IPC J-STD-001E

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1 GENERAL

1.1 Scope <no change>

~~When J-STD-001 is cited~~ <now part of clause 1.7.1>

1.2 Purpose <no change>

1.3 Classification <no change>

1.4 Measurement Units and Applications <no change>

1.4.1 Verification of Dimensions <no change>

1.5 Definition of Requirements The word **shall** is used in the text of this document wherever there is a requirement for materials, preparation, process control or acceptance of a soldered connection.

Where the word **shall** leads to a hardware defect for at least one class, the requirements for each class are in brackets next to the **shall** requirement. ~~annotated in text boxes located adjacent to that occurrence in the text. These boxes are summarized in Appendix A. Appendix A identifies each listed condition for each class as either ''Defect,'' ''Process Indicator,'' ''Acceptable,'' or ''No Requirement Specified.'' In case of a discrepancy between requirements in the text boxes and Appendix A, requirements listed in the text boxes take precedence~~

Examples:

N	No requirement has been established for this Class
A	Acceptable
P	Process Indicator
D	Defect

[A1P2D3] is Acceptable Class 1, Process Indicator Class 2 and Defect Class 3
[N1D2D3] is Requirement Not Establish Class 1, Defect Classes 2 and 3
[A1A2D3] is Acceptable Classes 1 and 2, Defect Class 3
[D1D2D3] is Defect for all Classes.

A defect for a Class 1 product means that the characteristic is also a defect for Class 2 and 3. A defect for a Class 2 product means that the characteristic is also a defect for a Class 3 product, but may not be a defect for a Class 1 product where less demanding criteria may apply.

The word ''should'' reflects recommendations and is used to reflect general industry practices and procedures for guidance only.

Line drawings and illustrations are depicted herein to assist in the interpretation of the written requirements of this standard. Text takes precedence over the figures.

IPC-HDBK-001, a companion document to this specification, contains valuable explanatory and tutorial information compiled by IPC Technical Committees that is relative to this specification. Although the Handbook is not a part of this specification, when there is confusion over the specification verbiage, the reader is referred to the Handbook for assistance.

When the space shuttle symbol appears next to a paragraph it indicates that J-STD-001ES *Space Applications Electronic Hardware Addendum to J-STD-001E* contains different requirements to this paragraph. The criteria in J-STD-001ES are not applicable unless the addendum is specifically required by procurement documentation.

1.5.1 Hardware Defects and Process Indicators Hardware characteristics or conditions that do not conform to the requirements of this specification are classified as either hardware defects or hardware process indicators. ~~Hardware defects listed in the applicable text boxes **shall** be identified, documented, and dispositioned, e.g., rework, scrap, use as is, or repair.~~

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~~Not all process indicators specified by this standard are listed in the text boxes. Hardware process indicator data should be monitored (see 11.3), but the hardware need not be dispositioned.~~

A defect is a condition that may affect the form, fit, or function of the item in its end use environment, or other risk factors as identified by the manufacturer (see 1.8.5). Defects **shall [D1D2D3]** be identified, documented, and dispositioned by the manufacturer based on the design, service, and customer requirements. Disposition is the determination of how defects are to be treated, and include, but are not limited to, rework, scrap, use as-is, or repair.

A process indicator is a condition (not a defect) that is attributable to variation in material, equipment operation, workmanship or processes, but that does not affect the form, fit, or function of a product. Not all process indicators specified by this standard are noted. Hardware process indicator data should be monitored (see 11.3), but the hardware need not be dispositioned.

It is the responsibility of the user (see 1.8.13) to define additional or unique defect categories applicable to the product. It is the responsibility of the manufacturer (see 1.8.5) to identify defects and process indicators that are unique to the assembly process (see 1.13.2).

1.5.2 Material and Process Nonconformance <no change>

1.6 General Requirements Use of this standard requires agreement on the class to which the product belongs. If the user and manufacturer do not establish and document the acceptance class, the manufacturer may do so.

~~Surface mount designs need to undergo 'Design for Reliability' procedures based on the design parameters, the use conditions, the design life, and the acceptable failure risk to assure the designs capability to reliably function for its intended use. For "Design for Reliability" information see IPC-D-279 and IPC-9701.~~

The soldering operations, equipment, and conditions described in this document are based on electrical/ electronic circuits designed and fabricated in accordance with the specifications listed in Table 1-1.

Table 1-1 Design and Fabrication Specification

Board Type	Design Specification	Fabrication Specification
Generic Requirements	IPC-2221	IPC-6011
Rigid Printed Boards	IPC-2222	IPC-6012 IPC-A-600
Flexible Circuits	IPC-2223	IPC-6013
Rigid Flex Board	IPC-2223	IPC-6013

~~**Note 1.** This document~~ <note was deleted>

1.7 Order of Precedence The contract always takes precedence over this standard, referenced standards and drawings.

1.7.1 Conflict In the event of conflict between the requirements of this standard and the applicable assembly drawing(s)/documentation, the applicable user approved assembly drawing(s)/documentation govern. In the event of a conflict between the text of this standard and the applicable documents cited herein, the text of this standard takes precedence. In the event of conflict between the requirements of this standard and an assembly drawing(s)/ documentation that has not been user approved, this standard governs.

When IPC J-STD-001 is cited or required by contract, the requirements of IPC-A-610 do not apply unless separately or specifically required. When IPC-A-610 or other related documents are cited along with IPC J-STD-001 the order of precedence **shall [D1D2D3** be defined in the procurement documents.

Note: When IPC-A-610 is used as a companion document to J-STD-001, the revisions of J-STD-001 and IPC-A-610 should correspond, e.g. J-STD-001D and IPC-A-610D. The likelihood of criteria not aligning increases when different revisions are used together.

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The user (customer) has the responsibility to specify acceptance criteria. If no criteria is specified, required, or cited, then best manufacturing practice applies. ~~When documents other than IPC-A-610 are cited, the order of precedence **shall [D1D2D3]** be defined in the procurement documents.~~

1.7.2 Clause References <no change>

1.7.3 Appendices <no change>

1.8 Terms and Definitions Other than those terms listed below, the definitions of terms used in this standard are in accordance with IPC-T-50.

1.8.1 Defect A nonconformance to the requirements of this standard ~~(listed in or referenced by Appendix A)~~ or other risk factors as identified by the manufacturer (see 1.8.5).

1.8.2 Disposition The determination of how defects should be treated. Dispositions include, but are not limited to, rework, use as is, scrap or repair.

1.8.3 Electrical Clearance The minimum spacing between noncommon uninsulated conductors (e.g., patterns, materials, hardware, residue) is referred to as ‘‘minimum electrical clearance’’ throughout this document and 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 B (derived from IPC-2221). ~~Any violation of minimum electrical clearance as a result of nonconformance to defined criteria is a defect condition.~~<moved to section 4>

1.8.4 High Voltage <no change>

1.8.5 Manufacturer (Assembler) <no change>

1.8.6 Objective Evidence <no change>

1.8.7 Process Control <no change>

1.8.8 Process Indicator <no change>

1.8.9 Proficiency <no change>

1.8.10 Solder Destination Side The solder destination side is that side of the printed circuit board (PCB) that the solder flows toward in a plated-through hole application.

1.8.11 Solder Source Side <no change>

1.8.12 Supplier <no change>

1.8.13 User <no change>

1.8.14 Wire Overwrap Wire overwrap occurs when a wire/lead is wrapped more than 360° and remains in contact with the terminal post, see Figure 1-1.

new

Figure 1-1 Overwrap

1.8.15 Wire Overlap Wire overlap occurs when a wire/lead is wrapped more than 360° and crosses over itself, i.e., does not remain in contact with the terminal post, see Figure 1-2.

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Figure 1-2 overlap

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1.9 Requirements Flowdown When this standard is contractually required, the applicable requirements of this standard (including product class - see 1.3) **shall [D1D2D3]** 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.

When a part is adequately defined by a specification, then the requirements of this standard should be imposed on the manufacture 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 (i.e., daughterboard) is procured, that assembly should 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.

1.10 Personnel Proficiency <no change>

1.11 Acceptance Requirements <no change>

1.12 General Assembly Requirements <no change>

1.13 Miscellaneous Requirements

1.13.1 Health and Safety <no change>

1.13.2 Procedures for Specialized Technologies <no change>

1.13.2.1 Manufacture of Devices Incorporating Magnetic Windings <no change>

1.13.2.2 High Frequency Applications <no change>

1.13.2.3 High Voltage Applications <no change>

2 APPLICABLE DOCUMENTS

3 MATERIALS, COMPONENTS AND EQUIPMENT REQUIREM ENTS

3.1 Materials The materials and processes used to assemble/manufacture electronic assemblies **shall [D1D2D3]** be selected such that their use, in combination, produce products acceptable to this standard.

When major elements of the proven processes are changed, (e.g., flux, solder paste, cleaning media or system, solder alloy or soldering system) validation of the acceptability of the change(s) **shall [N1N2D3]** be performed and documented. They can also pertain to a change in bare boards ~~supplier~~, solder resist or metallization. ~~An example of a method for accomplishing this is provided as Appendix C~~B.

3.2 Solder Solder alloys **shall [D1D2D3]** be in accordance with J-STD-006 or equivalent. Solder alloys other than Sn60Pb40, Sn62Pb36Ag2, and Sn63Pb37 ~~Sn60A, Pb36B, and Sn63A which~~that provide the required electrical and mechanical attributes may be used if all other conditions of this standard are met and objective evidence of such is available for review. Flux that is part of flux-cored solder wire **shall [D1D2D3]** meet the requirements of 3.3. Flux percentage is optional.

