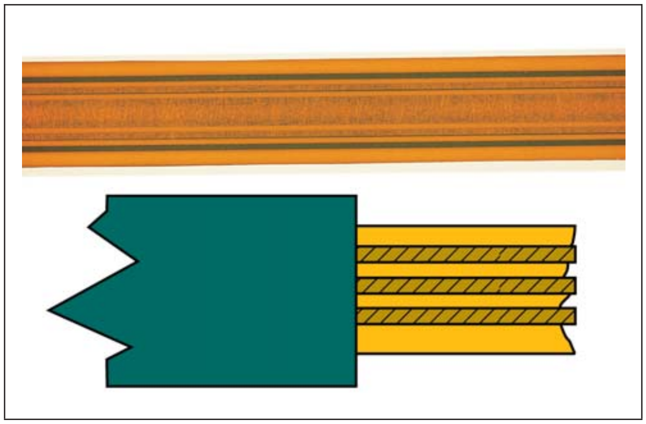

Figure 10-56

Acceptable – Class 1,2,3

- No nicks or tears in excess of that specified in the procurement documentation.
- Edge to conductor spacing of the flexible portion is within requirements specified on the procurement documentation.

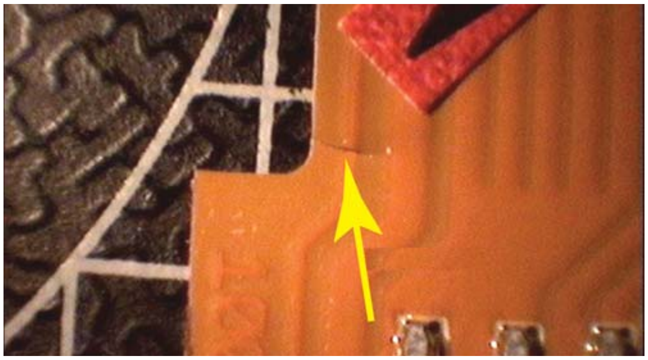

Figure 10-57

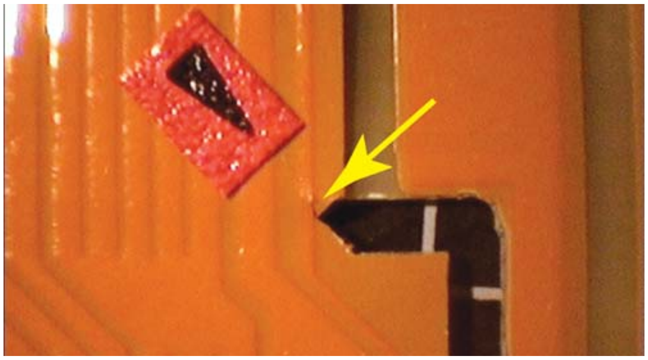

Figure 10-58

Defect – Class 1,2,3

- Edge to conductor spacing does not comply with specified requirements.
- Evidence of burns, charring or melting of the insulation.

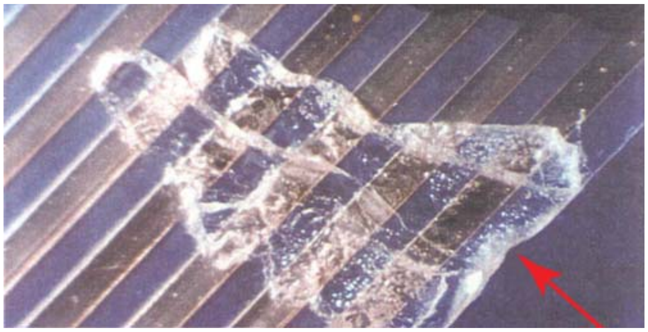

Figure 10-59

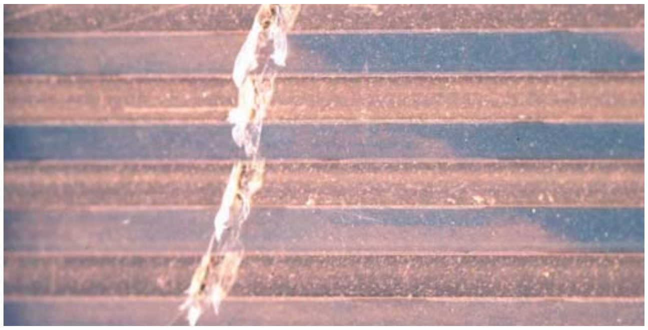

Figure 10-60

10.4.2 Flexible and Rigid-Flex Printed Circuitry – Delamination/Blister

10.4.2.1 Flexible and Rigid-Flex Printed Circuitry – Delamination/Blister – Flex

Sometimes delamination/blistering takes place in the flex circuitry during processing or the assembly soldering process.

Note: Ground and/or shield planes are treated as one conductive pattern and do not apply to adjacent pattern spacing when the imperfection is contained completely within common conductors.

There are no illustrations for these criteria.

Target – Class 1,2,3

- No blistering or delamination of the flex circuitry.

Acceptable – Class 1,2,3

- Delamination and blistering provided the area affected does not exceed 1% of the printed board area on each side due to assembly processing prior to soldering.
- The imperfection does not reduce the spacing between conductive patterns below the minimum conductor spacing.

Acceptable – Class 2,3

- Delamination (separation) or bubbles in the coverlayers of the flexible circuitry after thermal exposure due to soldering does not span more than 25% of the distance between adjacent conductive patterns.
- The separation is no larger than 0.8 x 0.8 mm [0.03 x 0.03 in] and maintains the coverfilm seal.
- The total number of separations **shall not** exceed three in any 25 mm x 25 mm [1 in x 1 in] of coverfilm surface area, and **shall not** exceed a total area of separation greater than 25 square mm, or 5 x 5 mm [0.2 x 0.2 in].
- The imperfection does not exceed the specified minimum distance between printed board edge and conductive pattern, or 2.5 mm [0.1 in] if not specified.

10.4.2.2 Flexible and Rigid-Flex Printed Circuitry – Delamination/Blister – Flex to Stiffener

Not Established – Class 1
Acceptable – Class 2,3

- The distance from stiffener board edge in the section of flex circuit which is intended to remain straight is 0.5 mm [0.02 in] or less.
- The distance from stiffener board edge in the section of the flex circuit which is intended to bend is 0.3 mm [0.01 in] or less.
- Delamination (separation) or bubbles in the coverlayers of the flexible circuitry does not span more than 25% of the distance between adjacent conductive patterns.

Figure 10-61

Not Established – Class 1
Defect – Class 2,3

- The distance from stiffener board edge in the section of flex circuit which is intended to remain straight exceeds 0.5 mm [0.02 in].
- The distance from stiffener board edge in the section of flex circuit which is intended to bend exceeds 0.3 mm [0.01 in].
- Delamination (separation) or bubbles in the coverlayers of the flexible circuitry span more than 25% of the distance between adjacent conductive patterns.

10.4.3 Flexible and Rigid-Flex Printed Circuitry – Solder Wicking

The edge of the coverlayer does not include adhesive squeeze out.

Target – Class 1,2,3

- Solder or plating on land covers all exposed metal and stops at coverlayer.

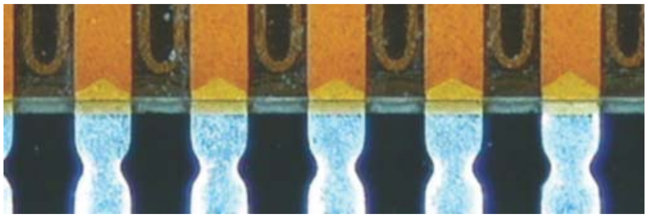

Figure 10-62

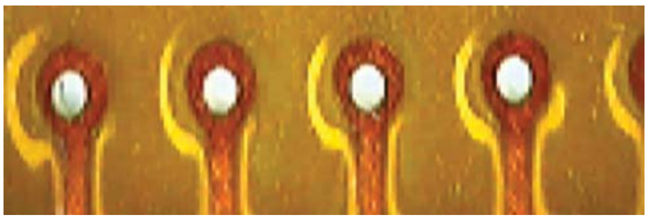

Figure 10-63

Acceptable – Class 1,2,3

- Solder wicking or plating migration does not extend into the area required to be flexible.

Acceptable – Class 2

- Solder wicking/plating migration does not extend under coverlayer more than 0.5 mm [0.02 in].

Acceptable – Class 3

- Solder wicking/plating migration does not extend under coverlayer more than 0.3 mm [0.01 in].

Figure 10-64

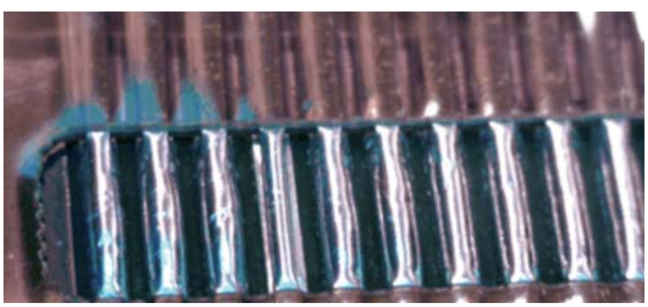

Figure 10-65

Defect – Class 2

- Solder wicking/plating migration extends under coverlayer more than 0.5 mm [0.02 in].

Defect – Class 3

- Solder wicking/plating migration extends under coverlayer more than 0.3 mm [0.01 in].

Defect – Class 1,2,3

- Solder wicking or plating migration extends into the area required to be flexible.
- Spacing as a result of solder wicking or plating migration violates minimum electrical clearance.

10.4.4 Flexible and Rigid-Flex Printed Circuitry – Attachment

These criteria are applicable to the solder attachment of flex on PCB (FOB). When sufficient data has been collected this will be expanded to include flex on flex (FOF) and connection using anisotropically conductive flex (ACF).

Figure 10-66

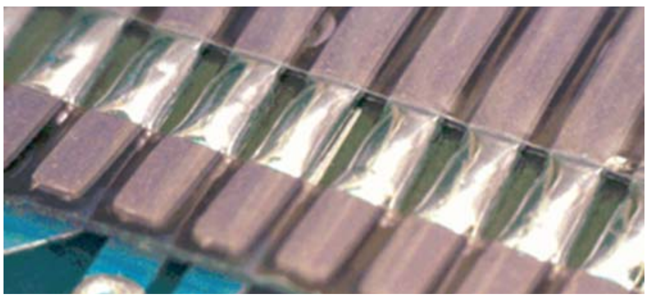

Figure 10-67

Target – Class 1,2,3

- No side overhang.
- Plated through-holes in the connection areas are filled 100%.
- Solder is fully wetted in edge semicircular plated holes.

Figure 10-68

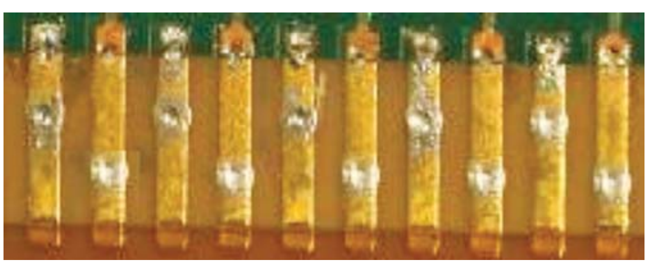

Figure 10-69

Acceptable – Class 1

- Side overhang of flex termination is equal to or less than 50% of flex termination width.

Acceptable – Class 2,3

- Side overhang of flex termination is equal to or less than 25% of flex termination width.

Acceptable – Class 1,2,3

- Plated through-holes in the connection areas are filled 50% or more.
- Wetted solder is visible in the edge semicircular plated holes.
- Unformed flex lead side fillets are 100% of lead to land interface.

10.4.4 Flexible and Rigid-Flex Printed Circuitry – Attachment (cont.)

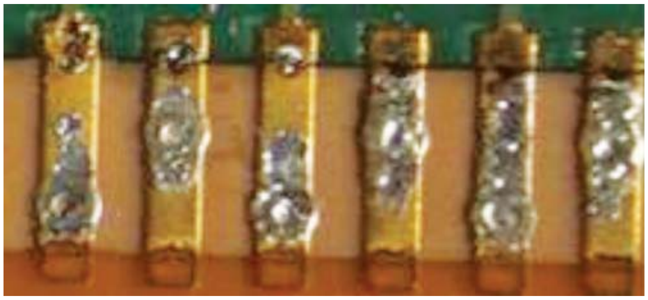

Figure 10-70

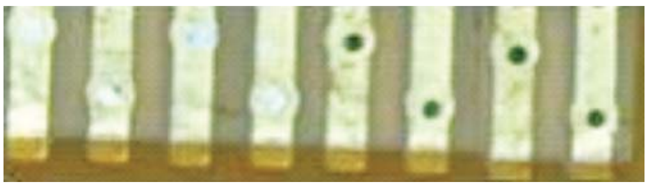

Figure 10-71

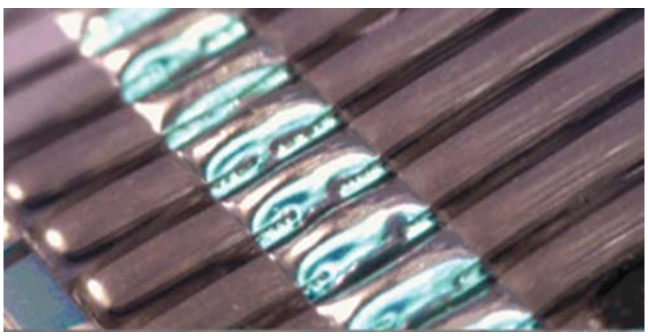

Figure 10-72

Process Indicator – Class 1,2,3

- No evidence of wetted solder in two adjacent edge semicircular plated holes.

Defect – Class 1

- Side overhang of flex termination is more than 50% of flex termination width.

Defect – Class 2,3

- Side overhang of flex termination is more than 25% of flex termination width.

Defect – Class 1,2,3

- Plated through-holes in the connection areas are less than 50% filled.
- No evidence of wetted solder in three or more adjacent edge semicircular plated holes.
- Unformed flex lead side fillets are less than 100% of lead to land interface.

10.5 Marking

This section covers acceptability criteria for marking of printed boards and other electronic assemblies.

Marking provides both product identification and traceability. It aids in assembly, in process control and field servicing. The methods and materials used in marking **shall** serve the intended purposes and **shall** be readable, durable and compatible with the manufacturing processes and should remain legible through the life of the product.

Method of verifying readability **shall** be as agreed between Manufacturer and User.

10.5 Marking (cont.)

Examples of the markings addressed by this section include the following:

a. Electronic Assemblies:

- Company logo
- Board fabrication part numbers and revision level
- Assembly part number, group number and revision level
- Component legends including reference designators and polarity indicators (only applies prior to assembly processing/cleaning)
- Certain inspection and test traceability indicators
- U.S. and other relevant regulatory agencies/certifications
- Unique individual serial number
- Date code

b. Modules and/or Higher Level Assemblies:

- Company logo
- Product identification numbers, e.g., drawing number, revision and serial number
- Installation and user information
- Relevant regulatory agencies' certification labels

The fabrication and assembly drawings are the controlling documents for the locations and types of markings. Marking criteria specified in the drawings will take precedence over these criteria.

In general, additive markings over metal surfaces are not recommended. Markings which serve as aids to assembly and inspection need not be visible after the components are mounted.

Assembly marking (part numbers, serial numbers) **shall** remain legible (capable of being read and understood as defined by the requirements of this Standard) after all tests, cleaning and other processes to which the item is subjected.

Component markings, reference designators and polarity indicators should be legible and components should be mounted in such a manner that markings are visible. However, unless otherwise required, it is an acceptable condition if these markings are removed or damaged during normal cleaning or processing.