3.2.1 Solder - Lead Free Solder alloys less than 0.1% lead by weight not listed by J-STD-006 may be used when such use is agreed upon by the manufacturer and the user.

3.2.2 Solder Purity Maintenance Solder used for preconditioning, gold removal, tinning of parts, and machine soldering **shall [N1D2D3]** be analyzed, replaced or replenished at a frequency to ensure compliance with the limits specified in Table 3-1.

Solder alloys other than Sn60Pb40, Sn62Pb36Ag2, or Sn63Pb37 ~~Sn60A, Sn63A, or Pb36B~~ tin/lead solders **shall [N1D2D3]** be in compliance with equivalent documented limits.

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If contamination exceeds the limits, intervals between the analyses, replacement or replenishment **shall [N1D2D3]** be shortened. The frequency of analysis should be determined on the basis of historical data, or monthly analyses. Records containing the results of all analyses and solder bath usage (e.g., total time in use, amount of replacement solder, or area throughput) **shall [N1D2D3]** be maintained for a minimum of one year for each process/ system.

SnPb alloys used for preconditioning or assembly **shall [N1D2D3]** have a tin content maintained within ± 1% of the nominal alloy being used. Tin content for SnPb alloys **shall [N1D2D3]** be tested at the same frequency as testing for copper/gold contamination. The balance of the SnPb bath **shall [N1D2D3]** be lead and/or the items listed in Table 3-1.

Lead-free alloys used for preconditioning or assembly **shall [N1D2D3]** have a tin content maintained within ± 1% of the nominal alloy being used. Tin content for lead-free alloys **shall [N1D2D3]** be tested at the same frequency as testing for copper/silver contamination. The balance of the lead-free bath **shall [N1D2D3]** be the items listed in Table 3-1.

~~The maximum contamination limits for lead-free alloys as listed in Table 3-1 are applicable for Sn96.4Ag3.0Cu0.5 (SAC305) per J-STD-006. Other lead-free solder alloy contamination limits may be used upon agreement between the user and the manufacturer.~~

Table 3-1 Maximum Limits of Solder Bath Contaminant

Contaminant	**Preconditioning Maximum Contaminant Weight Percentage Limit SnPb Alloys**	**Assembly Maximum Contaminant Weight Percentage Limit SnPb Alloys**	**Preconditioning and Assembly Maximum Contaminant Weight Percentage Limit Lead-free Alloys[1]**
Copper	0.75	0.3	1.1[3]
Gold	0.5	0.2	0.2
Cadmium	0.01	0.005	0.005
Zinc	0.008	0.005	0.005
Aluminum	0.008	0.006	0.006
Antimony	0.5	0.5	0.2
Iron	0.02	0.02	0.02
Arsenic	0.03	0.03	0.03
Bismuth	0.25	0.25	0.25
Silver[2]	0.75	0.1	4.0
Nickel	0.025	0.01	0.05
Lead	N/A	N/A	0.1
Total of Copper, Gold, Cadmium, Zinc, Aluminum Contaminates	N/A	0.4	NA

~~**Note 1:** The tin content of the solder **shall** be maintained within ± 1% of the nominal alloy being used. Tin content **shall** be tested at the same frequency as testing for copper/gold contamination. The balance of the bath **shall** be lead and/or the items listed above.~~

Note 1. Maximum contamination limits are applicable for Sn96.5Ag3.0Cu0.5 (SAC305) per J-STD-006. Other Lead-free solder alloy contamination limits may be used upon agreement between user and vendor.

Note 2. Not applicable for Pb36B: limits to be 1.75% to 2.25%.

Note 3. A maximum copper limit of 1.0% may be specified as agreed between user and supplier. Printed circuit assemblies that are characterized as thick and thermally demanding may have potential plated through hole fill and/or solder joint defects due to the impact of copper on solder flow characteristics.

3.3 Flux Flux **shall [D1D2D3]** be in accordance with J-STD-004 or equivalent.

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Flux **shall [N1N2D3]** conform to flux activity levels L0 and L1 of flux materials rosin (RO), resin (RE), or organic (OR), except ORL1 ~~organic flux activity level L1~~ **shall not [N1N2D3]** be used for no-clean soldering.

When other activity levels or flux materials are used, data demonstrating compatibility **shall [N1N2D3]** be available for review (see 3.1).

Note: Flux or solder paste soldering process combinations previously tested or qualified in accordance with other specifications do not require additional testing.

Type H or M fluxes **shall not [D1D2D3]** be used for tinning of stranded wires.

3.3.1 Flux Application <no change>

3.4 Solder Paste <no change>

3.5 Solder Preforms <no change>

3.6 Adhesives <no change>

3.7 Chemical Strippers Chemical solutions, pastes, and creams **shall not [D1D2D3]** cause damage or degradation. ~~Chemical strippers **shall not [D1D2D3]** be used with stranded wires.~~

3.8~~3.9~~ **Components** Components (e.g., electronic devices, mechanical parts, printed boards) selected for assembly **shall [D1D2D3]** be compatible with all materials and processes, e.g., temperature ratings, used to manufacture the assembly/product.

Moisture or process sensitive components (as classified by IPC/JEDEC J-STD-020, ECA/IPC/JEDEC J-STD-075 or other documented classification procedure) **shall [D1D2D3]** be handled in a manner consistent with IPC/ JEDEC J-STD-033 or other documented procedure.

~~**3.8 Heat Shrinkable Soldering Devices**~~ <moved to 4.19>

3.8.1~~3.9.5~~ **Component and Seal Damage** ~~Part bodies~~Components and lead seals **shall not [D1D2D3]** be degraded below the part specification requirements. ~~Visible cracks on glass-to-metal seals are not acceptable.~~

~~**3.9.6 Component Damage**~~ Minor surface flaws, discoloration, meniscus cracks, or chips in component bodies are acceptable. However, they **shall not [D1D2D3]** expose the component substrate or active element nor affect structural integrity. ~~There **shall not [D1D2D3]** be any damage to components in excess of component specification limits.~~ Components **shall not [D1D2D3]** be charred. ~~Visible cracks on glass-to-metal seals are not acceptable.~~

Note: Visual aids can be found in IPC-A-610.

3.8.2~~3.9.7~~ **Coating Meniscus** Component coating meniscus **shall not [N1D2D3]** be trimmed.

3.9~~3.11~~ **Soldering Tools and Equipment** Tools and equipment ~~used~~ **shall [D1D2D3]** be selected, used and maintained such that no damage or degradation that would be detrimental to the designed function of parts or assemblies result from their use. Soldering irons, equipment, and systems **shall [D1D2D3]** be chosen and employed to provide temperature control and isolation from electrical overstress or ESD (see 4.1). A tool used to cut leads **shall not [D1D2D3]** impart shock that damages a component lead seal or internal connection. See Appendix ~~B~~A for guidelines on tool selection and maintenance.

4 GENERAL SOLDERING AND ASSEMBLY REQUIREMENTS

4.1 Electrostatic Discharge (ESD) <no change>

4.2 Facilities <no change>

4.2.1 Environmental Controls <no change>

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4.2.2 Temperature and Humidity <no change>

4.2.3 Lighting Illumination at the surface of workstations should be at least 1000 lm/m2 (approximately 93 foot candles). ~~Light sources should be selected to prevent shadows.~~ Supplemental lighting may be necessary to assist in visual inspection.

Light sources should be selected to prevent shadows on the item being inspected except those caused by the item being inspected.

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 various printed circuit assembly features and contaminates with increased clarity..

4.2.4 Field Assembly Operations <no change>

4.3~~3.9.1~~ Solderability Electronic/mechanical components (including PCBs) and wires to be soldered **shall [D1D2D3]** meet the solderability requirements of J-STD-002 or equivalent and printed boards **shall [D1D2D3]** meet the requirements of J-STD-003 or equivalent. When a solderability inspection operation or pretinning and inspection operation is performed as part of the documented assembly process, that operation may be used in lieu of solderability testing (see 4.4).

4.4~~3.9.2~~ Solderability Maintenance The manufacturer **shall [D1D2D3]** ensure that all components, parts, leads, wiring, terminals, and printed boards that have met the requirements of 4.3 are solderable at the start of hand and/or machine soldering operations. The manufacturer should establish procedures to minimize part solderability degradation (see IPC-HDBK-001).

4.5~~3.9.3~~ Removal of Component Surface Finishes

Certain surface finishes on component terminations or PCB lands may impact the quality of the solder connection. Follow the requirements of 4.5.1 and 4.5.2.

The following requirements may be eliminated:

a. If there is documented objective evidence, available for review, that there are no gold related solder embrittlement issues, or other metallic surface finish solder joint integrity problems (e.g. with Sn or SnBi) associated with the soldering process being used (see IPC-HDBK-001 or IPC-AJ-820 handbook for guidance).
b. For electroless nickel immersion gold (ENIG), nickel-palladium-gold (NiPdAu), or electroless nickel electroless palladium immersion gold (ENEPIG) finishes.

4.5.1 Gold Removal Gold **shall [N1P2D3]** be removed:

a. From at least 95% of the surfaces to be soldered of the through-hole component leads with 2.54 µm [100 µin] or more of gold thickness.
b. From 95% of all surfaces to be soldered of surface mount components regardless of gold thickness.
c. From the surfaces to be soldered of solder terminals plated with 2.54 µm [100 µin] or more of gold thickness.

A double tinning process or dynamic solder wave may be used for gold removal prior to ~~soldering~~mounting the component on the assembly.

4.5.2 Other Metallic Surface Finishes Removal Other metallic surface finishes **shall [N1P2D3]** be removed from 95% of the surfaces to be soldered on components ~~**shall** be removed~~ if it is determined that the solder joint integrity will be compromised.

4.6~~4.10 Heat Sinks~~Thermal Protection When hand soldering, tinning or reworking a component identified as heat sensitive, protective measures ~~a thermal shunt or heat sink~~ **shall [D1D2D3]** be taken to minimize component heating or prevent thermal shock, e.g., heat sink, thermal shunt, preheat. Protection may be provided through a controlled heating process.

4.7~~3.9.4~~ Rework of Nonsolderable Parts A component lead, termination, or board not conforming to the solderability requirements of ~~3.9.1~~4.3 may be reworked (e.g., by dipping in hot solder) before soldering.

A reworked part **shall [D1D2D3]** conform to the requirements of ~~3.9.1~~4.3, less steam conditioning.

During tinning of leads, heat sinks **shall [D1D2D3]** be attached to the leads of components that are heat sensitive.

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4.8~~3.10~~ Presoldering Cleanliness Requirements The assembly ~~should~~ **shall [D1D2D3]** be clean of any matter that will inhibit compliance to the requirements of this standard.

4.9~~4.3~~ General Part Mounting Requirements When design restrictions mandate mounting components incapable of withstanding soldering temperatures incident to a particular process, such components **shall [D1D2D3]** be mounted and soldered to the assembly as a separate operation.

If cleaning is required, parts **shall [D1D2D3]** be mounted with sufficient clearances between the body and the PCB to assure adequate cleaning and cleanliness testing. Assemblies should be cleaned after each soldering operation so that subsequent placement and soldering operations are not impaired by contamination (see 8, Cleanliness Process Requirements).

~~On assemblies using mixed component mounting technology, through hole components should be mounted on one side of the printed board. Surface mounted components may be mounted on either or both sides of the assembly.~~<this was deleted>

Parts should be mounted such that part markings and reference designators are visible (see 9.2).

Any violation of minimum electrical clearance as a result of nonconformance to defined criteria is a defect condition.

4.9.1 Stress Relief At least one component lead **shall [D1D2D3]** have stress relief (see Figure 5-7) provided the component is not clip or adhesive mounted, or otherwise constrained. All leads **shall [D1D2D3]** have stress relief when the component is clip or adhesive mounted or otherwise constrained. Wires connected to terminals **shall [A1P2D3]** have stress relief.

4.10~~4.4~~ Hole Obstruction Parts and components **shall [A1P2D3]** be mounted such that they do not obstruct solder flow onto the solder destination side lands of plated through holes (PTHs) required to be soldered (see Figure 4-1 and ~~4.14.3~~4.18.3).

Figure 4-1 Hole Obstruction (changed component body color)

4.11~~4.5~~ Metal-Cased Component Isolation <no change>

4.12~~4.6~~ Adhesive Coverage Limits <no change>

4.13~~4.7~~ Mounting of Parts on Parts (Stacking of Components) <no change>

4.14~~4.8~~ Connectors and Contact Areas <no change>

4.15~~4.9~~ Handling of Parts <no change>

4.15.1~~4.9.1~~ Preheating <no change>

4.15.2~~4.9.2~~ Controlled Cooling <no change>

4.15.3~~4.9.3~~ Drying/Degassing <no change>

4.15.4~~34.9.4~~ Holding Devices and Materials <no change>

4.16~~4.11~~ Machine (Nonreflow) Soldering

4.16.1~~4.11.~~ Machine Controls The manufacturer **shall [N1D2D3]** maintain operating procedures describing the soldering process and the proper operation of the automatic soldering machine and associated equipment.

For the soldering machine, these procedures, as a minimum, **shall [N1D2D3]** define the preheat temperature, flux application procedures and coverage, solder temperature, controlled atmosphere (if used), rate of travel, frequency of temperature verification measurements, and frequency of solder bath analysis.

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If any of the above mentioned characteristics require an adjustment for a different printed circuit assembly, drawing number, or other positive identification element, the setting to be utilized **shall [N1D2D3]** be identified.

IPC-7530 provides guidance on developing an appropriate profile for wave and reflow soldering.

4.16.2~~4.11.2~~ Solder Bath <no change>

4.16.2.1~~4.11.2.~~ Solder Bath Maintenance <no change>

4.17~~4.12~~ Reflow Soldering <no change>

4.17.1 ~~4.13~~ Intrusive Soldering (Paste-in-Hole) See 6.2.2 for criteria when using reflow processes to form plated through-hole connections (intrusive soldering). ~~These criteria apply to reflow soldering of through-hole connections.~~

~~Solder **shall [D1D2D3]** be applied to the assembly such that the reflowed solder connections of the through hole connections, meet the requirements of Table 4-1.~~<moved to 6.2.2>

4.18~~4.14~~ Solder Connection All solder connections **shall [D1D2D3]** indicate evidence of wetting and adherence where the solder blends to the soldered surface. The solder connections should have a generally smooth appearance. Marks or scratches, e.g. probe marks, in the solder connection **shall not [D1D2D3]** degrade the integrity of the connection.

There are solder alloy compositions, component lead and terminal finishes, or printed board platings and special soldering processes (e.g., slow cooling with large mass PCBs) that may produce dull, matte, satin, gray, or grainy appearing solders that are normal for the material or process involved. These solder connections are acceptable.

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 [D1D2D3]** 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 [D1D2D3]** exceed 90° (Figure 4-2 A, B). As an exception, the solder connection to a termination may exhibit a wetting angle exceeding 90° (Figure 4-2 C, D) when it is created by the solder contour extending over the edge of the solderable termination area or solder resist.

~~**Table 4-1 Solder Acceptability, Intrusive Soldering, Supported Holes**[1]~~**<merged into Table 6-4>**

~~Criteria~~	~~Class 1~~	~~Class 2~~	~~Class 3~~
~~A. Vertical fill of solder.~~[2]	~~Not Specified~~	~~75%~~	~~75%~~
~~B. Wetting on solder source side of lead and barrel.~~[3]	~~270°~~	~~270°~~	~~330°~~
~~C. Percentage of land area covered with wetted solder on solder source side.~~[3]	~~75%~~	~~75%~~	~~75%~~
~~D. Fillet and wetting on solder destination side of lead and barrel.~~	~~Not Specified~~	~~180°~~	~~270°~~
~~E. Percentage of land area covered with wetted solder on solder destination side.~~	~~0~~	~~0~~	~~0~~

~~**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.~~
~~**Note 3.** Applies to any side to which solder paste was applied.~~

Figure 4-2 Acceptable Wetting Angles

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. All other solder fillet criteria are the same. ~~The photographs in Appendix D illustrate acceptable solder connections with various solder alloys and process conditions.~~

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 different wetting contact angles.

~~4.14.1 Exposed Basis Metal~~ <and> **~~4.14.2 Exposed Surface Finishes~~**<now combined into 4.18.1>

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4.18.1~~4.14.1~~ Exposed Surfaces
Except as noted elsewhere in this standard, the following requirements apply to exposed surfaces.
a. Exposed basis metal **shall not [D1D2D3]** prevent the formation of an acceptable solder connection.
b. Exposed Organic Solderability Preservatives (OSP) **shall not** (D1D2D3) prevent the formation of an acceptable solder connection.

4.18.2~~4.14.3~~ Solder Connection Defects <no change>

4.18.3~~4.14.4~~ Partially Visible or Hidden Solder Connections
Partially visible or hidden solder connections ~~are~~ **shall [A1~~,~~ P2~~,~~ D3]** ~~acceptable provided that~~meet the following conditions: ~~are met:~~
a. The design does not restrict solder flow to any connection element on the solder destination side lands (e.g., PTH component) of the assembly.
b. The visible portion, if any, of the connection on either side of the PTH solder connection (or the visible portion of the SMD connection) is acceptable.
c. Process controls are maintained in a manner assuring repeatability of assembly techniques.

4.19~~3.8~~ Heat Shrinkable Soldering Devices ~~Heat shrinkable soldering devices shall [D1D2D3] be installed in accordance with the requirements of the device manufacturer unless otherwise specified. See 8.1 for cleaning requirements.~~

When heat shrinkable soldering devices are used the following criteria **shall (D1D2D3)** be met:
a. Wires overlap for at least 3 conductor diameters and are approximately parallel.
b. The solder preform (ring) is centered over the splice.
c. Solder preform has melted and forms a fillet joining the connection (no evidence of the preform outline is visible).
d. Conductor contour is discernible.
e. Sleeving covers wire insulation on both ends of the spliced area by a minimum of 1 wire diameter.
f. No conductor strands piercing the sleeving.
g. Sleeve is discolored but not burned or charred.
h. Meltable sealing ring does not interfere with formation of required solder connection.
i. Meltable sealing ring provides a seal at both ends.