Markings are not deliberately altered, obliterated or removed by the manufacturer unless required by the assembly drawing(s)/documentation. Additional markings such as labels added during the manufacturing process should not obscure the original supplier's markings. Permanent labels need to comply with the adhesion requirements of 10.5.5.3. Components and fabricated parts need not be mechanically installed so that the reference designations are visible when installed.

These criteria are applicable when content marking is required.

Acceptable – Class 1,2,3

- Markings include the content specified by the controlling document.

Defect – Class 1,2,3

- Marking content incorrect.
- Marking missing.

10.5.1 Marking – Etched (Including Hand Printing)

Hand printing may include marking with indelible pen or mechanical etcher.

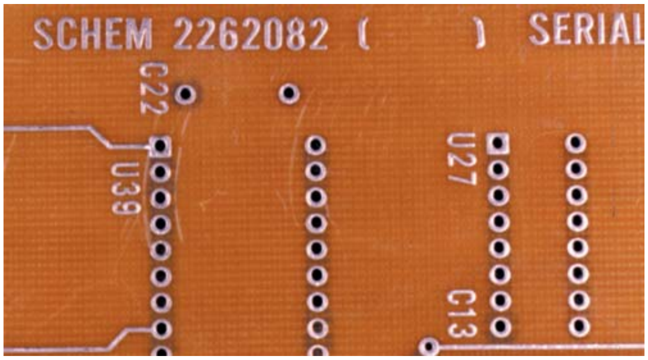

Figure 10-73

Target – Class 1,2,3

- Each number or letter is complete, i.e., none of the lines forming a character are missing or broken.
- Polarity and orientation markings are present and legible.
- Lines forming the character are sharply defined and uniform in width.
- Minimum spacing requirements between active conductors have also been maintained between etched symbolization and active conductors.

Figure 10-74

Acceptable – Class 1,2,3

- Edges of the lines forming a character may be slightly irregular. Open areas within characters may be filled providing the characters are legible and cannot be confused with another letter or number.
- Width of the lines forming a character may be reduced by up to 50% providing they remain legible.
- Lines of a number or letter may be broken provided the breaks do not make the marking illegible.

10.5.1 Marking – Etched (Including Hand Printing) (cont.)


Figure 10-75

Acceptable – Class 1
Process Indicator – Class 2,3

- Legends are irregularly formed but the general intent of the legend or marking is discernible.

Defect – Class 1,2,3

- Missing or illegible characters in the markings.
- Marking violates the minimum electrical clearance limits.
- Solder bridging within or between characters or characters/conductors preventing character identification.
- Lines forming a character are missing or broken to the extent that the character is not legible or is likely to be confused with another character.

10.5.2 Marking – Screened

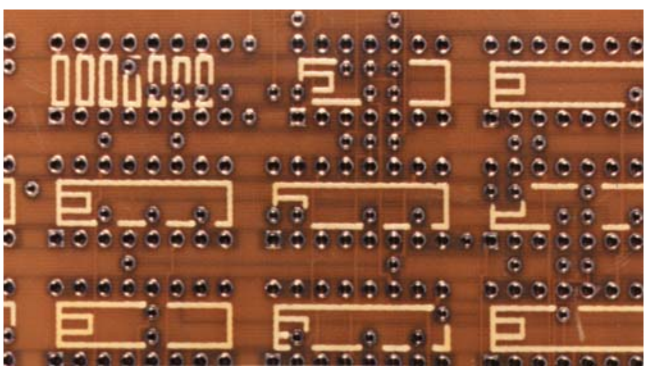
Figure 10-76

Target – Class 1,2,3

- Each number or letter is complete, i.e., none of the lines forming a character are missing or broken.
- Polarity and orientation markings are present and legible. Lines forming the character are sharply defined and uniform in width.
- Ink forming the markings is uniform, i.e., there are no thin spots or excessive build-ups.
- The open areas within characters are not filled (applies to numbers 0, 6, 8, 9 and letters A, B, D, O, P, Q, R).
- There are no multiple images.
- Ink is confined to the lines of the character, i.e., there are no smeared characters and the build-up of material outside the characters is held to a minimum.
- Ink markings may touch or cross over conductors but are no closer than tangent to a land required to have a solder fillet.

10.5.2 Marking – Screened (cont.)

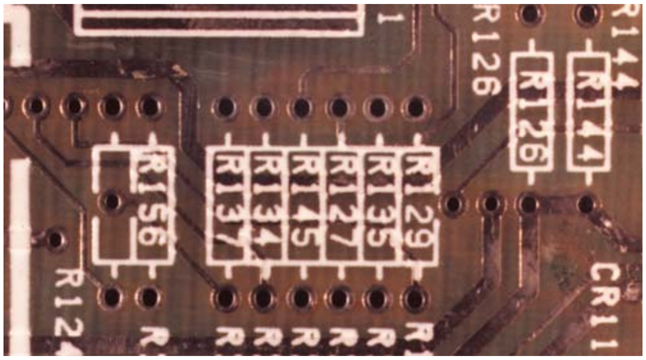

Figure 10-77

Acceptable – Class 1,2,3

- Ink may be built up outside the line of a character providing the character is legible.
- Marking ink on the land does not interfere with soldering requirements.

Acceptable – Class 1
Process Indicator – Class 2,3

- Lines of a number or letter may be broken (or the ink thin over a portion of the character) providing the breaks do not make the markings illegible.

Process Indicator – Class 2,3

- The open areas within characters may be filled providing the characters are legible, i.e., cannot be confused with another letter or number.

Defect – Class 1,2,3

- Marking ink is present on the land interfering with the solder requirements of Tables 7-4, 7-5 or 7-7, or with the surface mount soldering requirements of Section 8.

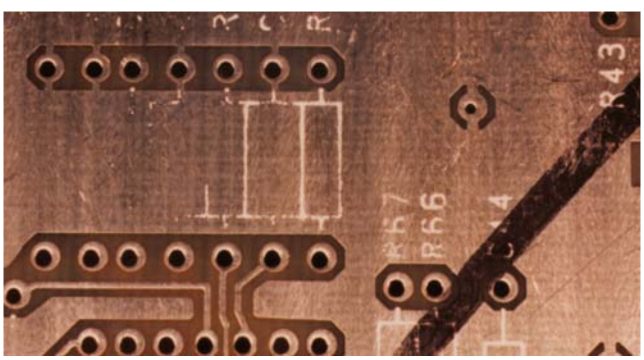
Figure 10-78

Acceptable – Class 1
Process Indicator – Class 2,3

- Marking that is smeared or blurred but is still legible.
- Multiple images are legible.

Defect – Class 1,2,3

- Missing or illegible markings or reference designators for component location, or component outlines.
- Missing or illegible characters in the markings.
- Open areas of characters are filled and are not legible, or are likely to be confused with another number or letter.
- Lines forming a character are missing, broken or smeared to the extent that the character is not legible or is likely to be confused with another character.

10.5.3 Marking – Stamped

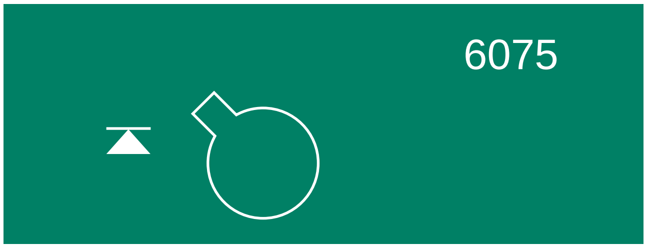

Figure 10-79

Target – Class 1,2,3

- Each number or letter is complete, i.e., none of the lines forming a character are missing or broken.
- Polarity and orientation markings are present and legible.
- Lines forming the character are sharply defined and uniform in width.
- Ink forming the markings is uniform, i.e., there are no thin spots or excessive build-ups.
- The open areas within characters are not filled (applies to numbers 0, 6, 8, 9 and letters A, B, D, O, P, Q, R).
- There are no multiple images.
- Ink is confined to the lines of the character, i.e., there are no smeared characters and the build-up of material outside the characters is held to a minimum.
- Ink markings may touch or cross over conductors but are no closer than tangent to a solderable land.

Acceptable – Class 1,2,3

- Ink may be built up outside the line of a character providing the character is legible.
- Marking ink is present on the land (see soldering requirements of Tables 7-4, 7-5 or 7-7, or the surface mount soldering requirements of Section 8).

Figure 10-80

Acceptable – Class 1
Process Indicator – Class 2,3

- Lines of a number or letter may be broken (or the ink thin over a portion of the character) providing the breaks do not make the markings illegible.
- The open areas within characters may be filled providing the characters are legible, i.e., cannot be confused with another letter or number.
- Marking that has been smeared or blurred but is still legible.
- Multiple stamped markings are acceptable provided the general intent can be determined.
- Missing or smeared marking does not exceed 10% of the character and the character is still legible.

10.5.3 Marking – Stamped (cont.)

Figure 10-81

Defect – Class 1,2,3

- Marking ink is present on the land interfering with the solder requirements of Tables 7-4, 7-5 or 7-7, or with the surface mount soldering requirements of Section 8.
- Missing or illegible characters in the markings.
- Open areas of characters are filled and are not legible, or are likely to be confused with another number or letter.
- Lines forming a character are missing, broken or smeared to the extent that the character is not legible or is likely to be confused with another character.

10.5.4 Marking – Laser

Figure 10-82

Target – Class 1,2,3

- Each number or letter is complete and legible, i.e., none of the lines forming a character are missing or broken.
- Polarity and orientation markings are present and legible.
- Lines forming the character are sharply defined and uniform in width.
- Marking forming the characters is uniform, i.e., there are no thick or thin spots.
- The open areas within characters are not filled (applies to numbers 0, 6, 8, 9 and A, B, D, O, P, Q, R).
- Marking is confined to the lines of the character, i.e., do not touch or cross over solderable surfaces.
- The depth of the marking does not adversely affect the function of the part.
- There is no exposed copper when marking on the ground plane of printed circuitry boards.
- There is no delamination when marking on the printed circuit board dielectric.

Acceptable – Class 1,2,3

- Marking may be built up outside the line of a character providing the character is legible.

10.5.4 Marking – Laser (cont.)

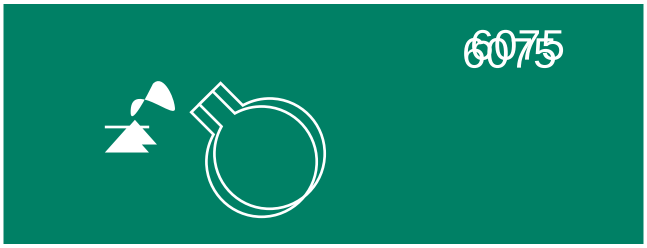

Figure 10-83

Acceptable – Class 1
Process Indicator – Class 2,3

- Multiple image is still legible.
- Missing marking is not more than 10% of the character.
- Lines of a number or letter may be broken (or thin over a portion of the character).

Defect – Class 1,2,3

- Missing or illegible characters in the markings.
- Open areas of characters are filled and are not legible, or are likely to be confused with another number or letter.
- Lines forming a character are missing, broken or smeared to the extent that the character is not legible or is likely to be confused with another character.
- The depth of the marking adversely affects the function of the part.
- Marking exposes copper on the ground plane of printed circuit boards.
- Delamination on the printed circuit board dielectric from marking.
- Markings touch or cross over solderable surfaces.

10.5.5 Marking – Labels

Permanent labels are commonly used to attach machine readable data, but may include text. Readability, adhesion and damage criteria apply to all permanent labels.

10.5.5.1 Marking – Labels – Bar Coding/Data Matrix

Bar coding matrix bar coding (Data Matrix) is a method of product identification for process control and traceability because of ease and accuracy of data collection and processing. This marking can occupy small areas (some can be attached to the thickness edge of the PWB) and can withstand the normal wave soldering and cleaning operations. Coding can also be laser scribed directly on to the base material. Acceptability requirements are the same as other types of markings except for legibility where machine readability replaces human readability.

10.5.5.2 Marking – Labels – Readability


Figure 10-84

Figure 10-85

Figure 10-86

Figure 10-87

Target – Class 1,2,3

- No spots or voids on printed surfaces.

Acceptable – Class 1,2,3

- Spots or voids on printed surfaces of machine readable code are permissible provided that code can be read successfully with three (3) or fewer attempts.
- Text is legible.

Defect – Class 1,2,3

- Machine readable code cannot be successfully read within three (3) attempts.
- Missing or illegible characters in the markings.

10.5.5.3 Marking – Labels – Adhesion and Damage

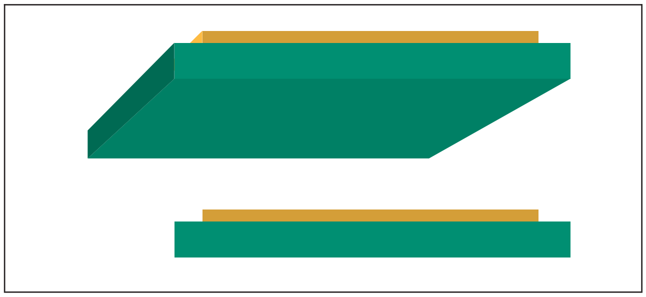

Figure 10-88

Target – Class 1,2,3

- Adhesion is complete, shows no sign of damage or peeling.

Acceptable – Class 1,2,3

- Label lifted 10% or less of the label area.
- Physical damage is 10% or less of the label area and does not affect form, fit or function.
- Damage does not affect legibility or the barcode readability.

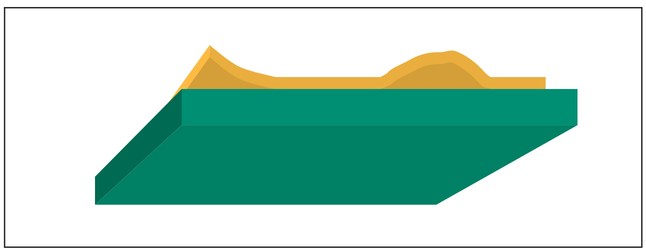

Figure 10-89

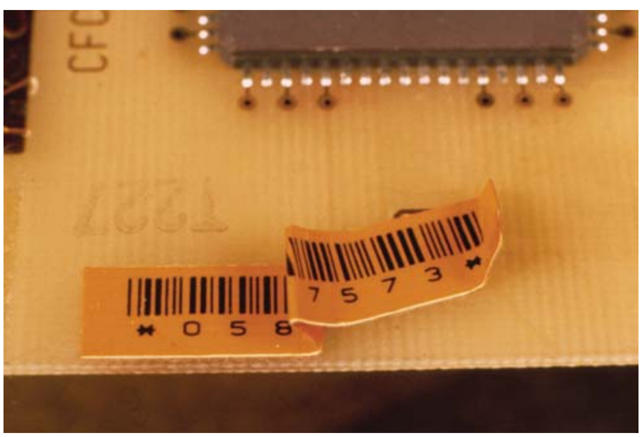

Figure 10-90

Defect – Class 1,2,3

- More than 10% of the label area is peeling.
- Missing labels.
- Label wrinkle affects readability.
- Physical damage is greater than 10% of the label area or affects form, fit or function.
- Damage affects legibility or the barcode readability.

10.5.5.4 Marking – Labels – Position

Acceptable – Class 1,2,3

- Label is applied in the required position.

Defect – Class 1,2,3

- Label is not applied in the required position.

10.5.6 Marking – Radio Frequency Identification (RFID) Tags

Radio Frequency Identification Marking (RFID tags) is widely used in industry. These tags contain an electronic circuit (a microchip) that operates at the specified frequency. The RFID tags contain electronic data that may consist of any of the aforementioned marking information, as well as additional data provided for tracking/traceability purposes. For the RFID tags to function properly, it is important that they be physically located from the specified distance away from the reader. The RF signal must not be obstructed by objects such as metal, water (depends on frequency) or any other object that would distort, or otherwise prevent proper transmission of the RF signal to the tag reader.

There are no illustrations for these criteria.