~~Wire contour should be visible in the solder fillet.~~ Terminations made using heat shrinkable solder devices are exempt from the cleaning requirements. ~~Wire shall not (N1P2P3) bulge the sleeving.~~

5 WIRES AND TERMINAL CONNECTIONS

5.1 Wire and Cable Preparation

5.1.1 Insulation Damage Insulation discoloration resulting from thermal stripping is permissible, however, the insulation **shall not [D1D2D3]** be charred. Chemical stripping material criteria are provided in 3.7.~~insulation stripping agents shall be used only for solid wire and are to be neutralized or removed prior to soldering.~~

Insulation deformation may be allowed provided:
a. Insulation **shall not [A1P2D3].** have cuts, breaks, cracks, or splits
b. Insulation **shall not [A1D2D3]** be melted into the wire strands**.**
c. Insulation thickness **shall not [D1D2D3]** be reduced by more than 20%.
d. Insulation **shall not [A1D2D3]** have uneven or ragged pieces of insulation (frays, tails, tags) greater than 50% of the insulation outside diameter or 1mm [0.039 in] whichever is more**.**
e. Insulation may have slight discoloration as a result of thermal stripping, but **shall not [D1D2D3]** be charred.

Chemical insulation stripping agents **shall [D1D2D3]** be used only for solid wire**.** Chemical solutions, pastes and creams used to strip solid wire **shall [D1D2D3]** be neutralized or removed prior to soldering.

Note: To prevent continuing degradation of the wire surface, the residue of chemical insulation stripping products should be removed within three (3) hours of the completion of chemical stripping activity.

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5.1.2 Strand Damage The number of damaged (nicked or broken) strands in a ~~single~~ multistranded wire **shall not [D1D2D3]** exceed the limits given in Table 5-1. See 6.1.2 for damage criteria applicable to solid conductor wires/leads. There **shall [A1D2D3]** be no strand separation (birdcaging) greater than one strand diameter or ~~allowed~~ beyond the outside diameter of the insulation. (Recommendations and requirements on wires used in high voltage applications are provided in 1.13.2.3.)

Wire strands **shall not** [N1D2D3] be altered or cut to fit terminals.

Table 5-1 ~~Damaged Strand Limits~~Allowable Strand Damage

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
~~Less than 7~~ 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%	5%	5%

Note 1: No damaged strands for wires used at a potential for 6 kV or greater.
Note 2: For plated wires, a visual anomaly that does not expose basis metal is not considered to be strand damage.
Note 3: Damaged strands have nicks or scrapes exceeding 10% of cross sectional area.

5.1.3~~5.1.1~~ Tinning of Stranded Wire Portions of stranded wire that will be soldered **shall [N1D2D3]** be tinned prior to mounting when:
a. Wires will be formed for attachment to solder terminals.
b. Wires will be formed into splices (other than mesh) and optional when heat shrinkable solder devices are used.

Solder wicking **shall not [D1D2D3]** extend to a portion of the wire which is required to remain flexible. The solder **shall [N1D2D3]** wet the tinned portion of the wire and should penetrate to the inner strands of the wire.

Solder build-up or icicles within the tinned wire area **shall not [D1D2D3]** affect subsequent assembly steps.

Stranded wires **shall not [D1D2D3]** be tinned when:
a. Wires will be used in crimp terminations.
b. Wires will be used in threaded fasteners.
c. Wires will be used in forming mesh splices.
~~• Wires will be used in heat shrinkable solder device.~~

5.2 Solder Terminals Terminals and solder cups **shall not [A1D2D3]** be modified to accept oversize conductors.

5.3 Bifurcated, Turret and Slotted Terminal Installation

5.3.1 Shank Damage <no change>

5.3.2 Flange Damage <no change>

Figure 5-1 Flange Damage

5.3.3 Flared Flange Angles <no change>

Figure 5-2 Flare Angles

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5.3.4 Terminal Mounting - Mechanical Terminals not connected to printed circuit or ground planes **shall [N1D2D3]** be of the rolled flange configuration (see Figure 5-3). A printed foil land **shall not [N1D2D3]** be used as a seating surface for a rolled flange ~~provided that~~ unless the land is isolated and not connected to an active printed circuit or ground plane.

Figure 5-3 Terminal Mounting - Mechanical
1. Shank
2. ~~Flat shoulder~~Terminal base
3. Rolled flange

5.3.5 Terminal Mounting - Electrical Terminals **shall [N1D2D3]** be mounted with flared flanges in noninterfacial PTHs provided the mounting is in conjunction with a land or ground plane on the flared side as shown in Figure 5-4A. Terminals **shall not [N1D2D3]** be flared to the base material of the printed board.

Terminals may be mounted in ~~non-PTHs~~unsupported holes with active circuitry on the top side and a roll flange on the back side of the board (see Figure 5-4B).

Figure 5-4 Terminal Mounting - Electrical

5.3.6 Terminal Soldering Terminals mounted ~~in accordance with 5.3,~~ and soldered to the printed board ~~in unsupported holes or noninterfacial PTHs should exhibit evidence of good wetting to both the terminal flange/shoulder and land or conductive plane. The soldered connection~~ **shall [D1D2D3]** meet the requirements shown in Table 5-2.

Table 5-2 Terminal Soldering Requirements<no change>

5.4 Mounting to Terminals

5.4.1 General Requirements <no change>

5.4.1.1 Insulation Clearance (C) The clearance (C) (Figure 5-5) between the end of the insulation and the solder of the connection **shall not [D1D2D3]** permit shorting or violation of minimum electrical clearance between noncommon conductors. The clearance between the end of wire insulation and the solder of the connection is as follows:
a. Minimum Clearance: The insulation ~~is in contact with but~~ **shall not [A1D2D3]** be embedded in the solder connection ~~but~~and **shall not ~~[A1D2D3]~~[D1D2D3]** interfere with formation of the ~~fillet~~ required solder connection. The contour of the wires should not be obscured at the termination of the insulation.
b. Maximum Clearance: Clearance **shall [A1P2D3]** be two wire diameters (including insulation) or 1.5 mm [0.0591 in], whichever is larger.

Figure 5-5 Insulation Clearance Measurement

5.4.1.2 Service Loops ~~Lead~~ When service loops are required, wires **shall [N1P2D3]** have sufficient length to allow at least one field repair ~~be dressed in the proper position with a slight loop or gradual bend~~ as shown in Figure 5-6. ~~The bend should be sufficient to allow at least one field repair.~~

Figure 5-6 Service Loop for Lead Wiring
1. ~~Acceptable~~Service loop
2. No service loop~~Not acceptable (insufficient)~~

5.4.1.3 Stress Relief At least one ~~C~~component lead~~s~~ **shall [D1D2D3]** have stress relief (see Figure 5-7) provided the component is not clip or adhesive mounted, or otherwise constrained~~)~~. All leads **shall [D1D2D3]** have stress relief when the component is clipped or adhesive mounted or otherwise constrained. Wires connected to terminals **shall [A1P2D3]** have stress relief.

Figure 5-7 Stress Relief Examples New figure

5.4.1.4 Orientation of Lead or Wire Wrap <no change>

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5.4.1.5 Continuous Runs A continuous solid bus wire may be run from terminal to terminal if three or more bifurcated, turret, or pierced terminals are to be connected (see Figure 5-8). A curvature **shall [D1D2D3]** be included in the unwrapped wire portion of the jumper to provide relief of tension from environmental loading. The connections to the first and last terminals **shall [D1D2D3]** meet the required wrap for individual terminals.

The following additional requirements **shall [A1P2D3]** be met:
~~a. The connection to the first and last terminals meet the required wrap for individual terminals.~~
~~b~~a. For each intermediate turret terminal, the wire is wrapped around or interweaves each terminal.
~~c~~b. For each intermediate bifurcated terminal, the wire passes through the slot and is in contact with the base of the terminal or a previously installed wire.
c~~d~~. For each intermediate pierced or perforated terminal, the wire is in contact with at least two nonadjacent contact surfaces of each intermediate terminal.

Figure 5-8 Continuous Runs <new>

5.4.1.6 Insulation Sleeving (Wires Soldered to Pierced, Hook and Cup Terminals) When insulation sleeving is installed over a wire soldered to a pierced, hook or cup terminal, there **shall [D1D2D3]** be no damage, e.g. splits, holes, cracks or exposure of conductors, etc., to the sleeving. ~~that would allow shorting of the wire or violation of minimum electrical clearance to adjacent circuitry.~~

The sleeving **shall [D1D2D3]** fit snugly and extend over the insulation a minimum of 6.0 mm [0.236 in], or two wire diameters, whichever is greater, and extend over the terminal beyond the solder termination.

5.4.1.7 Lead and Wire End Extensions <no change>

5.4.2 Bifurcated and Turret Terminals

5.4.2.1 Wire and Lead Wrap-Around - Turret and Straight Pin Leads and wires **shall [D1D2D3]** meet the requirements of Table 5-3 and **should** be mechanically secured to their terminals before soldering (Figure 5-9). Such mechanical securing should prevent movement between the parts of the connection during the soldering operation. ~~Leads and wires **shall [A1P2D3]** have a minimum of 180º contact between the wire/lead and the terminal. Leads and wires **shall not [D1D2D3]** have less than 90º of contact between the wire and the terminal.~~

On straight pins, the top wire on the terminal **shall [A1P2D3]** be at least one wire diameter below the top of the terminal.

Figure 5-9 Wire and Lead Wrap Around <keys were moved from right view to left view>

1. Upper guide slot
2. Lower guide slot
3. Base

TABLE 5-3 Turret and Straight Pin 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.	Accept	Process Indicator	Defect
≥180 ° Contact between lead/wire and post	Accept		
> 360 ° and overlaps itself. Note 1	Accept	Defect	
Wire violates minimum electrical clearance.	Defect		

Note 1: A wire that is wrapped more than 360° and remains in contact with the terminal post is considered an overwrap or spiral wrap and is not a defect. A wire that is wrapped more than 360° and crosses over itself, i.e., does not remain in contact with the terminal post, is an overlap and is a defect. See Figures 1-1 and 1-2.

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5.4.2.2 Termination of Small Gauge Wire (AWG 30 and Smaller) As an exception to the requirements of 5.4.2.1, AWG 30 and smaller wires **shall [D1D2D3]** meet the wrap requirements of Table 5-4. ~~wire size AWG 30 or smaller **shall [P2D3]** be wrapped at least once and should be wrapped no more than three complete turns around the terminal.~~

Table 5-4 AWG 30 and Smaller Wire Wrap Requirements

Criteria	Class 1	Class 2	Class 3
≤180°	Accept	Defect	Defect
180° to <360°	Accept	Process Indicator	Defect
≥360 °	Accept		

5.4.2.3 Side Route Connection - Bifurcated Terminals When practical, except for bus wire, wires should be placed in ascending order with the largest on the bottom. Lead and wire ends may extend beyond the base of terminals provided the minimum electrical clearance is maintained. The attachments should be maintained such that clearance between wires and clearance between the wires and the terminal board or panel is a minimum consistent with the wire insulation thickness.

For side route connections wrapped to a post on the terminal, the wire or component lead **shall [D1D2D3]** be dressed through the slot. Wires may be wrapped to either post of the terminal assuring positive contact of the wire with at least one corner of the post (see Figure 5-10). There **shall [A1P2D3]** be positive contact of the wire with at least one corner of the post (Figure 5-10) ~~and a minimum 90° contact between the wires/leads and the terminal~~and **shall** [D1D2D3] meet the requirements of Table 5-5. As an exception on Class 1 and Class 2 assemblies, wires/leads 0.75mm [(0.0295 in] or larger may be routed straight through.

Table 5-5 Bifurcated Terminal Wire Placement – Side Route

Criteria	Class 1	Class 2	Class 3
<90^{O} wrap	Defect	Defect	Defect
≥ 90^{O} wrap	Accept	Accept	Accept
Violates Minimum Electrical Clearance	Defect	Defect	Defect
≥360 ° and wire end overlaps itself, Note 1	Accept	Defect	

Note 1: A wire that is wrapped more than 360° and remains in contact with the terminal post is considered an overwrap or spiral wrap and is not a defect. A wire that is wrapped more than 360° and crosses over itself, i.e., does not remain in contact with the terminal post, is an overlap and is a defect. See Figures 1-1 and 1-2.

~~Table 5-3~~ Table 5-6 provides the staking criteria for side route connections that do not meet minimum wrap criteria. Wires or leads **shall [A1P2D3]** extend beyond the post of the terminal and be in contact with the base of the terminal or the previously installed wire.

~~Table 5-3~~Table 5.6 Staking Requirements of Side Route Straight Through Connections - Bifurcated Terminals

Wire Diameter	Class 1	Class 2	Class 3
<0.75 mm [0.0295 in][1]	Defect if not staked		
≥0.75 mm [0.0295 in][2]	Acceptable if not staked	Process Indicator if not staked	Defect if not staked

1. AWG-22 and smaller
2/ AWG-20 and larger

Figure 5-10 Side Route Connections and Wrap on Bifurcated Terminal

5.4.2.4 Top and Bottom Route Connections Bottom routed wires **shall [~~A1P2~~D1D2D3]** meet the requirements of Table 5-7~~be wrapped on the terminal base or post with a minimum of 90° bend~~ (see Figure 5-11). Wire insulation **shall not [A1P2D3]** enter the base of post of terminal. When top routed wires to bifurcated terminals are required by the design, the wire **shall [A1P2D3]** feed straight into the terminal between the ~~tines~~posts. Remaining space between the ~~tines~~ posts **shall [A1P2D3]** be filled by having the wire bent double or by using a separate filler wire (see Figure 5-11).

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Table 5-7 Bifurcated Terminal Wire Placement – Bottom Route

Criteria	Class 1	Class 2	Class 3
<90° wrap on parallel sides of post	Accept	Process Indicator	Defect
90° to 180° wrap on parallel sides of post	Accept	Accept	Accept

Figure 5-11 Top and Bottom Route Terminal Connection

5.4.3 Slotted Terminals Slotted terminals **shall [A1P2D3]** be terminated with the lead/wire extending straight through the opening of the terminal with no wrap. The wire **shall not [A1P2D3]** extend above the top of the terminal post. The lead/wire end **shall [A1P2D3]** be discernable on the exit side of the terminal and **shall [D1D2D3]** not violate minimum electrical clearance. Solder as a minimum **shall [D1D2D3]** wet 100% of the portion of the lead/wire that is in contact with the terminal. Solder may completely fill the slot.

5.4.4 Hook Terminals Connections to hook terminals **shall** [D1D2D3] meet the requirements of Table 5-8.
~~Wire(s) **shall [A1D2D3]** be wrapped 180° minimum.~~ <this is all part of Table 5-8 now>
~~b.Wire(s) **shall [A1D2D3]** be no closer than one wire diameter to the end of the hook.~~
~~c.Wire(s) should be within the arc of the hook (see Figure 5-12).~~
~~d.For components using hook terminations, wires **shall [A1P2D3]** be spaced a minimum of two lead diameters or 1.0 mm [0.039 in], whichever is greater, from the base of the terminal.~~

Table 5-8 Hook Terminal Wire Placement

Criteria	Class 1	Class 2	Class 3
<90° wrap	Defect		
90° to <180° wrap	Accept	Process Indicator	Defect
≥180° wrap	Accept		
>360 ° and wire end overlaps itself[1]	Accept	Defect	
Less than one wire diameter space from end of hook to closest wire	Accept	Process Indicator	Defect
Wire attached outside the arc of the hook and less than two lead diameters or 1mm [0.039 in] whichever is greater from the terminal base	Accept	Process Indicator	Defect
Wire violates minimum electrical clearance.	Defect		

Note 1: A wire that is wrapped more than 360° and remains in contact with the terminal post is considered an overwrap or spiral wrap and is not a defect. A wire that is wrapped more than 360° and crosses over itself, i.e., does not remain in contact with the terminal post, is an overlap and is a defect. See Figures 1-1 and 1-2.

Figure 5-12 Hook Terminal Connections

5.4.5 Pierced or Perforated Terminals For wiring to a single terminal, the wire(s) **shall [D1D2D3]** meet the requirements of Table 5-9, (see Figure 5-13). ~~pass through the eye and contact two nonadjacent sides of the terminal or be wrapped around the terminal a minimum of 90°~~

For user approved designs that incorporate staking/bonding of wires, the wire(s) attached to pierced terminals **shall [A1D2D3]** contact at least two surfaces of the terminal.

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Table 5-9 Pierced/Perforated Wire Placement

Criteria	Class 1	Class 2	Class 3
<90° wrap	Accept	Defect	
≥ 90° wrap	Accept		
>360 ° and wire end overlaps itself[1]	Accept	Defect	
Wire does not pass through the eye and contact two sides of the terminal	Accept	Defect	
Wire end violated minimum electrical clearance	Defect		

Note 1: A wire that is wrapped more than 360° and remains in contact with the terminal post is considered an overwrap or spiral wrap and is not a defect. A wire that is wrapped more than 360° and crosses over itself, i.e., does not remain in contact with the terminal post, is an overlap and is a defect. See Figures 1-1 and 1-2.

NEW
Figure 5-13 Pierced or Perforated Terminal Wire Wrap

5.4.6 Cup and Hollow Cylindrical Terminals The strands of any wire **shall [~~A1P2D3~~D1D2D3]** meet the requirements of 5.1. The wire or wires **shall [N1P2D3]** be inserted for the full depth of the ~~cup~~terminal.

The wire or wires **shall [A1P2P3]** be in contact with the back wall of the cup or other wires. ~~for the full depth of the cup.~~

5.5 Soldering to Terminals A solder fillet **shall [D1D2D3]** join the wire/lead to the terminal. Leads with a wrap of 180° or greater **shall [D1D2D3]** show evidence of good wetting for a minimum of 75% of the minimum required wrap area. Straight through terminations or leads wrapped less than 180° **shall [D1D2D3]** show evidence of good wetting for 100% of the lead to terminal contact area. For top routed wires in bifurcated terminals, solder **shall [D1D2D3]** be wetted at least 75% of the height of the terminal posts.

~~**5.5.1 Turret and Straight Pin Terminals**~~ Wetted solder in the wire to post contact area (Figure 5-14) **shall [D1D2D3]** conform to ~~Table 5-4~~Table 5-10.