Target – Class 1,2,3

- The RFID tag is located within the specified distance from the tag reader such that the reader can access the RF signal.
- The free-air path between the RFID tag and the reader is free of obstructions, e.g., metal, water, etc., that may preclude transmission of the RF signal from the tag to the reader.
- The RFID tag is attached to the object in a manner that will not preclude transmission of the RF signal.
- The RFID tag is not damaged to the extent that the information embedded therein cannot be read by the reader.
- The RF signal is not distorted to the extent that the data cannot be clearly discerned using the reader.

Defect – Class 1,2,3

- The RFID tag is not located within the specified distance from the tag reader such that the reader cannot access the RF signal.
- The free-air path between the RFID tag contains obstructions, e.g., metal, water, etc., that preclude transmission of the RF signal from the tag to the reader.
- The RFID tag is attached to the object in a manner that precludes transmission of the RF signal.
- The RFID tag is damaged to the extent that the information embedded therein cannot be read by the reader.
- The RF signal is distorted to the extent that the data cannot be clearly discerned using the reader.

10.6 Cleanliness

This section covers acceptability requirements for cleanliness of assemblies, which includes any components with any electrical interfacing surfaces, e.g., connector mating surfaces, compliant pins, etc. The following are examples of the more common contaminants found on printed board assemblies. Others may appear, however, and all abnormal conditions should be evaluated. The conditions represented in this section apply to both primary and secondary sides of the assemblies. See IPC-CH-65 for additional cleaning information.

Contaminant is not only to be judged on cosmetic or functional attributes, but as a warning that something in the cleaning system is not working properly.

Testing a contaminant for functional effects is to be performed under conditions of the expected working environment for the equipment.

Every production facility should have a standard based on how much of each type of contaminant can be tolerated. Testing with ionic extract devices based on J-STD-001, insulation resistance tests under environmental conditions and other electrical parameter tests as described in IPC-TM-650 are recommended for setting a facility standard.

See 1.10 for inspection magnification requirements.

10.6.1 Cleanliness – Flux Residues

The flux classification (see J-STD-004) and assembly process, i.e., no-clean, clean, etc., need to be identified and considered when applying these criteria.

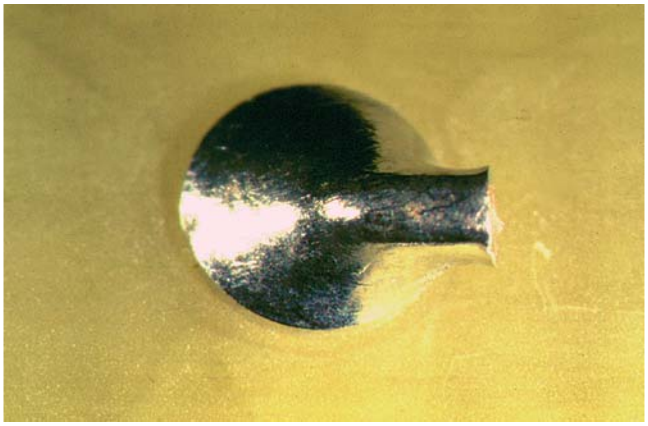

Figure 10-91

Target – Class 1,2,3

- Clean, no discernible residue.

Acceptable – Class 1,2,3

- No discernible residue from cleanable fluxes is allowed.
- Flux residues from no-clean processes may be allowed.

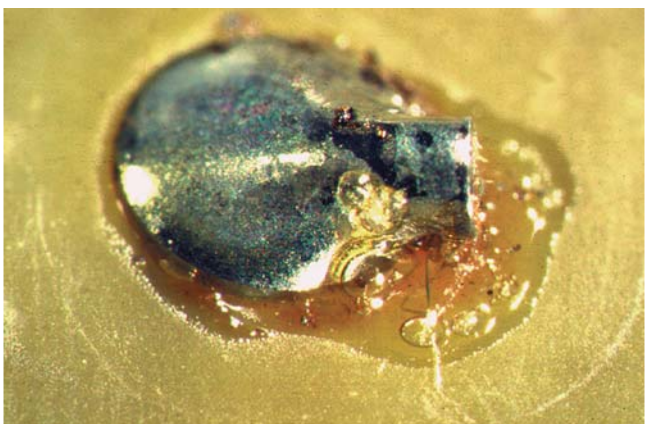

Figure 10-92

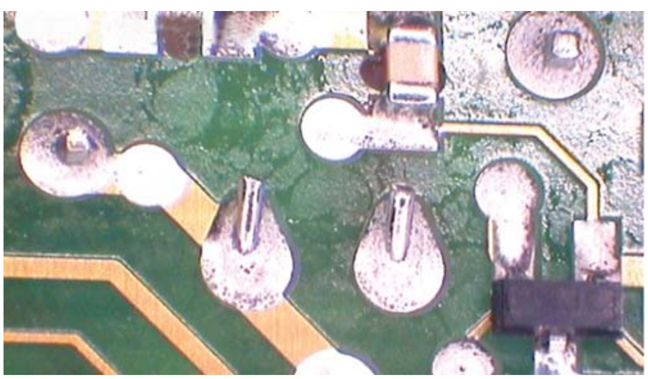

Figure 10-93

Defect – Class 1,2,3

- Discernible residue from cleanable fluxes, or any activated flux residues on electrical contact surfaces.

Note 1: Class 1 may be acceptable after qualification testing. Check also for flux entrapment in and under components.

Note 2: Flux residue activity is defined in J-STD-001 and J-STD-004.

Note 3: Processes designated ''no-clean'' need to comply with end-product cleanliness requirements.

10.6.2 Cleanliness – Foreign Object Debris (FOD)

In the following criteria, the words ''entrapped,'' ''encapsulated,'' and ''attached'' are intended to mean that service environment of the product will not cause particulate matter to become dislodged. The method to determine if the FOD could break loose in the service environment should be agreed between the Manufacturer and User.

Target – Class 1,2,3

- Clean.

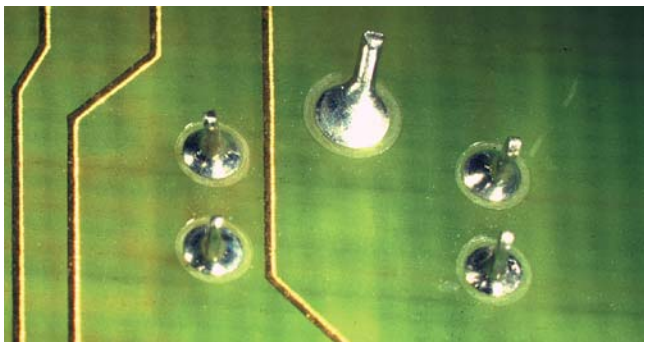

Figure 10-94

Acceptable – Class 1,2,3

- FOD meets the following criteria:
  – Attached/entrapped/encapsulated on the PCA surface or solder mask.
  – Do not violate minimum electrical clearance.

Figure 10-95

Defect – Class 1,2,3

- FOD that is not attached, entrapped, encapsulated, see 5.2.7.1 and 10.8.2.
- Violate minimum electrical clearance.

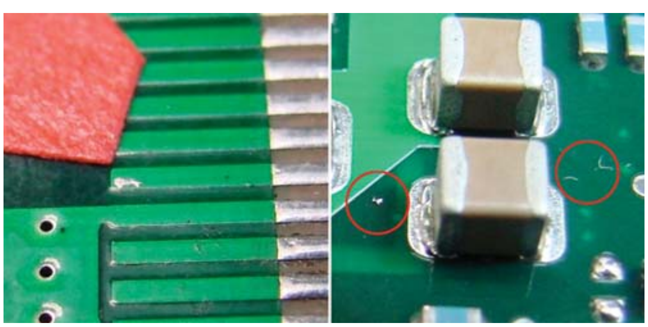

Figure 10-96

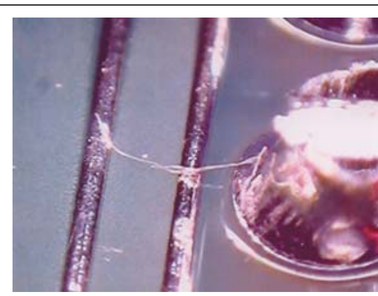

Figure 10-97

10.6.3 Cleanliness – Chlorides, Carbonates and White Residues

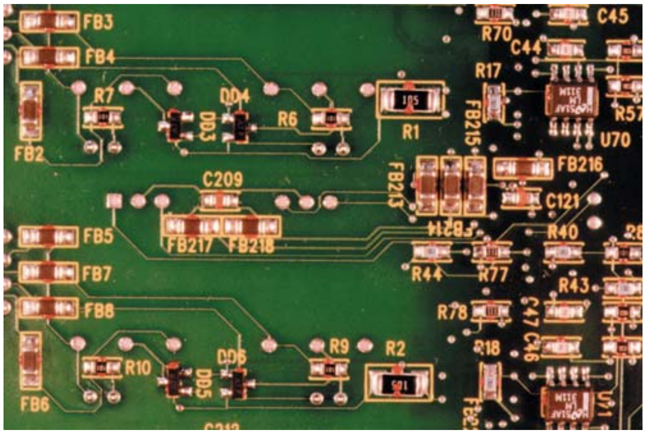

Figure 10-98

Target – Class 1,2,3

• No discernible residue.

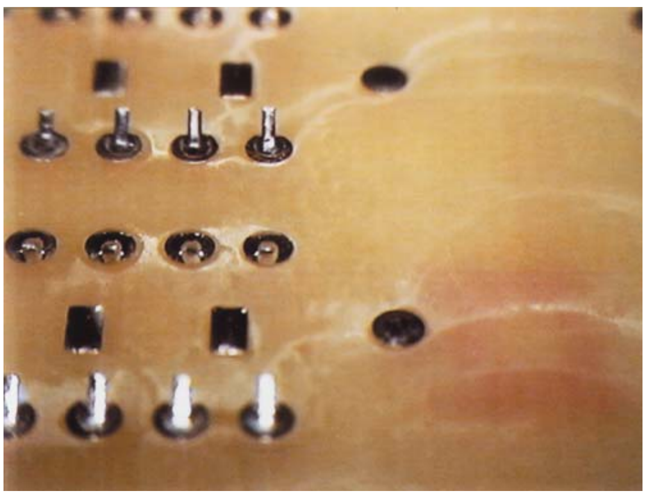

Figure 10-99

Defect – Class 1,2,3

• White residue on PCB surface.

• White residues on or around the soldered termination.

• Metallic areas exhibit crystalline white deposit.

Note: White residues resulting from no-clean or other processes are acceptable provided the residues from chemistries used have been qualified and documented as benign, see 10.6.4.

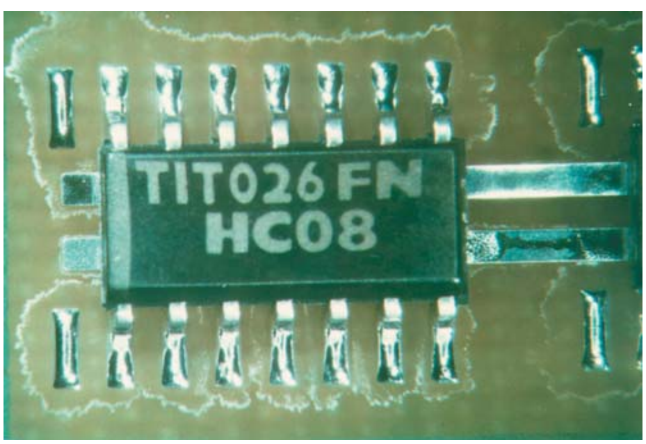

Figure 10-100

10.6.3 Cleanliness – Chlorides, Carbonates and White Residues (cont.)

Figure 10-101

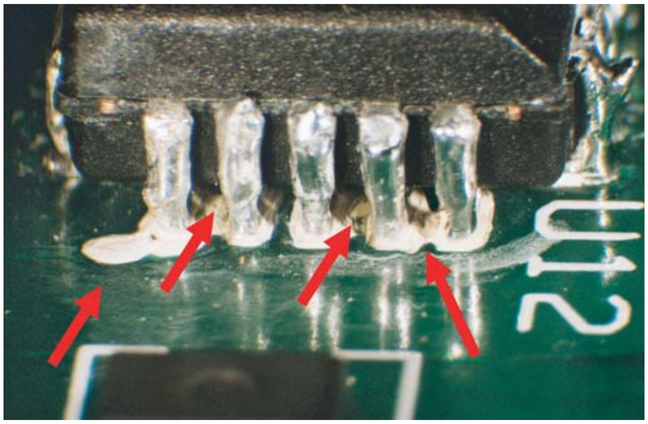

Figure 10-102

10.6.4 Cleanliness – Flux Residues – No-Clean Process – Appearance

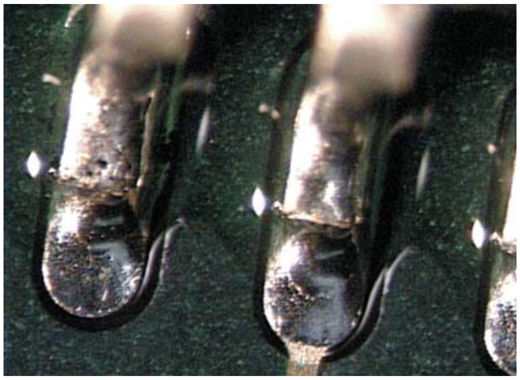

Figure 10-103

Figure 10-104

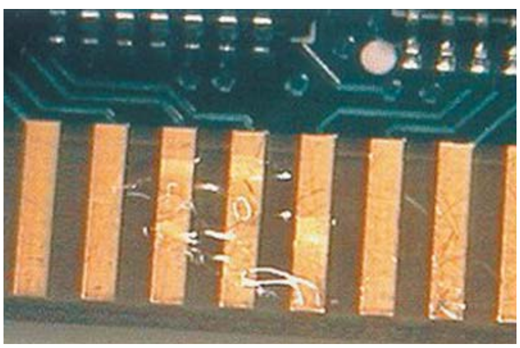

Figure 10-105

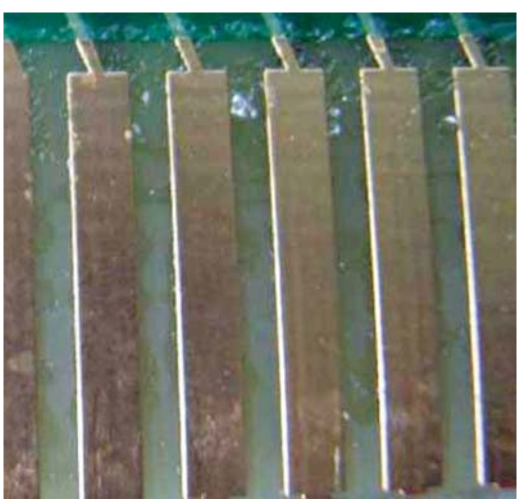

Figure 10-106

Acceptable – Class 1,2,3

- Flux residue on, around or bridging between noncommon lands, component leads and conductors.
- Flux residue does not inhibit visual inspection.
- Flux residue does not inhibit access to test points of the assembly.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Finger prints in no clean residue.

Defect – Class 2,3

- Flux residue inhibits visual inspection.
- Flux residue inhibits access to test points.
- Wet, tacky or excessive flux residues that may spread onto other surfaces.

Defect – Class 1,2,3

- No-clean flux residue on any electrical mating surface that inhibits electrical connections.

Note 1: There is no defect for discoloration of OSP coated assemblies that come in contact with flux residues from no-clean process.

Note 2: Residue appearance may vary depending upon flux characteristics and solder processes.

10.6.5 Cleanliness – Surface Appearance

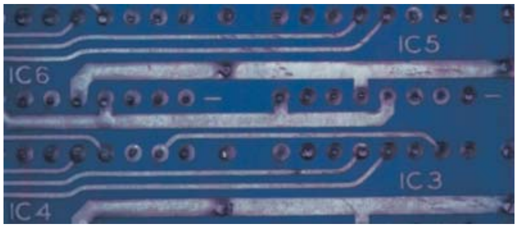

Figure 10-107

Acceptable – Class 1,2,3

- Dulling of clean metallic surfaces.

Figure 10-108

Defect – Class 1,2,3

- Colored residues or rusty appearance on metallic surfaces or hardware.
- Evidence of corrosion.

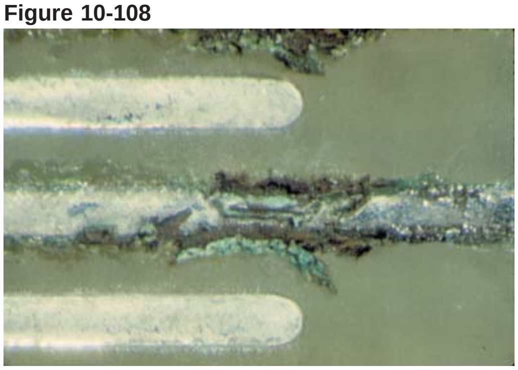

Figure 10-109

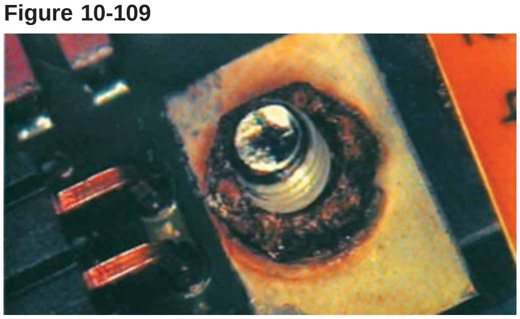

Figure 10-110

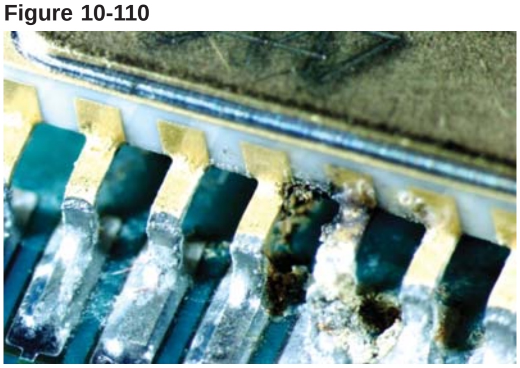

Figure 10-111

10.7 Solder Mask Coating

This section covers the acceptability requirements for solder mask coatings on electronic assemblies after assembly.

Additional information on solder mask is available in IPC-SM-840.

Solder Mask (Resist) – A heat-resisting coating material applied to selected areas to prevent the deposition of solder upon those areas during subsequent soldering. Solder mask material may be applied as a liquid or a dry film. Both types meet the requirements of this guideline.

Although not rated for dielectric strength, and therefore not satisfying the definition of an ‘‘insulator or insulating material,’’ some solder mask formulations provide limited insulation and are commonly used as surface insulation where high voltages are not a consideration.

In addition, solder mask is useful in preventing PCB surface damage during assembly operations.

Tape Test – The tape test referenced in this section is IPC-TM-650, Test Method 2.4.28.1.

See IPC-6012 and IPC-A-600.

10.7.1 Solder Mask Coating – Wrinkling/Cracking

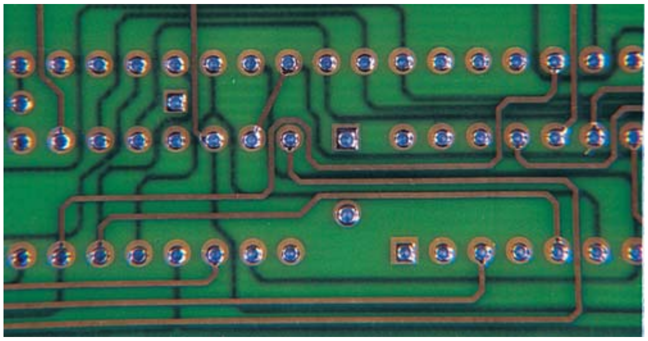

Figure 10-112

Target – Class 1,2,3

- There is no evidence of cracking of the solder mask after the soldering and cleaning operations.

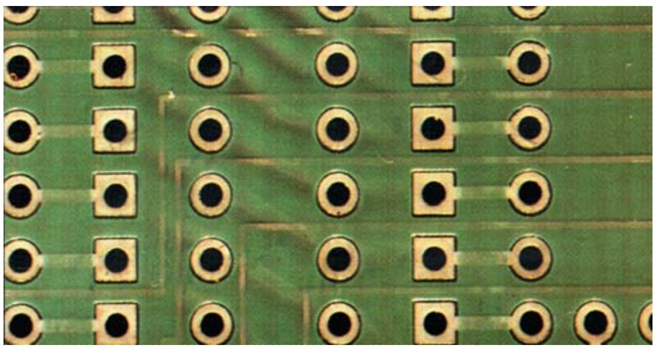

Figure 10-113

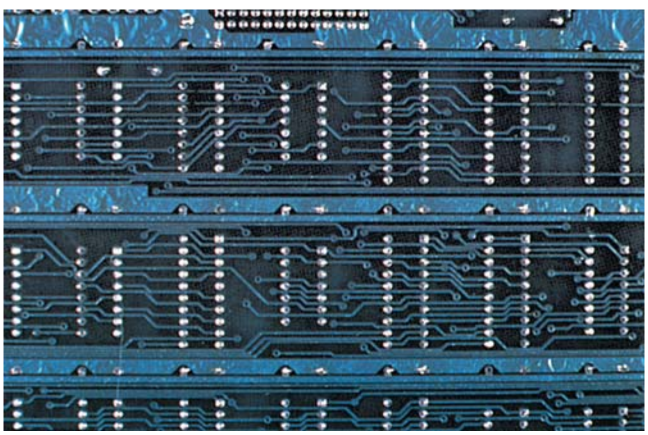

Figure 10-114

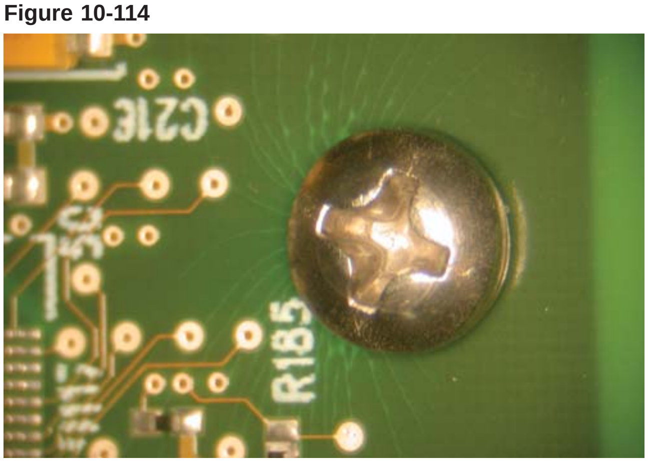

Figure 10-115

Acceptable – Class 1,2,3

- Minor wrinkling is located in an area that does not bridge between conductive patterns and meets the adhesion tape pull test, IPC-TM-650, 2.4.28.1, see Figure 10-113.
- Wrinkling of the solder mask film over area of reflowed solder is acceptable providing there is no evidence of breaking, lifting or degradation of the film. Adhesion of wrinkled areas can be verified using a tape pull test.
- Cracking of solder mask without loss of adhesion.

10.7.1 Solder Mask Coating – Wrinkling/Cracking (cont.)

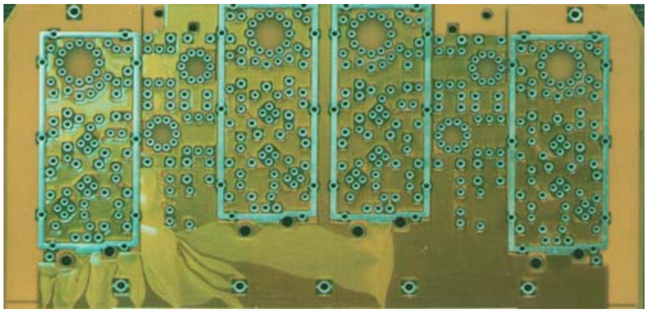

Figure 10-116

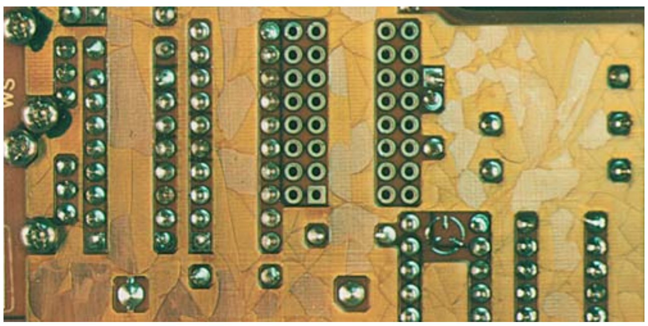

Figure 10-117

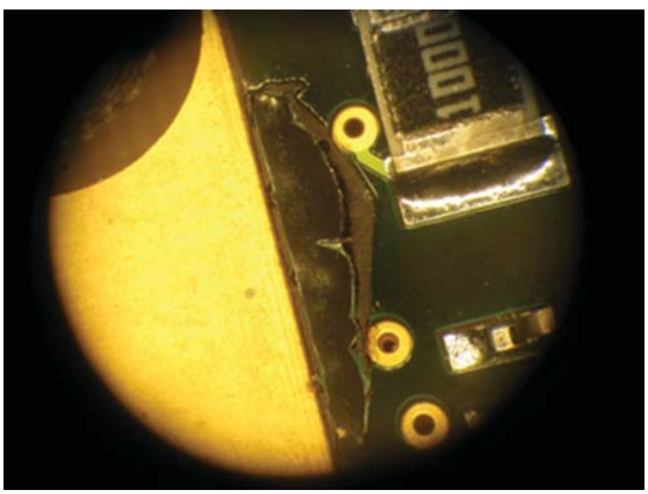

Figure 10-118

Defect – Class 1,2,3

- Solder mask particles cannot be completely removed and will affect the operation of the assembly.

10.7.2 Solder Mask Coating – Voids, Blisters, Scratches

During solder assembly operation, the mask prevents solder bridging. Blistering and loose particles of solder mask material are acceptable after the completion of the assembly provided they will not affect other functions in the assembly.

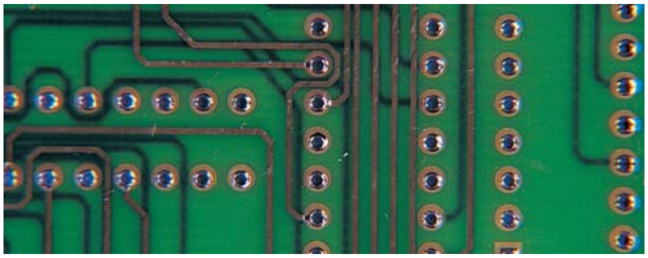

Figure 10-119

Target – Class 1,2,3

- No blisters, scratches, voids or wrinkling evident under solder mask after soldering and cleaning operations.

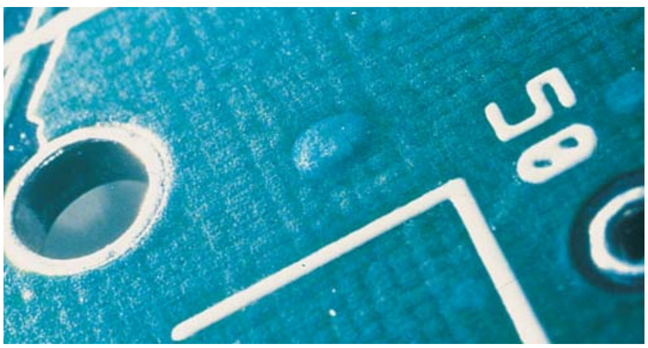

Figure 10-120

Acceptable – Class 1,2,3

- Blisters, scratches, voids that do not expose conductors and do not bridge adjacent conductors, conductor surfaces or create a hazardous condition which would allow loose mask particles to become enmeshed in moving parts or lodged between two electrically conductive mating surfaces.
- Solder flux, oil or cleaning agents are not trapped under blistered areas.

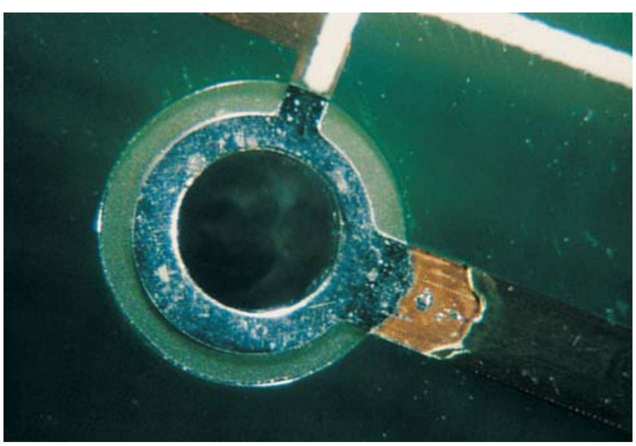

Figure 10-121

Process Indicator – Class 2,3

- Blisters/flaking expose base conductor material.

10.7.2 Solder Mask Coating – Voids, Blisters, Scratches (cont.)

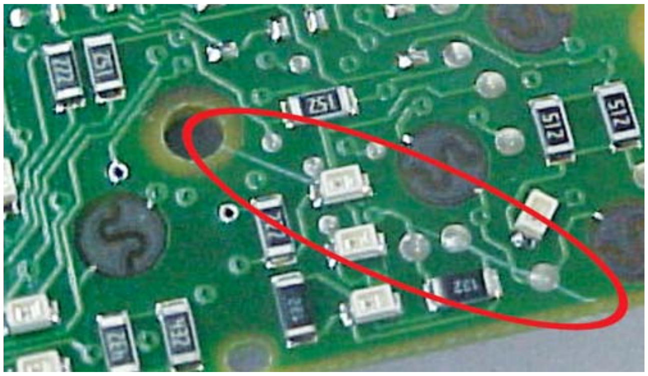

Figure 10-122

Acceptable – Class 1
Defect – Class 2,3

- Coating blisters/scratches/voids allow film to flake in critical assemblies after a tape test.
- Solder fluxes, oils or cleaning agents are trapped under coating.

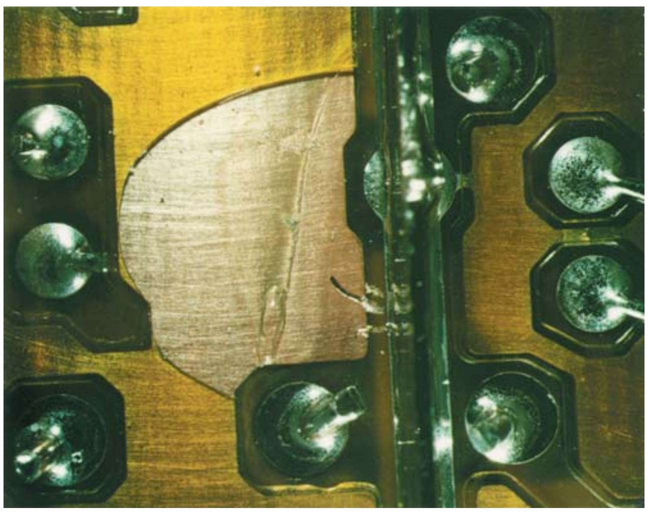

Figure 10-123

Defect – Class 1,2,3

- Coating blisters/scratches/voids bridge adjacent noncommon circuits.
- Loose particles of solder mask material that could affect form, fit or function.
- Coating blisters/scratches/voids have permitted solder bridges.