~~Table 5-4~~Table5-10 Solder ~~Height~~ Requirements Wire to Post

	Class 1	Class 2	Class 3
Depression of solder between the post and the lead/wire is not greater than:	50% of wire/lead radius		25% wire/lead radius

(new)
Figure 5-14 Solder Height

5.5.1~~5.5.2~~ Cup and Hollow Cylindrical Terminals

a. A fillet **shall [N1P2D3]** be formed along the surfaces of contact between the wire and terminal.
b. Solder **shall [D1D2D3]** fill at least 75% of terminal.
c. Any solder buildup on the outside of the cup **shall not [D1D2D3]** affect form, fit or function.
d. Solder **shall [N1P2D3]** wet the entire inside of a terminal.
e. Solder **shall [D1D2D3]** be visible in the inspection hole (if present). ~~and may rise slightly above it. Solder may overfill the cup.~~

6 THROUGH-HOLE MOUNTING AND TERMINATIONS

6.1 Through-Hole Terminations - General Axial Leaded components, when mounted horizontal to the board surface, should be approximately centered between the mounting holes. The entire length of the component body should be in contact with the board surface. The maximum space between the component body and the board **shall [N1N2P3]** not exceed 0.7 mm [0.028 in]. Components that are required to be mounted off the board **shall [D1D2D3]** be elevated at least 1.5 mm [0.059 in]. Components mounted in unsupported holes and required to be elevated **shall [D1D2D3]** be provided with lead forms at the board surface, or other mechanical support.

Axial leaded components mounted vertically in unsupported holes **shall [D1D2D3]** be mounted with lead forms or other mechanical support.

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Axial lead components mounted vertically in supported holes **shall [D1D2D3]** have component height ~~requirements~~ and clearance (from the board to the body or weld bead) requirements in accordance with the user determined dimension and **shall not [D1D2D3]** impact form, fit or function.

6.1.1 Lead Forming <no change>

Figure 6-1 Lead Bends

Table 6-1 Lead Bend Radius

Lead Diameter	Minimum Bend Radius (R)
Less than 0.8 mm [0.031 in]	1 diameter/thickness
~~From~~ 0.8 to 1.2 mm [0.031 to 0.047 in]	1.5 diameters/thickness
Greater than 1.2 mm [0.047 in]	2 diameters/thickness

6.1.2 Lead Deformation Limits Leads **shall not [D1D2D3]** have nicks or deformation exceeding 10% of the diameter, width, or thickness of the lead except as allowed for flattened leads (see 7.1.4). ~~Exposed basis metal is acceptable provided it does not prevent the formation of an acceptable solder connection.~~

6.1.3 ~~Lead~~ Termination Requirements Component leads in supported holes 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.

Lead Terminations in unsupported holes **shall [N1N2D3]** be clinched a minimum of 45°.

If a lead or wire is clinched, the lead **shall [N1N2D3]** be wetted in the clinched area. The outline of the lead should be discernible in the solder connection.

Tempered leads **shall not [D1D2D3]** be terminated with a (full) clinched configuration.

Lead protrusion **shall not [D1D2D3]** violate minimum electrical clearance requirements. Lead protrusion **shall [D1D2D3]** be in accordance with Table 6-2 for ~~un~~supported holes or Table 6-3 for unsupported holes.

Connector leads, relay leads, tempered leads and leads greater than 1.3 mm (.051 in) diameter ~~leads~~ are exempt from the maximum length requirement provided that they do not violate minimum electrical spacing. ~~at the next higher assembly level.~~

Table 6-2~~3~~ Protrusion of Leads in Supported Holes

	Class 1	Class 2	Class 3
(L) min.	End is discernible in solder1		
(L) max.~~2~~	No danger of shorts	2.5 mm [0.0984 in]	1.5 mm [0.0591 in]

Note 1. For boards greater than 2.3 mm [0.0906~~86~~ in] thick, with components having preestablished lead lengths, e.g., DIPs, sockets, connectors, as a minimum need to have the component or lead shoulder flush to the board surface, but the lead end may not be ~~visible~~ discernible in the subsequent solder connection.

~~**Note 2.** Lead protrusion should not exceed 2.5 mm [0.0984 in] if there is a possibility of violation of minimum electrical spacing, damage to soldered connections due to lead deflection or penetration of static protective packaging during subsequent handling or operating environments.~~

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Table 6-32 Protrusion of Leads in Unsupported Holes

	Class 1	Class 2	Class 3
(L) min.	End is discernible in solder1		Sufficient to clinch
(L) max[1]	No danger of shorts		

Note 1. Lead protrusion should not exceed 2.5 mm [0.0984 in] if there is a possibility of violation of minimum electrical spacing, damage to soldered connections due to lead deflection or penetration of static protective packaging during subsequent handling or operating environments.

~~**Note 2.** See 6.2.1.~~

6.1.4 Lead Trimming Leads may be trimmed after soldering provided the cutters do not damage the component or solder connection due to physical shock. Tempered leads **shall not [N1D2D3]** be trimmed unless specified on the drawings.

New
Figure 6-2 Lead Trimming

When lead cutting is performed after soldering, the solder terminations **shall [N1D2D3]** either be reflowed or visually inspected at 10X to ensure that the original solder connection has not been damaged (e.g., fractured) or deformed. Lead trimming after soldering that cuts into solder fillets **shall [N1N2D3]** be reflowed (Figure 6-2). If the solder connection is reflowed this is considered part of the soldering process and not rework. This requirement does not apply to components that are designed such that a portion of the lead is intended to be removed after soldering (e.g., break-away tie bars).

6.1.5 Interfacial Connections ~~Unsupported holes with leads or~~ PTHs without leads ~~not subjected to mass soldering and~~ used for interfacial connections need not be filled with solder. ~~PTHs not exposed to solder because of permanent or temporary maskant and used for interfacial connections need not be filled with solder.~~

6.1.6 Coating Meniscus In Solder For Class 1 and 2 as an exception to Tables 6-4 or 6-5, as appropriate for supported or unsupported holes, on the solder destination side the meniscus may be covered by solder but on the solder source side there **shall [D1D2D3]** be 360° visible solder wetting and no visible coating meniscus in the solder connection. Solder connections **shall [N1N2D3]** meet the requirements of Tables 6-4 or 6-5, as appropriate.

~~**6.2 Unsupported Holes**~~**<Unsupported hole criteria moved to follow supported hole criteria>**
~~**6.2.1 Lead Termination Requirements for Unsupported Holes**~~
~~**Table 6-4 Unsupported Holes with Component Leads, Minimum Acceptable Conditions**~~

6.2~~6.3~~ Supported Holes

6.2.1~~6.3.1~~ Solder Application Solder **shall [N1D2D3]** only be applied to one side of a PTH except for intrusive soldering. Heat may be simultaneously applied to both sides of the PTH.

6.2.2~~6.3.2~~ Through-Hole Component Lead Soldering When soldering component leads into PTH connections, the goal of the process is to accomplish 100% fill of the PTH with solder and good wetting to the lands, lead, and barrel top and bottom. The solder connection shall [D1D2D3] ~~provide evidence of good wetting and the PTH solder fill shall~~ ~~[D1D2D3]~~ meet the requirements of Table 6-4, regardless of the soldering process, e.g. hand soldering, wave soldering, intrusive soldering, etc. ~~and Figure 6-21, with solder wetted to the hole wall.~~

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As an exception to the Class 2 fill requirements in Table 6-45, the minimum permissible vertical fill of a PTH is 50% or 1.19mm (0.047 inch), whichever is less, provided the following conditions are met:
a. The PTH is connected to thermal or conductor layers that act as thermal heat sinks.
b. The component lead is discernible in the lead termination side.
c. The solder fillet on the lead termination side is wetted 360° of the PTH barrel and 360° of the lead.
d. Surrounding PTHs meet requirements of Table 6-4.
~~for plated-through holes connected to thermal or conductor planes that act as thermal heat sinks, a 50% vertical fill of solder is permitted, but with solder extending 360° around the lead with 100% wetting from barrel walls to lead on the secondary side, and the surrounding PTHs meeting requirements of Table 6-5.~~

Table 6-45 Supported Holes with Component Leads, Minimum Acceptable Conditions Note 1

Criteria		Class 1	Class 2	Class 3
A	Vertical fill of solder. Notes 2,3 and Figure 6-3,~~4~~	Not specified	75%	75%
B	~~Circumferential wetting on solder destination side of lead and barrel.~~Circumferential wetting of lead and barrel on solder destination side.	Not specified	180°	270°
C	Percentage of original land area covered with wetted solder on solder destination side.	0	0	0
D	~~Circumferential fillet and wetting on solder source side of lead and barrel. Note 24~~ Circumferential fillet and wetting of lead and barrel on solder source side.	270°	270°	330°
E	Percentage of original land area covered with wetted solder on solder source side. Note 1	75 %	75 %	75 %

Note 1. Wetted solder refers to solder applied by any solder process including intrusive soldering. For intrusive soldering there may not be an external fillet between the lead and the land.
Note 23. The 25% unfilled height includes the sum of both source and destination side depressions.
Note 34. Class 2 may have less than 75% vertical fill as noted in 6.3.2.
~~**Note 42.** Applies to any side to which solder or solder paste was applied.~~

Figure 6-312 Vertical Fill Example

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.

6.36.2 Unsupported Holes

6.3.16.2.1 Lead Termination Requirements for Unsupported Holes Lead protrusion for unsupported holes **shall [D1D2D3]** meet the requirements of Table 6-3. Solder **shall [D1D2D3]** meet the requirements of Table 6-636-4.

Table 6-66-4 Unsupported Holes with Component Leads, Minimum Acceptable Conditions[1,4]

Criteria	Class 1	Class 2	Class 3
A. Fillet wetted to lead and land	270º	270º	330º Note 2
B. Percentage of land area covered with wetted solder[3]	75%	75%	75%

Note 1. Double sided boards with functional lands on both sides need to comply to A and B 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.