10.7.3 Solder Mask Coating – Breakdown

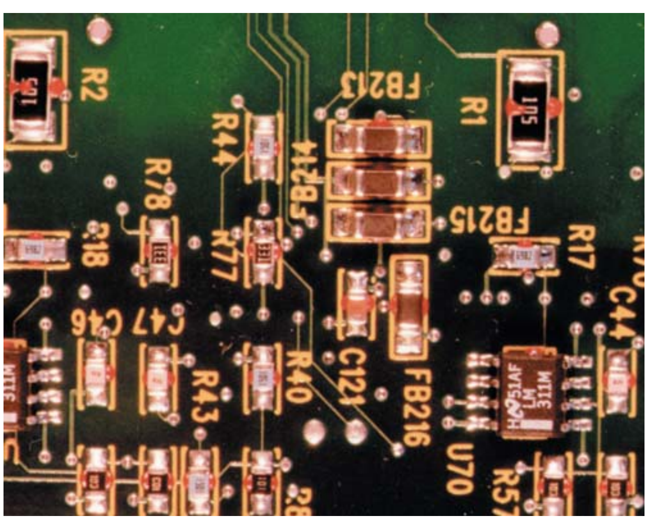

Figure 10-124

Acceptable – Class 1,2,3

- Solder mask surfaces are homogeneous with no flaking or peeling.

Defect – Class 1,2,3

- Solder mask has powdery whitish appearance with possible inclusions of solder metal.

10.7.4 Solder Mask Coating – Discoloration

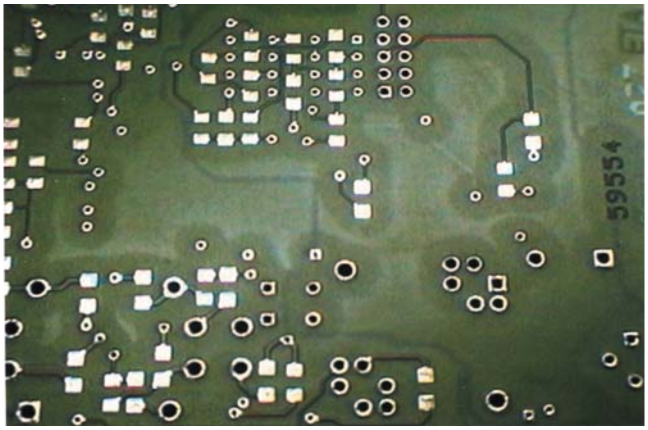

Figure 10-125

Acceptable – Class 1,2,3

- Discoloration of the solder mask material.

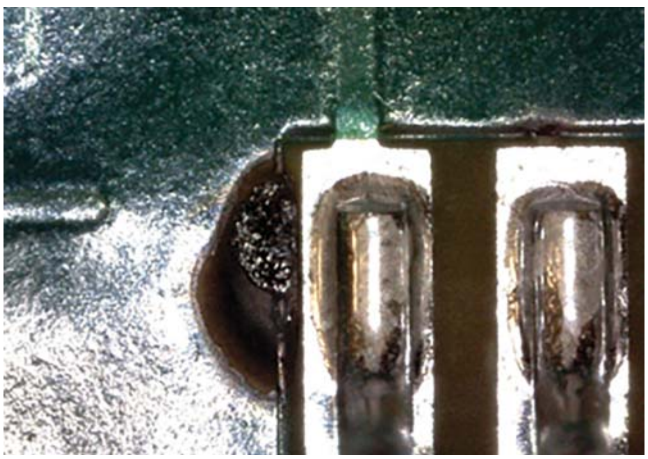

Figure 10-126

Defect – Class 1,2,3

- Burned or charred solder mask material.

10.8 Conformal Coating

This section covers the acceptability requirements for conformal coatings on electronic assemblies.

Additional information on conformal coating is available in IPC-CC-830 and IPC-HDBK-830.

10.8.1 Conformal Coating – General

Conformal coatings should be transparent, uniform in color and consistency and uniformly cover the board and components. Uniform coating distribution depends partly on the method of application and may affect visual appearance and corner coverage. Assemblies coated by dipping may have a drip line or localized build-up of the edge of the board. This build-up may contain a small amount of bubbles but it will not affect the functionality or reliability of the coating.

10.8.2 Conformal Coating – Coverage

The assembly may be examined with the unaided eye, see 1.12.2. Materials that contain a fluorescent pigment may be examined with blacklight to verify coverage. White light may be used as an aid for examining coverage.

Outer layer conductors/circuits covered by soldermask are not considered exposed conductors.

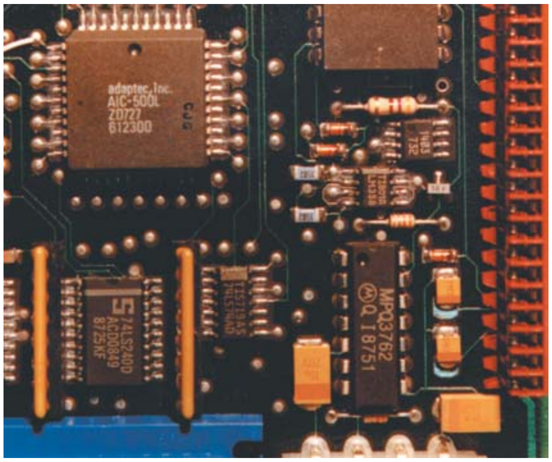

Figure 10-127

Target – Class 1,2,3

- No loss of adhesion.
- No voids or bubbles.
- No dewetting, mealing, peeling, wrinkles (nonadhering areas), cracks, ripples, fisheyes or orange peel.
- No embedded/entrapped foreign material.
- No discoloration or loss of transparency.
- Completely cured and uniform.

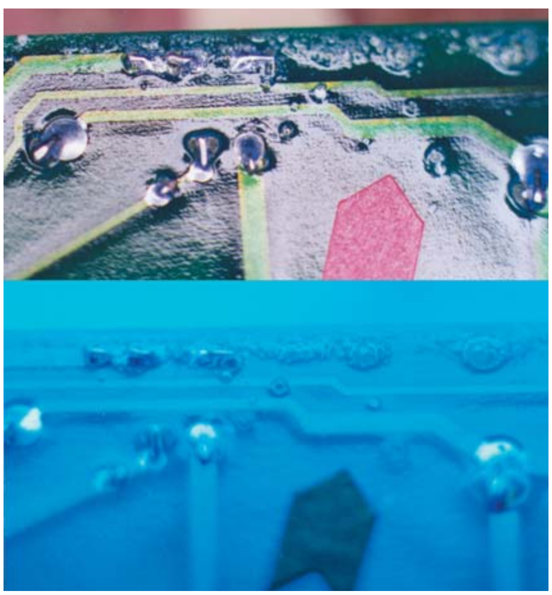

Figure 10-128

Acceptable – Class 1,2,3

- Completely cured and homogenous.
- Coating only in those areas where coating is required.
- No bridging of exposed conductive surfaces (no solder mask) from:
  - Loss of adhesion voids or bubbles
  - Dewetting/nonwetting
  - Cracks
  - Ripples
  - Fisheyes
  - Orange peel, see Figure 10-130
  - Flaking
- Entrapped material does not violate minimum electrical clearance between components, lands or conductive surfaces.

Figure 10-129

Process Indicator – Class 1,2,3

- No bridging or exposed conductive surfaces from:
  - Loss of adhesion
  - Voids
  - Bubbles

10.8.2 Conformal Coating – Coverage (cont.)

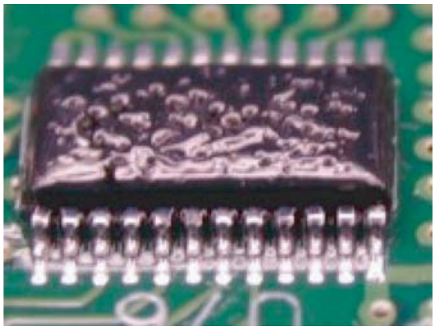
Figure 10-130

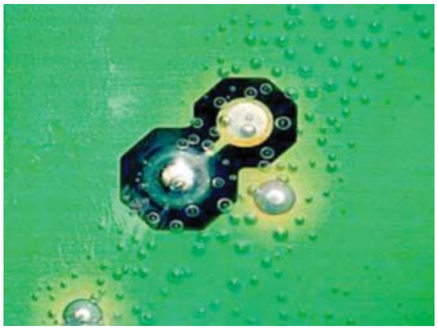
Figure 10-131


Figure 10-132

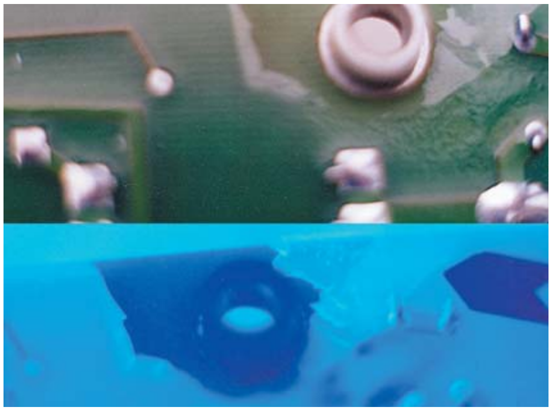
Figure 10-133

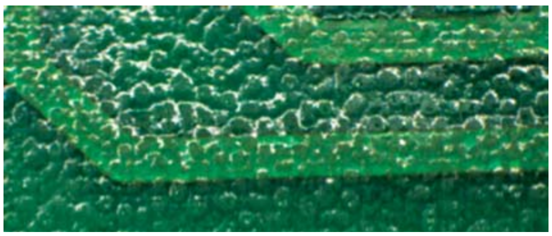
Figure 10-134

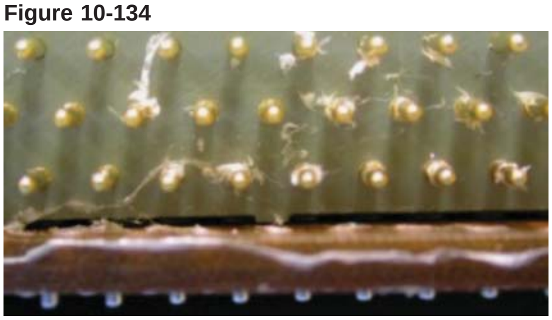
Figure 10-135

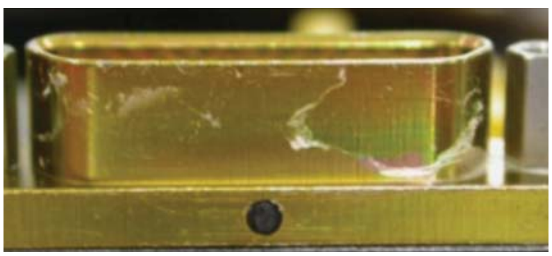
Figure 10-136

Defect – Class 1,2,3

- Coating is not cured.
- Coating is not applied to required areas.
- Coating is on areas required to be free of coating, e.g., mating surfaces, adjustable hardware, wicking into connector housings, etc.
- Bridging of adjacent lands or exposed conductive surfaces caused by:
  - Loss of adhesion
  - Voids or bubbles
  - Dewetting/nonwetting
  - Cracks
  - Fisheyes
  - Flaking
- Any entrapped material that bridges lands or adjacent conductive surfaces, exposes circuitry or violates minimum electrical clearance between components, lands or conductive surfaces.
- Discoloration or loss of transparency.

10.8.3 Conformal Coating – Thickness

Table 10-1 provides coating thickness requirements. The thickness is to be measured on a flat, unencumbered, cured surface of the printed circuit assembly or a coupon that has been processed with the assembly. Coupons may be of the same type of material as the printed board or may be of a nonporous material such as metal or glass. As an alternative, a wet film thickness measurement may be used to establish the coating thickness provided there is documentation that correlates the wet and dry film thickness.

Note: Table 10-1 of this Standard is to be used for printed circuit assemblies. The coating thickness requirements in IPC-CC-830 are used only for test vehicles associated with coating material testing and qualification.

Table 10-1 Coating Thickness

Type AR	Acrylic	0.03-0.13 mm [0.001-0.005 in]
Type ER	Epoxy	0.03-0.13 mm [0.001-0.005 in]
Type UR	Urethane	0.03-0.13 mm [0.001-0.005 in]
Type SR	Silicone	0.05-0.21 mm [0.002-0.008 in]
Type XY	Paraxylylene	0.01-0.05 mm [0.0004-0.002 in]

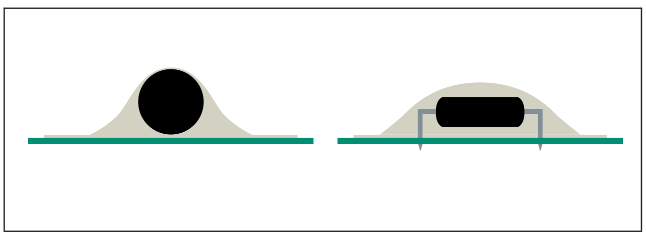

Figure 10-137

Acceptable – Class 1,2,3

- Coating meets the thickness requirements of Table 10-1.

Defect – Class 1,2,3

- Coating does not meet thickness requirements of Table 10-1.

10.8.4 Electrical Insulation Coating

10.8.4.1 Electrical Insulation Coating – Coverage

This material is used to provide insulation to an exposed conductor when conformal coating is insufficient to provide enough protection and encapsulation is too much.

All of the considerations used for conformal coating are applicable for insulation coating, except the surface where insulation coating is applied is generally not smooth enough for a uniform coating surface. Thin coating is not a target attribute.

There are no illustrations for these criteria.

10.8.4.2 Electrical Insulation Coating – Thickness

Acceptable – Class 1,2,3

- Complete coverage with no exposed metal.

Defect – Class 1,2,3

- Exposed metal.

Note: The thickness requirements of 10.8.3 do not apply.

10.9 Encapsulation

There are no illustrations for these criteria.

Acceptable – Class 1,2,3

- Encapsulation material extends over and surrounds all areas required to be encapsulated.
- Encapsulation material is not present in areas not designated to be encapsulated.
- Completely cured and uniform.
- The encapsulant is free of bubbles, blisters or breaks that affect the printed circuit assembly operation or sealing properties of the encapsulant material.
- No visible cracks, crazing, mealing, peeling and/or wrinkles in the encapsulant material.
- Entrapped foreign material does not violate minimum electrical clearance between components, lands or conductive surfaces.
- Potting material has hardened and is tack free to the touch after curing.

Note: Minor surface swirls, striations or flow marks are not considered defects.

10.9 Encapsulation (cont.)

Defect – Class 1,2,3

- Encapsulation material missing from areas required to be encapsulated.
- Encapsulation material is present in areas not designated to be encapsulated or that interferes with the electrical or physical function of the assembly.
- Encapsulation material is not cured (exhibits tackiness).
- Bubbles, blisters or breaks that affect the printed circuit assembly operation or sealing properties of the encapsulant material.
- Visible cracks, crazing, mealing, peeling and/or wrinkles in the encapsulant material.
- Any entrapped material that bridges lands or adjacent conductive surfaces, exposes circuitry or violates minimum electrical clearance between components, lands or conductive surfaces.
- Discoloration or loss of transparency.

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11 Discrete Wiring

Discrete wiring refers to a substrate or base upon which discrete wiring techniques are used to obtain electronic interconnections. Separate visual criteria for each type are depicted in this section.

Discrete Wiring Acceptability Guidelines

The routing and terminating of discrete wires to form point-to-point electrical connections by use of special machines or tools may be employed to replace or supplement printed conductors on board assemblies. Application may be in planar, two-dimensional or three-dimensional configurations.

In addition to the criteria in this section the criteria of Section 5 are applicable.

The following topics are addressed in this section:

11.1 Solderless Wrap

This section establishes visual acceptability criteria for connections made by the solderless wrap method.

It is assumed that the terminal/wire combination has been designed for this type of connection.

The tightness of the wire wrap should be validated by the tool verification process.

It is also assumed that a monitoring system exists that uses test connections to verify that the operator/tooling combination is capable of producing wraps that meet strip force requirements.

Depending on the service environment, the connecting instructions will specify whether the connection will be conventional or modified.

Once applied to the terminal, an acceptable solderless wrap connection **shall not** be subjected to excessive heat nor have any mechanical operations performed on it.

It is not acceptable to attempt to correct a defective connection by reapplying the wrapping tool or by applying other tools.

The reliability and maintainability advantages of the solderless wrap connection method are such that no repair of a defective wrap by soldering is to be made. Defective connections are unwrapped using a special tool (not stripped off the terminal) and then a new wire wrapped to the terminal. New wire **shall** be used for each wrap/rewrap, but the terminal may be rewrapped many times.

11.1.1 Solderless Wrap – Number of Turns

For this requirement, countable turns are those turns of bare wire in intimate contact with the corners of the terminal starting at the first contact of bare wire with a terminal corner and ending at the last contact of bare wire with a terminal corner, see Table 11-1.

A modified wrap is required for Class 3. It has an additional amount of insulated wire wrapped to contact at least three corners of the terminal.

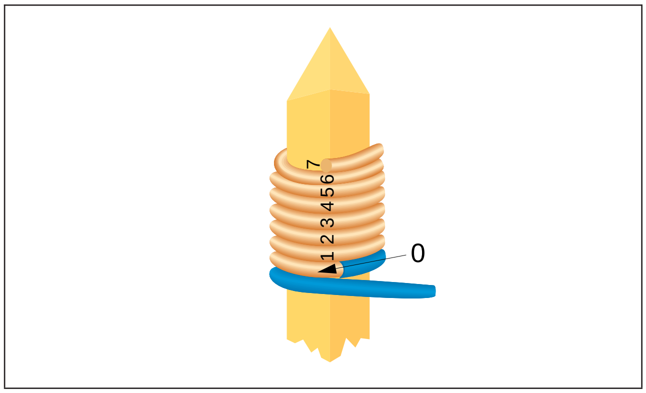

Figure 11-1

Target – Class 1,2,3

- One-half turn more than the minimum shown in Table 11-1.

Acceptable – Class 1,2

- Countable turns meet the requirements of Table 11-1.

Acceptable – Class 3

- Countable turns meet the requirements of Table 11-1.
- Meets requirements of modified wrap.

Table 11-1 Minimum Turns of Bare Wire

Wire Gauge (AWG)	Turns
28 – 34	7
26	6
24	5
22	5
20	4
18	4

Note: Maximum turns of bare and insulated wire is governed only by tooling configuration and space available on the terminal.

Defect – Class 1,2,3

- Number of countable turns does not comply with Table 11-1.

Defect – Class 3

- Does not meet requirements of modified wrap.

11.1.2 Solderless Wrap – Turn Spacing

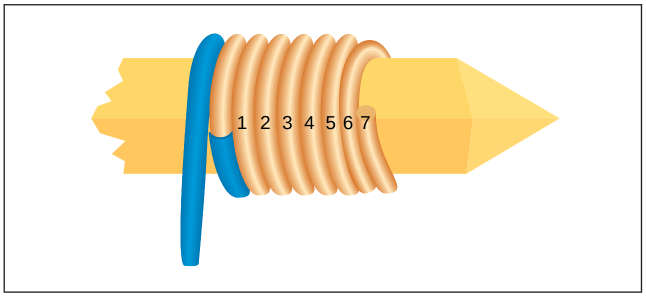

Figure 11-2

Target – Class 1,2,3

• No space between any turns.

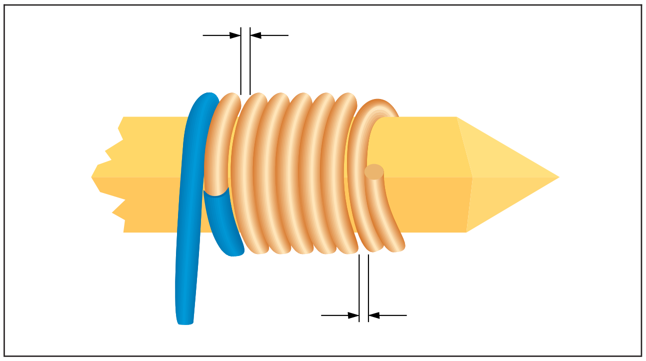

Figure 11-3

Acceptable – Class 1

• No space over one wire diameter.

Acceptable – Class 2

• No space over one-half wire diameter within countable turns.

• No space over one wire diameter elsewhere.

Acceptable – Class 3

• No more than three turns spaced apart.

• No space over one-half wire diameter within the wrap.

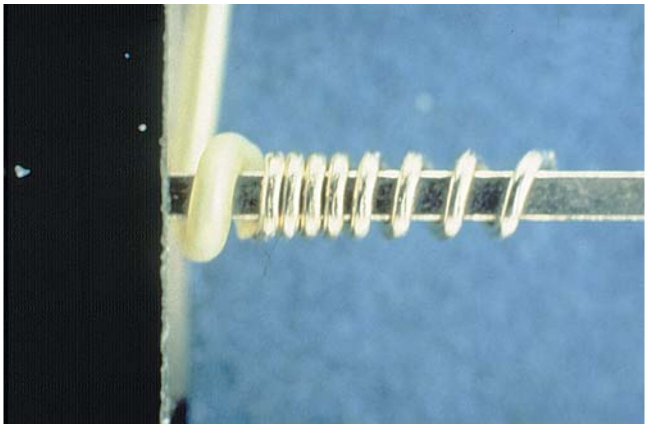

Figure 11-4

Defect – Class 1

• Any space over one wire diameter.

Defect – Class 2

• Any space over one-half wire diameter within countable turns.

Defect – Class 3

• Any space more than one-half wire diameter.

• More than three spaces any size.

11.1.3 Solderless Wrap – End Tails and Insulation Wrap

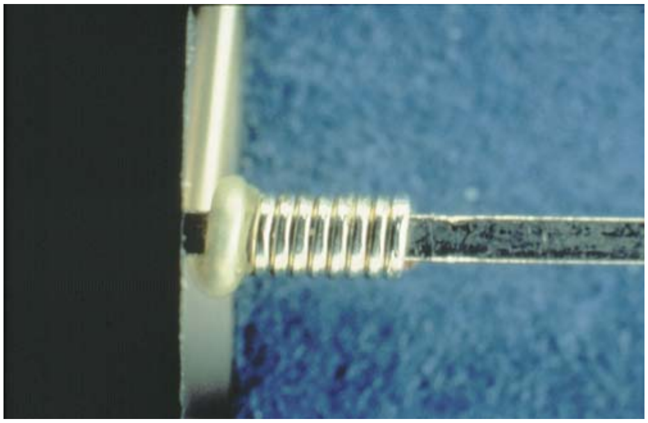

Figure 11-5

Target – Class 1,2

- End tail does not protrude beyond outer surface of wrap.
- Insulation reaches terminal.
- No wire clippings present.

Target – Class 3

- End tail does not protrude beyond outer surface of wrap with insulation modified wrap, see 11.1.1.

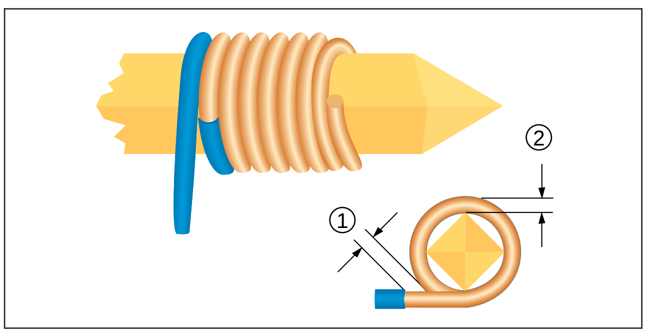

Figure 11-6
1. Insulation clearance
2. Wire diameter (viewed from bottom)

Acceptable – Class 1

- Does not violate minimum electrical clearance.
- Exposed conductor in the insulation.

Acceptable – Class 2

- Insulation end meets clearance requirements to other circuitry.
- End tail does not extend more than 3 mm [0.1 in] from outer surface of wrap.

Acceptable – Class 3

- End tail projects no more than one wire diameter from outer surface of wrap.
- Insulation must contact minimum of three corners of post.

11.1.3 Solderless Wrap – End Tails, Insulation Wrap (cont.)

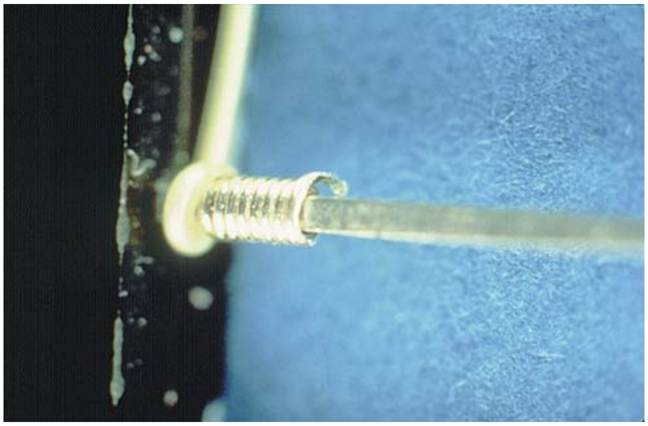

Figure 11-7

Acceptable – Class 1
Defect – Class 2,3

- End tail is greater than 3 mm [0.1 in].

Defect – Class 3

- End tail is greater than one wire diameter.

Figure 11-8

Defect – Class 1,2,3

- End tail violates minimum electrical clearance.

11.1.4 Solderless Wrap – Raised Turns Overlap

Raised turns are squeezed out of the helix, therefore no longer have intimate contact with the terminal corners. Raised turns may overlap or override other turns.

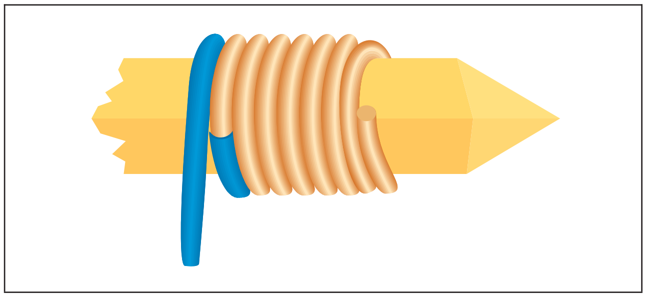

Figure 11-9

Target – Class 1,2,3

- No raised turns.

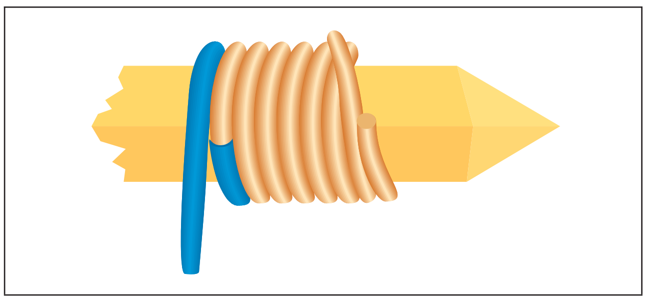

Figure 11-10

Acceptable – Class 1

- Raised turns anywhere provided remaining total turns still have contact and meet minimum turns requirement.

Acceptable – Class 2

- No more than one-half turn raised within countable turns, any amount elsewhere.

Acceptable – Class 3

- No raised turns within countable turns, any amount elsewhere.

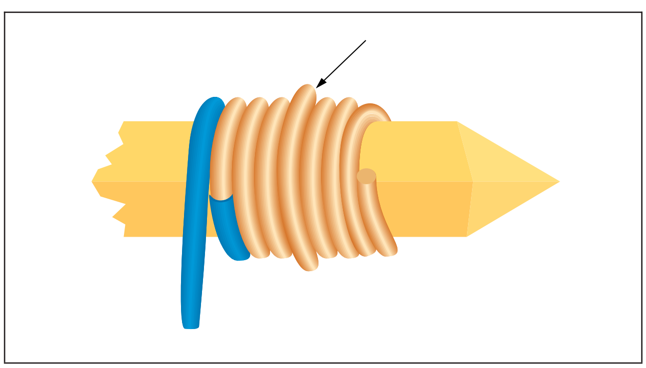

Figure 11-11

Defect – Class 1

- Remaining total turns that still have contact do not meet minimum turn requirements.

Defect – Class 2

- More than one-half raised turn within countable turns.

Defect – Class 3

- Any raised turns within countable turns.

11.1.5 Solderless Wrap – Connection Position

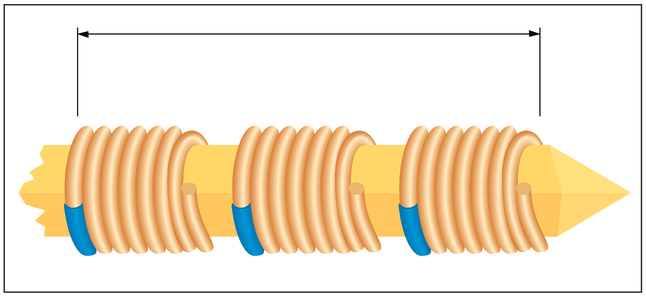

Figure 11-12

Target – Class 1,2,3

- All turns of each connection on working length of terminal.
- Visible separation between each connection.

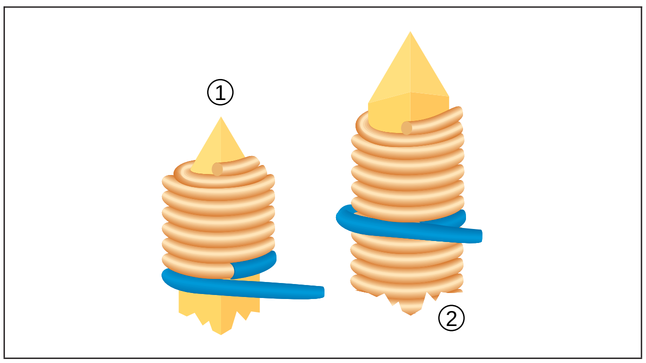

Figure 11-13
1. Wrap extends above working length
2. Insulation turn overlaps previous wrap

Acceptable – Class 1,2

- Extra turns of bare wire or any turns of insulated wire (whether or not for modified wrap) beyond end of working length of terminal.

Acceptable – Class 1

- Extra turns of bare wire or any turns of insulated wire overlap a preceding wrap.

Acceptable – Class 2

- Turns of insulated wire only overlap a preceding wrap.

Acceptable – Class 3

- Wraps may have an insulated wire overlap the last turn of uninsulated wire.
- No turns of bare or insulated wire beyond either end of working length.

11.1.5 Solderless Wrap – Connection Position (cont.)

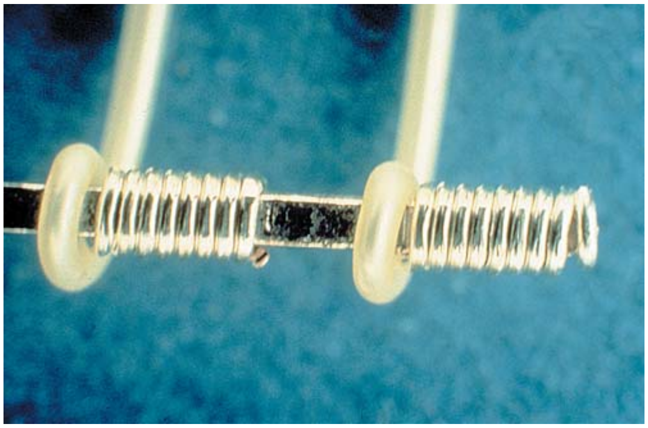

Figure 11-14

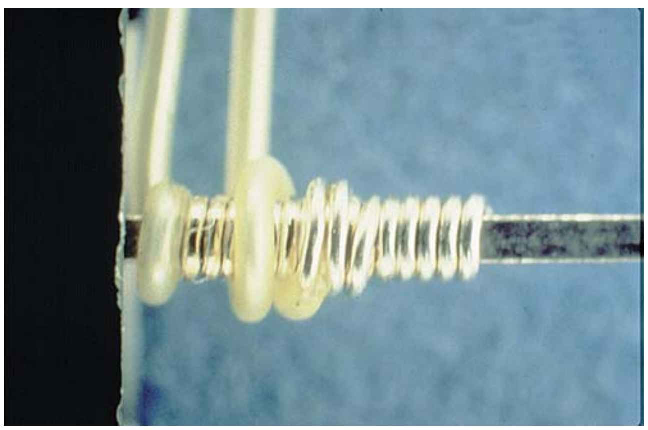

Figure 11-15

Defect – Class 1,2,3

- Insufficient number of countable turns in contact with the terminal.
- Any countable turns of bare wire overlapping wire turns of a preceding connection.
- Spacing requirements are violated.