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7 SURFACE MOUNTING OF COMPONENTS

7.1 Surface Mount Device Lead Forming <no change>

Figure 7-1 Surface Mount Device Lead Forming

Figure 7-2 Surface Mount Device Lead Forming

Table 7-1 SMT Lead Forming Minimum Lead Length <no change>

~~e.~~a. **7.1.1 Lead Deformation Limits** <no change>

7.1.2 Flat Pack Parallelism <no change>

7.1.3 Surface Mount Device Lead Bends <no change>

7.1.4 Flattened Leads <no change>

7.1.5 Dual-in-Line Packages (DIPs) <no change>

7.1.6 Parts Not Configured for Surface Mounting <no change>

~~**7.2 Devices with Externally Deposited Elements** .~~<Moved to 7.5.4>

7.2~~7.3~~ Leaded Component Body ~~Clearing~~ Clearance The maximum clearance between the bottom of a leaded component body and the printed circuit surface should be 2 mm [0.078 in]. Parts insulated from circuitry or over surfaces without exposed circuitry may be mounted flush. Uninsulated parts mounted over exposed circuitry **shall [N1N2D3]** have their leads formed to provide a minimum of 0.25 mm [0.00984 in] between the bottom of the component body and the exposed circuitry.

7.2.1~~7.3.1~~ Axial-Leaded Components <no change>

7.3~~7.4~~ Parts Configured for Butt Lead Mounting <no change>

7.4 Hold Down of Surface Mount Leads <no change>

7.5~~7.6~~ Soldering Requirements <no change>

7.5.1~~7.6.1~~ Misaligned Components <no change>

7.5.2~~7.6.2~~ Unspecified and Special Requirements <no change>

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Table 7-2 Surface Mount Components

Bottom Only Terminations	~~7.6.~~7.5.3
Rectangular or Square End Component Termination	~~7.6.~~7.5.4
Cylindrical End Cap Terminations ~~(MELF)~~	~~7.6.~~7.5.5
Castellated Terminations	~~7.6.~~7.5.6
Flat ~~Ribbon, ''L'', and~~ Gull Wing Leads ~~Terminations~~	~~7.6.~~7.5.7
Round or Flattened (Coined) Gull Wing Leads ~~Terminations~~	~~7.6.~~7.5.8
''J'' Lead Terminations	~~7.6.~~7.5.9
Butt Connection Terminations	~~7.6.~~7.5.10
Flat Lug Lead Terminations	~~7.6.~~7.5.11
Tall Profile Components Having Bottom Only Terminations	~~7.6.~~7.5.12
Inward Formed L-shaped Ribbon Lead Terminations	~~7.6.~~7.5.13
Surface Mount Area Array Packages	~~7.6.~~7.5.14
Quad Flat Pack-No Leads QFN	~~7.6.~~7.5.15
Bottom Thermal Plane Terminations (D-Pak)	~~7.6.~~7.5.16
Flatten Post Connections/Square Solder Land, Round Flatten Post	7.5.17

7.5.3~~7.6. 3~~ Bottom Only Terminations Discrete chip components, leadless chip carriers, and other devices having metallized terminations on the bottom side only (except ball grid arrays) **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-3 and Figure 7-3 for each product classification. The widths of the component and land are W and P, respectively, and the termination overhang describes the condition whereby 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).

Table 7-3 Dimensional Criteria - Bottom Only Terminations

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		75% (W) or 75% (P), whichever is less
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	50% S		75% S
Termination/Plating Length	~~L~~R	Note 2		
~~Termination~~Land Length	S	Note 2		
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, determined by design.
Note 3. Wetting is evident.

Figure 7-3 Bottom Only Terminations updated

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7.5.4~~7.6.4~~ Chip Components - Rectangular or Square End Components - 1, 3 or 5 Side Termination

These criteria apply to component types such as Chip Resistor, Chip Capacitor, ~~and~~ Square End MELF and network passive parts (R-NET, etc.) that have this type of termination. Solder connections to components having terminations of a square or rectangular configuration **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-4 and Figure 7-4 for each product classification. For 1 sided termination, the solderable side is the vertical end face of the component.

The element of chip component with exposed deposited electrical element **shall [N1P2P3]** be mounted away from the board.

Table 7-4 Dimensional Criteria - Chip Components - Rectangular or Square End Components - 1, 3 or 5 Side Termination

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. Note 6		(G) + 25% (H) or (G) + 0.5 mm [0.02 in], whichever is less. Note 6
Solder Thickness	G	Note 3		
Termination Height	H	Note 2		
Minimum End Overlap	J	Required		
Width of Land	P	Note 2		
Termination Width	W	Note 2		
Side Mounting/Billboarding, Notes 7, 8				
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
Terminations ~~Faces~~		Component has three or more ~~faces~~wettable termination areas on each end		

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. The maximum fillet may overhang the land and/or extend onto the top of the end cap metallization; however, the solder does not extend further onto the top of the component body.
Note 5: (C) is measured from the narrowest side point of the solder fillet.
Note 6: Designs with open, unfilled via in ~~pad~~ land may preclude meeting these criteria. Solder acceptance criteria should be defined between the user and the manufacturer.
Note 7: These criteria are for chip components that may flip (rotate) onto the narrow edge during assembly.
Note 8: These criteria may not be acceptable for certain high frequency or high vibration applications.

Figure 7-4 Rectangular or Square End Components

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7.5.5~~7.6.5~~ Cylindrical End Cap ~~(MELF)~~ Terminations This component is sometimes referred to as MELF (Metal Electrode Leadless Face). Solder connections to components having cylindrical end cap terminations **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-5 and Figure 7-5 for each product classification.

7-5 Dimensional Criteria - Cylindrical End Cap ~~(MELF)~~ Terminations

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. Note 7		(G) + 25% (W) or (G) + 1.0 mm [0.0394 in], whichever is less. Note 7
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/Plating 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 from the narrowest point of the solder fillet.
Note 3. Unspecified parameter 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 of the component termination; however, the solder does not extend further onto the component body.
Note 6. Does not apply to components with end-only terminations.
Note 7: Designs with via in ~~pad~~ land may preclude meeting these criteria. Solder acceptance criteria should be defined between the user and the manufacturer.

Figure 7-5 MELF Terminations

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7.5.6~~7.6.6~~ Castellated Terminations Connections formed to castellated terminations **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-6 and Figure 7-6 for each product classification.

Table 7-6 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)		75% (W)
Minimum Side Joint Length~~, Note 4~~	D	Note 3	Depth of castellation	
Maximum Fillet Height	E	~~G+ H~~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 parameter or variable in size as determined by design.
Note 3. Wetting is evident.
~~**Note 4.** Length "D" is dependent on fillet height "F".~~
Note 4. The maximum fillet may extend past the top of the castellation provided it does not contact the body..

Figure 7-6 Castellated Terminations <updated>
1. Side overhang
~~2. Corner (termination) fillet required if metallization is present~~
~~3~~2. Side joint length
~~4~~3. Side overhang/end joint width

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7.5.7~~7.6.7~~ Flat ~~Ribbon, "L", and~~ Gull Wing Leads Connections formed to ~~F~~flat ~~ribbon, "L",~~ and gull wing shaped leads of either stiff or flexible materials **shall [D1D2D3]** meet the alignment and solder fillet requirements of Table 7-7 and Figure 7-7 for each product classification.

In the following criteria, the word~~s~~ "~~"~~plastic" ~~component"~~ ~~are~~ is 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).

Table 7-7 Dimensional Criteria - Flat ~~Ribbon, "L," and~~ 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		
Minimum End Joint Width		C	50% (W)		75% (W)
Minimum Side Joint Length Note 6	when (L) is ≥3 W	D	(1 W) or 0.5 mm [0.02 in], whichever is less	3(W) or 75% (L), whichever is longer	
	when (L) is<3W			100 % (L)	
Maximum Heel Fillet Height		E	Note 4		
Minimum Heel Fillet Height	(T) ≤0.38 mm [0.0149 in],	F	Note 3	(G) +(T) Note 5	(G) +(T) Note 5
	(T) >0.38 mm [0.0149 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 parameter or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. Solder fillet may extend through the top bend. Solder does not touch package body or end seal, except for plastic SOIC or SOT devices. Solder should not extend under the body of surface mount components whose leads are made of Alloy 42 or similar metals.
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. Fine pitch leads (component terminations on less than 0.65 mm [0.025 in] centers as defined by IPC-T-50) require a minimum side fillet length of 0.5 mm [0.02 in].

Figure 7-7 Flat ~~Ribbon, "L," and~~ Gull Wing Leads
1. Side overhang
2. Toe overhang
3. End joint width
4. Land
5. Lead
6. ~~Other lead configurations~~See 7.5.11 Flat Lug Leads
7. See Note 4, Table 7-7
8. Center line of (T)
9. Line bisecting lower bend
10. Toe down heel fillet height
11. Side joint length

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7.5.8~~7.6.8~~ Round or Flattened (Coined) Gull Wing Leads Connections formed to round or flattened (coined) gull wing leads **shall [D1D2D3]** meet the dimensional and fillet requirements of Table 7-8 and Figure 7-8 for each product classification.