11.1.6 Solderless Wrap – Wire Dress

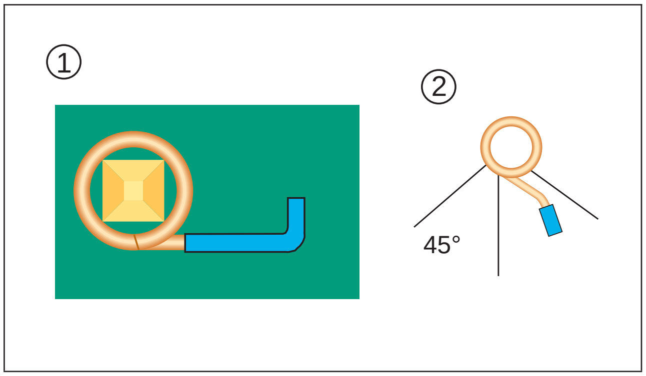

Figure 11-16
1. Direction of turns
2. Proper radius

Acceptable – Class 1,2,3

- The dress of wire is oriented so that force exerted axially on the wire will not tend to unwrap the connection, or to relieve the bite of wire on the corners of the terminal post. This requirement is satisfied when the wire is routed so as to cross the 45° line as shown.

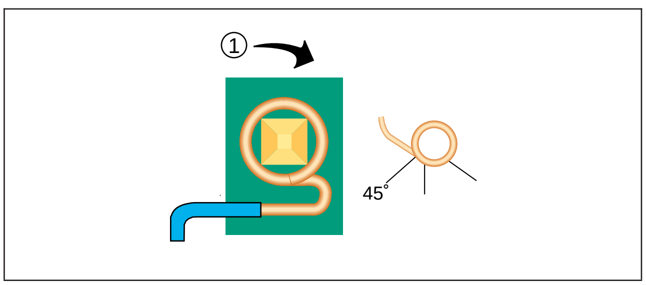

Figure 11-17
1. Direction of turns

Defect – Class 1,2,3

- Axially exerted external forces on the wrap will cause the wrap to unwind or loosen the wire bite at the post corners.

11.1.7 Solderless Wrap – Wire Slack

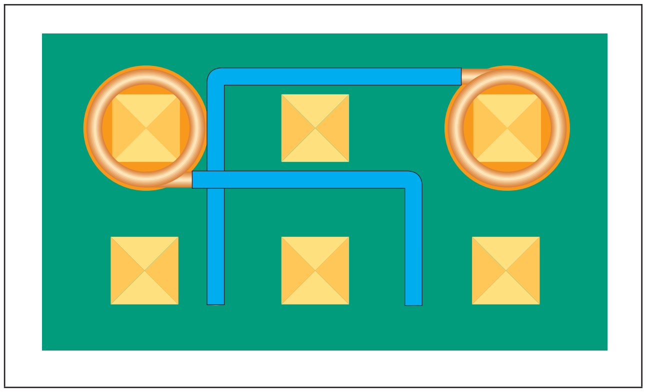

Figure 11-18

Acceptable – Class 1,2,3

- Wiring needs to have sufficient slack so that it will not pull around corners of the other terminal posts or bridge and load other wires.

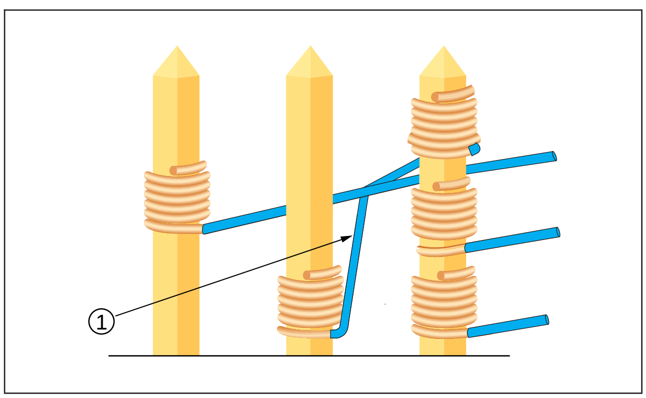

Figure 11-19
1 Wire crossing

Defect – Class 1,2,3

- Insufficient wire slack causing:
  - Abrasion between wire insulation and wrap post.
  - Tension on wires between wrap post causing distortion of posts.
  - Pressure on wires that are crossed by a taut wire.

11.1.8 Solderless Wrap – Wire Plating

Plating

Wire used for solderless wrap is normally plated to improve connection reliability and minimize subsequent corrosion.

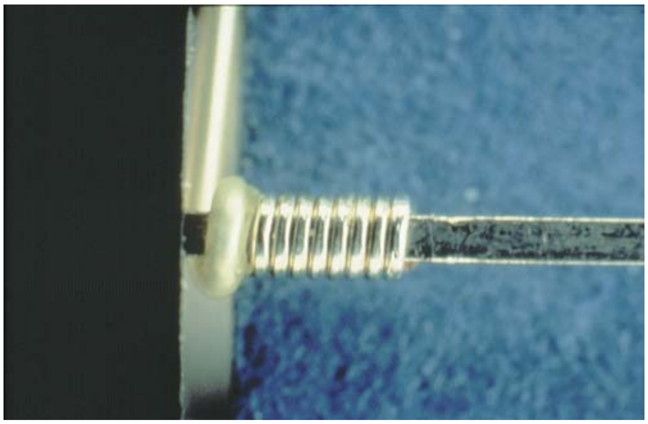

Figure 11-20

Target – Class 1,2,3

- After wrapping, uninsulated wire has no exposed copper.

Acceptable – Class 1

- Any amount of exposed copper.

Acceptable – Class 2

- Up to 50% of countable turns show exposed copper.

Defect – Class 2

- More than 50% of countable turns show exposed copper.

Defect – Class 3

- Any exposed copper (last one-half turn and wire end excluded).

11.1.9 Solderless Wrap – Damaged Insulation

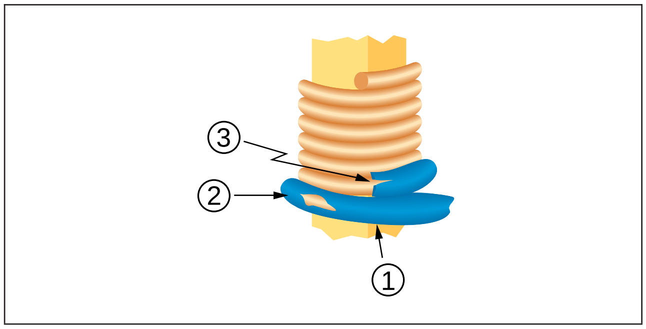

Figure 11-21
1. Initial contact corner
2. Insulation split
3. Insulation cut or frayed

Acceptable – Class 1,2,3

- After initial contact with post:
  - Insulation damage.
  - Splits.
  - Cut or frayed insulation.

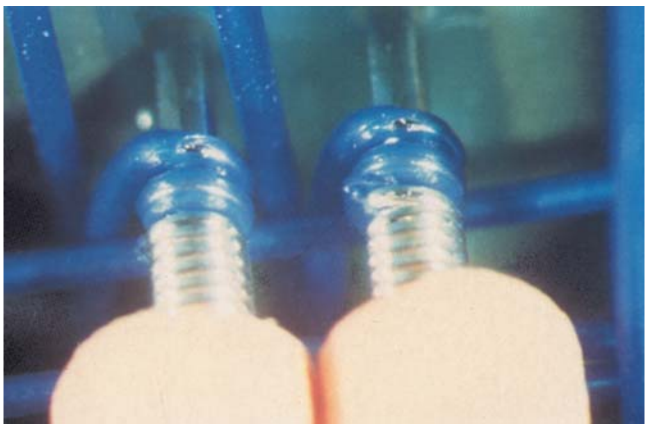

Figure 11-22

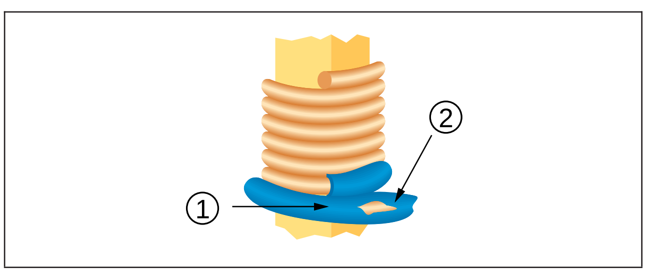

Figure 11-23
1. Initial contact corner
2. Split insulation, etc., prior to initial contact of post. Conductor is exposed.

Defect – Class 1,2,3

- Minimum electrical clearance violated.

Defect – Class 2,3

- Splits, cuts or fraying of insulation prior to initial contact of wire to corner of post.

11.1.10 Solderless Wrap – Damaged Conductors and Terminals

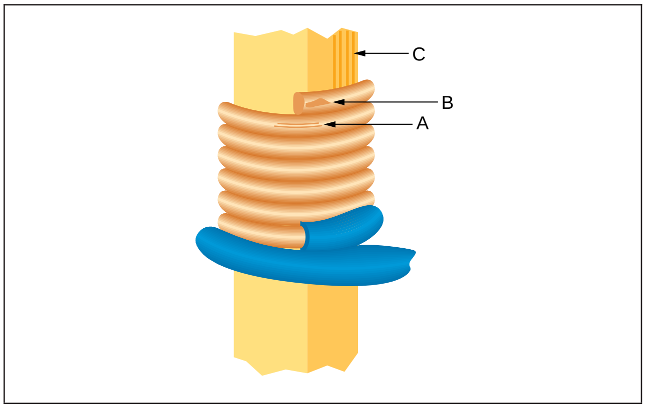

Figure 11-24

Target – Class 1,2,3

- Wire finish is not burnished or polished, nicked, scraped, gouged or otherwise damaged.
- Wire wrap terminals are not burnished, scraped or otherwise damaged.

Acceptable – Class 1,2,3

- Finish on the wire is burnished or polished (slight tool marks), see Figure 11-24-A.
- The top or last turn damaged from the wrap tool such as nicks, scrapes, gouges, etc., not exceeding 25% of wire diameter, see Figure 11-24-B.
- Damage to terminal caused by tool such as burnishing, scraping, etc., see Figure 11-24-C.

Acceptable – Class 1,2
Defect – Class 3

- Base metal is exposed on terminal.

12 High Voltage

This section provides the unique criteria for soldered connections that are subject to high voltages, see 1.8.6. The term ''high voltage'' will vary by design and application. The high voltage criteria in this document are only applicable when specifically required in the drawings/procurement documentation. Convex solder fillets may obscure wetting criteria. These criteria are applicable to wires or leads attached to terminals, bare terminals, and through-hole connections. The requirements are to assure that there are no sharp edges or sharp points to help mitigate arcing (corona discharge). Additional mitigation, e.g., wire insulation, encapsulation, may be required. For high voltage strand damage, see Table 6-2.

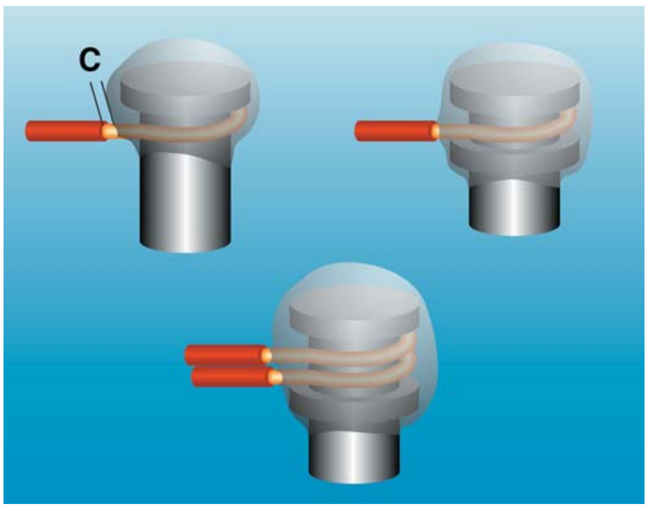

Figure 12-1

Target – Class 1,2,3

- Balled solder connection has a completely rounded, continuous and smooth profile.
- No evidence of sharp edges, solder points, icicles, inclusions (foreign material) or wire strands.
- All edges of the terminal are completely covered with a continuous smooth layer of solder forming a solder ball.
- Balled solder connection does not exceed specified height requirements.
- Insulation clearance (C) is minimal so that insulation is close to the solder connection without interfering with formation of the required solder ball.

12 High Voltage (cont.)

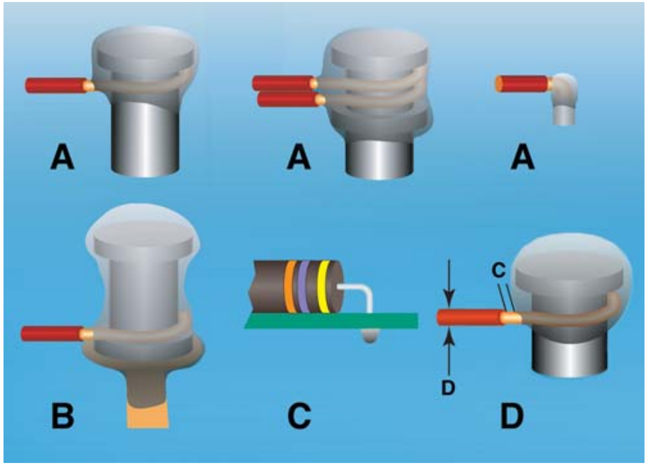

Figure 12-2

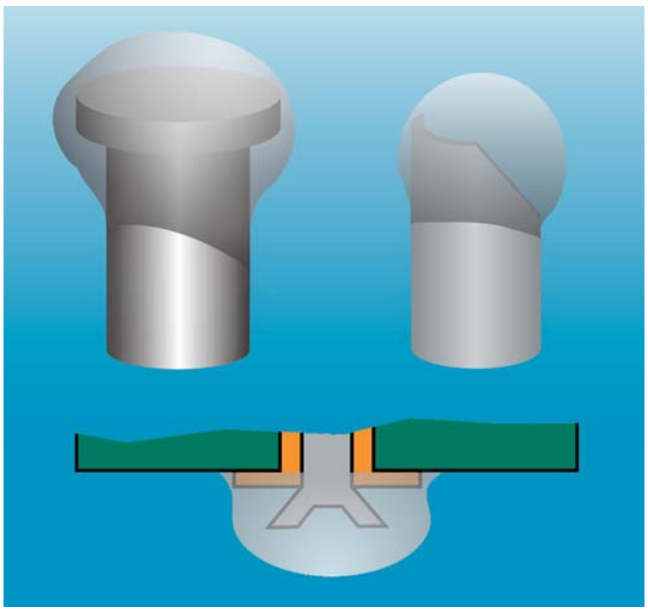

Figure 12-3

Acceptable – Class 1,2,3

- Solder connection has an egg-shaped, spherical or oval profile that follows the contour of terminal and wire wrap, see Figure 12-1.
- All sharp edges of the component lead and terminals are completely covered with a continuous smooth rounded layer of solder forming a solder ball, see Figure 12-2-A.
- Solder connections may have evidence of some layering or reflow lines, see 5.2.8.
- No evidence of sharp edges, solder points, icicles, inclusions (foreign material) or wire strands.
- Wire/lead outline is discernible with a smooth flow of solder on wire/lead and terminal. Individual strands may be discernible, see Figure 12-2-B.
- Straight-through leads facilitate ball soldering, see Figure 12-2- C.
- All sharp edges of the terminal's radial split are completely covered with a continuous smooth layer of solder forming a balled solder connection.
- There is no evidence of burrs or frayed edges on the hardware.
- Insulation clearance (C) is less than one overall diameter (D) away from the solder connection, see Figure 12-2-D.
- No evidence of insulation damage (ragged, charred, melted edges or indentations).
- Balled solder connection does not exceed specified height requirements.

12 High Voltage (cont.)

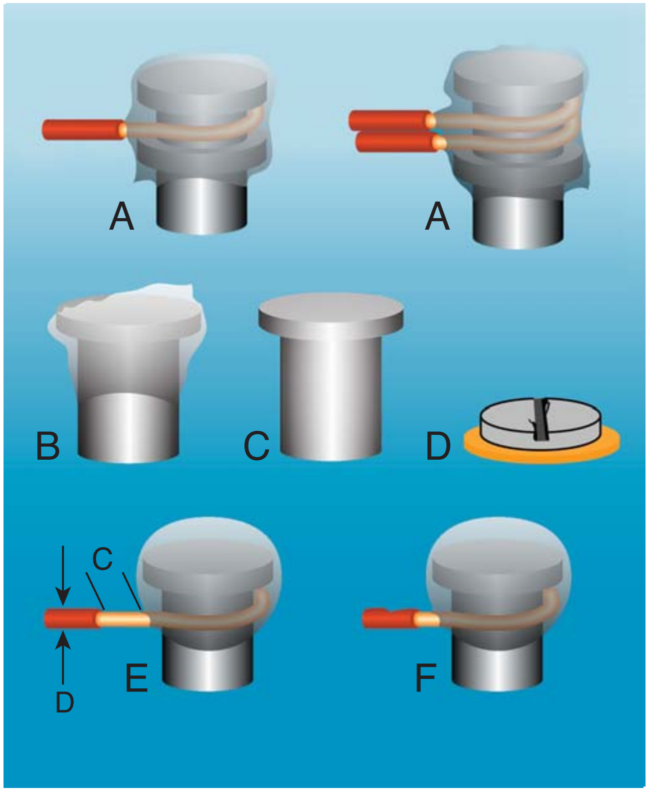

Figure 12-4

Defect – Class 1,2,3

- Discernible sharp edges, solder points, icicles, or inclusions (foreign material), see Figure 12-4-A.
- Evidence of edges not smooth and round with nicks or crevices.
- Solder follows contour of terminal and wire wrap but there is evidence of the sharp edge of the terminal protruding, see Figure 12-4-B.
- Evidence of wire strands not completely covered or discernible in the solder connection.
- Terminal lug is void of solder, see Figure 12-4-C.
- Hardware has burrs or frayed edges, see Figure 12-4-D.
- Insulation clearance (C) is one wire diameter (D) or more, see Figure 12-4-E.
- Evidence of insulation damage (ragged, charred, melted edges or indentations), see Figure 12-4-F.
- Balled solder connection does not comply with height or profile (shape) requirements.

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Minimum Electrical Clearance – Electrical Conductor Spacing

NOTE: Appendix B is quoted from IPC-2221 Generic Standard on Printed Board Design and is provided for information only. It is current as of publication date of this document. The User has the responsibility to determine the most current revision level of IPC-2221 and specify the specific application to their product. Paragraph and table numbers are from IPC-2221.

The following statement from IPC-2221 applies to this Appendix ONLY: **1.4 Interpretation – "Shall,"** the imperative form of the verb, is used throughout this standard whenever a requirement is intended to express a provision that is mandatory.

IPC-2221 – **6.3 Electrical Clearance** Spacing between conductors on individual layers should be maximized whenever possible. The minimum spacing between conductors, between conductive patterns, and between conductive materials (such as conductive markings or mounting hardware) and conductors **shall** be in accordance with Table 6-1, and defined on the master drawing.

Layer to layer conductive spaces (z-axis) should be in accordance with Table 6-1. Z-axis minimum spacing requirements may be reduced with appropriate qualification.

Note: The designer should be aware that the profile roughness of the copper foil determines the minimum dielectric distance between opposing copper points within a thin core laminate. See also IPC-4101 for tolerances by class and thickness of core; IPC-4562 for surface roughness of copper foil types; and IPC-6012 for the method to determine minimum dielectric thickness. Designers should be careful not to use minimum dielectric spacing values to determine overall printed board thickness.

See Section 10 for additional information on process allowances affecting electrical clearance.

When mixed voltages appear on the same board and they require separate electrical testing, the specific areas **shall** be identified on the master drawing or appropriate test specification. When employing high voltages and especially AC and pulsed voltages greater than 200 volts potential, the dielectric constant and capacitive division effect of the material **shall** be considered in conjunction with the recommended spacing.

For voltages greater than 500V, the (per volt) table values **shall** be added to the 500V values. For example, the electrical spacing for a Type B1 board with 600V is calculated as:

600V – 500V = 100V
0.25 mm [0.00984 in] + (100V x 0.0025 mm)
= 0.50 mm [0.0197 in] clearance

When, due to the criticality of the design, the use of other conductor spacings is being considered, the conductor spacing on individual layers (same plane) **shall** be made larger than the minimum spacing required by Table 6-1 whenever possible. Board layout should be planned to allow for the maximum spacing between external layer conductive areas associated with high impedance or high voltage circuits. This will minimize electrical leakage problems resulting from condensed moisture or high humidity. Complete reliance on coatings to maintain high surface resistance between conductors **shall** be avoided.

IPC-2221 – **6.3.1 B1–Internal Conductors** Internal conductor-to-conductor, and conductor-to-plated-through hole electrical clearance requirements at any elevation (see Table 6-1).

IPC-2221 – **6.3.2 B2–External Conductors, Uncoated, Sea Level to 3050 m [10,007 feet]** Electrical clearance requirements for uncoated external conductors are significantly greater than for conductors that will be protected from external contaminants with conformal coating. If the assembled end product is not intended to be conformally coated, the bare board conductor spacing **shall** require the spacing specified in this category for applications from sea level to an elevation of 3050 m [10,007 feet] (see Table 6-1).

IPC-2221 – **6.3.3 B3–External Conductors, Uncoated, Over 3050 m [10,007 feet]** External conductors on uncoated bare board applications over 3050 m [10,007 feet] require even greater electrical spacings than those identified in category B2 (see Table 6-1).

IPC-2221 – **6.3.4 B4–External Conductors, with Permanent Polymer Coating (Any Elevation)** When the final assembled board will not be conformally coated, a permanent polymer coating over the conductors on the bare board will allow for conductor spacings less than that of the uncoated boards defined by category B2 and B3. The assembly electrical clearances

Minimum Electrical Clearance – Electrical Conductor Spacing

of lands and leads that are not conformally coated require the electrical clearance requirements stated in category A6 (see Table 6-1). This configuration is not applicable for any application requiring protection from harsh, humid, contaminated environments.

Typical applications are computers, office equipment, and communication equipment, bare boards operating in controlled environments in which the bare boards have a permanent polymer coating on both sides. After they are assembled and soldered the boards are not conformal coated, leaving the solder joint and soldered land uncoated.

Note: All conductors, except for soldering lands, **shall** be completely coated in order to ensure the electrical clearance requirements in this category for coated conductors.

IPC-2221 – **6.3.5 A5–External Conductors, with Conformal Coating Over Assembly (Any Elevation)** External conductors that are intended to be conformal coated in the final assembled configuration, for applications at any elevation, will require the electrical clearances specified in this category.

Typical applications are military products where the entire final assembly will be conformal coated. Permanent polymer coatings are not normally used, except for possible use as a solder resist. However, the compatibility of polymer coating and conformal coating must be considered, if used in combination.

IPC-2221 – **6.3.6 A6–External Component Lead/Termination, Uncoated, Sea Level to 3050 m [10,007 feet]** External component leads and terminations, that are not conformal coated, require electrical clearances stated in this category.

Typical applications are as previously stated in category B4. The B4/A6 combination is most commonly used in commercial, nonharsh environment applications in order to obtain the benefit of high conductor density protected with permanent polymer coating (also solder resist), or where the accessibility to components for rework and repair is not required.

IPC-2221 – **6.3.7 A7–External Component Lead/Termination, with Conformal Coating (Any Elevation)** As in exposed conductors versus coated conductors on bare board, the electrical clearances used on coated component leads and terminations are less than for uncoated leads and terminations.

Table 6-1 Electrical Conductor Spacing

Voltage Between Conductors (DC or AC Peaks)	Minimum Spacing						
	Bare Printed Board				Assembly		
	B1[1]	B2	B3	B4	A5	A6	A7
0-15	0.05 mm [0.002 in]	0.1 mm [0.004 in]	0.1 mm [0.004 in]	0.05 mm [0.002 in]	0.13 mm [0.00512 in]	0.13 mm [0.00512 in]	0.13 mm [0.00512 in]
16-30	0.05 mm [0.002 in]	0.1 mm [0.004 in]	0.1 mm [0.004 in]	0.05 mm [0.002 in]	0.13 mm [0.00512 in]	0.25 mm [0.00984 in]	0.13 mm [0.00512 in]
31-50	0.1 mm [0.004 in]	0.64 mm [0.025 in]	0.64 mm [0.025 in]	0.13 mm [0.00512 in]	0.13 mm [0.00512 in]	0.4 mm [0.016 in]	0.13 mm [0.00512 in]
51-100	0.1 mm [0.004 in]	0.64 mm [0.025 in]	1.5 mm [0.0591 in]	0.13 mm [0.00512 in]	0.13 mm [0.00512 in]	0.5 mm [0.020 in]	0.13 mm [0.00512 in]
101-150	0.2 mm [0.0079 in]	0.64 mm [0.025 in]	3.2 mm [0.126 in]	0.4 mm [0.016 in]	0.4 mm [0.016 in]	0.8 mm [0.031 in]	0.4 mm [0.016 in]
151-170	0.2 mm [0.0079 in]	1.25 mm [0.0492 in]	3.2 mm [0.126 in]	0.4 mm [0.016 in]	0.4 mm [0.016 in]	0.8 mm [0.031 in]	0.4 mm [0.016 in]
171-250	0.2 mm [0.0079 in]	1.25 mm [0.0492 in]	6.4 mm [0.252 in]	0.4 mm [0.016 in]	0.4 mm [0.016 in]	0.8 mm [0.031 in]	0.4 mm [0.016 in]
251-300	0.2 mm [0.0079 in]	1.25 mm [0.0492 in]	12.5 mm [0.4921 in]	0.4 mm [0.016 in]	0.4 mm [0.016 in]	0.8 mm [0.031 in]	0.8 mm [0.031 in]
301-500	0.25 mm [0.00984 in]	2.5 mm [0.0984 in]	12.5 mm [0.4921 in]	0.8 mm [0.031 in]	0.8 mm [0.031 in]	1.5 mm [0.0591 in]	0.8 mm [0.031 in]
≥500 See para. 6.3 For calc.	0.0025 mm/ volt	0.005 mm/ volt	0.025 mm/ volt	0.00305 mm/ volt	0.00305 mm/ volt	0.00305 mm/ volt	0.00305 mm/ volt

Note 1. These values presume woven fiberglass coated with epoxy-based resin systems; other sytems may have different values.

Index

Index (cont.)

Index (cont.)

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IPC-A-610G

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1. I recommend changes to the following:

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___ Test Method number ________, paragraph number ________

The referenced paragraph number has proven to be:

___ Unclear ___ Too Rigid ___ In Error

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2. Recommendations for correction:

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3. Other suggestions for document improvement:

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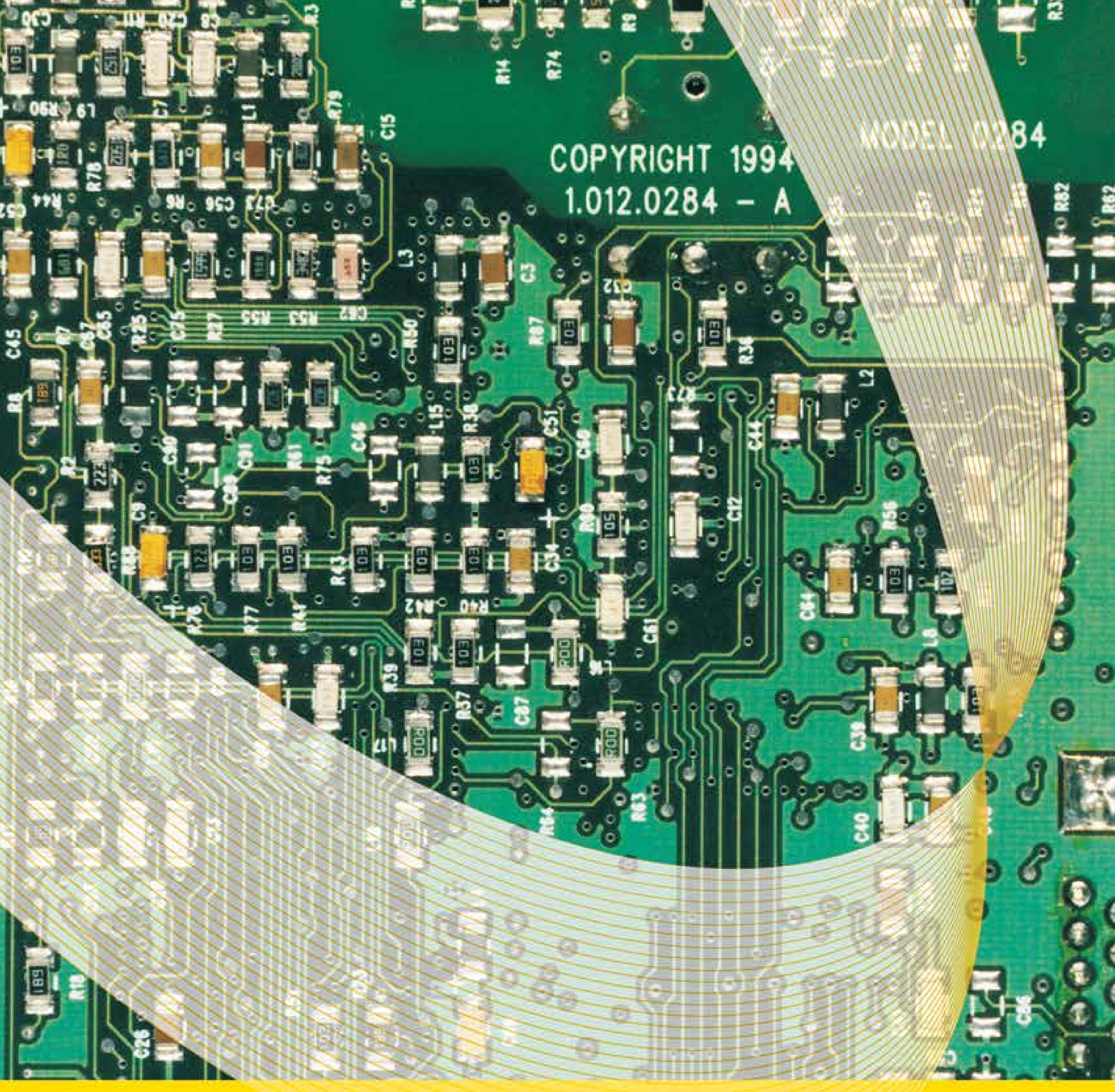

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