Table 7-8 Dimensional Criteria - Round or Flattened (Coined) 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		
Minimum End Joint Width	C	Note 3		75% (W)
Minimum Side Joint Length	D	100% (W)		150% (W)
Maximum Heel Fillet Height	E	Note 4.		
Minimum Heel Fillet Height	F	Note 3	(G) + 50% (T) Note 5	(G) +(T) Note 5
Solder Thickness	G	Note 3		
Formed Foot Length	L	Note 2		
Minimum Side Joint Height	Q	Note 3	(G) + 50% (T)	
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 parameter or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. Solder fillet may extend through the top bend. Solder does not touch package body or end seal. ~~, except for plastic SOIC or SOT devices.~~ Solder should not extend under the body of surface mount components whose leads are made of Alloy 42 or similar metals.
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.

Figure 7-8 Round or Flattened (Coined) Gull Wing Leads

7.5.9~~7.6.9~~ ‘‘J’’ Leads Connections formed to leads having a ‘‘J’’ shape at the connection site **shall [D1D2D3]** meet the dimensional and fillet requirements of Table 7-9 and Figure 7-9 for each product classification.

Table 7-9 Dimensional Criteria -‘‘J’’ Leads<no change>

Figure 7-9 ‘‘J’’ Leads

This redline document shows significant changes from Rev D.

7.5.10~~7.6.10~~ Butt/I Connections (Not Permitted for Class 3 Products) Connections formed to leads positioned perpendicular to a circuit land in a butt/I configuration **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-10 and Figure 7-10 for each product classification.

Table 7-10 Dimensional Criteria - Butt/I Connections ~~(Not Applicable to Class 3)~~

Feature	Dim.	Class 1	Class 2
Maximum Side Overhang	A	25% (W) Note 1	Not permitted
~~Maximum~~ Toe Overhang	B	Not permitted	
Minimum End Joint Width	C	75% (W)	75% (W)
Minimum Side Joint Length	D	Note 2	
Maximum Fillet Height	E	Note 4	
Minimum Fillet Height	F	0.5 mm [0.0197 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 parameter or variable in size as determined by design.
Note 3. Wetting is evident.
Note 4. Maximum fillet may extend into the bend radius. Solder does not touch package body.

Figure 7-10 Butt/I ~~Joint~~Connection

7.5.11~~7.6.11~~ Flat Lug Leads Connections formed to the leads of power dissipating components with flat lug lead **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-11 and Figure 7-11.

Table 7-11 Dimensional Criteria - Flat Lug Leads<no change>

Figure 7-11 Flat Lug Leads

This redline document shows significant changes from Rev D.

7.5.12~~7.6.12~~ Tall Profile Components Having Bottom Only Terminations Connections formed to the termination areas of tall profile components (component height is more than twice the component width or thickness, whichever is less) having bottom only terminations **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-12 and Figure 7-12. If the height of the component exceeds the thickness of the component, it should not be used in products subject to vibration and/or shock unless an appropriate adhesive is used to reinforce the component mounting.

Table 7-12 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	
Minimum End Joint Width	C	50% (W)	75% (W)	(W)
Minimum Side Joint Length	D	Note 3	50% (S)	75% (S)
Solder Fillet Thickness	G	Note 3		
Termination/Plating Length	R	ADD R TO DRAWING 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. The component solderable termination area does not overhang PCB land area.

Figure 7-12 Tall Profile Components Having Bottom Only Terminations changed L TO R

7.5.13~~7.6.13~~ Inward Formed L-Shaped Ribbon Leads Connections formed to components having Inward Formed L-shaped lead terminations **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-13 and Figure 7-13.

Table 7-13 Dimensional Criteria - Inward Formed L-Shaped Ribbon Leads5

Feature	Dim.	Class 1	Class 2	Class 3
Maximum Side Overhang	A	50% (W) Notes 1, 5		25% (W) or 25% (P), whichever is less; Notes 1, 5
Maximum Toe Overhang	B	Note 1	~~Not Permitted~~Note 1	
Minimum End Joint Width	C	50% (W)		75% (W) or 75% (P), whichever is less
Minimum Side Joint Length	D	Note 3	50% (L)	75% (L)
Maximum Fillet Height	E	(H) +(G) Note 4	(H) +(G) Note 4	(H) +(G) Note 4
Minimum Fillet Height, Notes 5, 6	F	Wetting is evident on the vertical surface(s) of the component termination	(G) + 25% (H) or (G) + 0.5 mm [0.0197 in], whichever is less	
Solder Fillet Thickness	G	Note 3		
Lead Height	H	Note 2		
Minimum Land Extension	K	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 on the inside of the lead bend.
Note 5. Where a lead has two prongs, the connection to each prong is to meet all the specified requirements.
Note 6. Designs with via in ~~pad~~ land may preclude meeting these criteria. Solder acceptance criteria should be defined between the user and the manufacturer.

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Figure 7-13 Inward Formed L-Shaped Ribbon Lead <updated picture>

7.5.14~~7.6.14~~ Surface Mount Area Array Packages ~~These criteria are intended to apply to ball grid array (BGA) devices with solder balls that collapse during reflow.~~

~~A BGA~~The area array criteria ~~criterion~~ defined herein assumes an inspection process is established to determine compliance for either X-Ray or 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.

Visual inspection requirements:
- When visual inspection is the method used to verify product acceptance the magnification levels of Tables 11-1 and 11-2 apply.
- The solder terminations on the outside row (perimeter) of the ~~BGA~~ area array component should be visually inspected whenever practical.
- The ~~BGA~~ area array component needs to align in both X & Y directions with the corner markers on the PCB (if present).
- Absence of ~~BGA~~ leads, e.g. solder ball~~(s)~~ or columns, are defects unless specified by design.

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.

~~BGA~~ Area array process guidance is provided in IPC-7095, which contains recommendations developed from extensive discussion of ~~BGA~~ process development issues.

Note: X-ray equipment not intended for electronic assemblies or not properly set up can damage sensitive components.

Surface mount area array packages **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-14 for components with collapsing balls, Table 7-15 for components with noncollapsing balls, and Table 7-16 for column grid arrays.

7.5.14.1 Ball Grid Array Components with Collapsing Balls Ball grid array (BGA) components with collapsing balls shall **[D1D2D3]** meet the requirements of Table 7-14.

Table 7-14 Dimensional Criteria ~~–~~ ~~Area Array~~/Ball Grid Array Components with Collapsing Balls

Feature	Classes 1,2,3
Alignment	Solder ball offset does not violate minimum electrical clearance.
Solder Ball Spacing, Figure 7-14	Solder ball offset (c) does not violate minimum electrical clearance.
Soldered Connection	a. Solder connections meet the criteria of 4.18 b. BGA solder balls contact and wet to the land forming a continuous elliptical round or pillar connection
Voids	25% or less voiding of any ball in the x-ray image area. Notes 1, 2
Under-fill or staking material	Required underfill or staking material is present and completely cured.

Note 1. Design induced voids, e.g., microvia in land, are excluded from this criteria. In such cases acceptance criteria will need to be established between the manufacturer and user.

Note 2. Manufacturers may use test or analysis to develop alternate acceptance criteria for voiding that consider the end-use environment.

Figure 7-14

This redline document shows significant changes from Rev D.

7.5.14.2 Ball Grid Array Components with Noncollapsing Balls Ball grid array components with noncollapsing balls **shall [D1D2D3]** meet the requirements of Table 7-15.

Table 7-15 Ball Grid Array Components with Noncollapsing Balls

Feature	Classes 1,2,3
Alignment	Solder ball offset does not violate minimum electrical clearance.
Soldered Connection	a. Solder connections meet the criteria of 4.18 b. Solder is wetted to the solder balls and land terminations.
Under-fill or staking material	Required underfill or staking material is present and completely cured.

7.5.14.3 Column Grid Array Components Column grid array (CGA) components **shall [D1D2D3]** meet the requirements of Table 7-16.

Table 7 16 – 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 4.18	
	External columns show complete filleting for the portions of the columns that are visible	
Under-fill or staking material	Required underfill or staking material is present and completely cured.	

7.5.15~~7.6.15 Quad Flat Pack (No Leads) (QFNL)~~Bottom Termination Components (BTC) These criteria are also applicable to Small Outline Integrated Circuit (No Leads) [SOICNL].

Criteria for nonvisible part of thermal plane solder connections are not described in this document and will need to 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. Solder, when required, **shall [D1D2D3]** meet documented requirements.

Connections formed to components having no significant external lead form **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-17 and Figure 7-15.

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 and a toe fillet will not form.

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.

This redline document shows significant changes from Rev D.

Table 7-177 15 Dimensional Criteria - QFN

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)	75% (W)	
Minimum Side Joint Length	D	Note 4		
Solder Fillet Thickness	G	Note 3		
Minimum Toe (End) Fillet Height	F	Notes 2, 5		(G)+(H), Notes 2, 5
Termination Height	H	Note 5		
Solder coverage of thermal padland		Note 4		
Land Width	P	Note 2		
Termination Width	W	Note 2		
Thermal Plane Void Criteria		Note 6		

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. See 4.18.3.
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. Acceptance criteria will need to be established between the manufacturer and user.

Figure 7-15

7.5.167.6.16 Components with Bottom Thermal Plane Terminations (D-Pak) Criteria for nonvisible part of thermal plane solder connections are not described in this document and will need to 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. Solder, when required, **shall [D1D2D3]** meet documented requirements. When soldering these types of components voiding in the thermal plane is common.

Note: The criteria for leads other than the thermal plane termination are provided in the criteria for the type of lead termination used.7.6.7.5.7.

Connections formed to components with bottom thermal plane terminations **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-18.7 16.

Table 7-187 16 Dimensional Criteria - Bottom Thermal Plane Terminations

Feature (all connections except thermal plane)	Dim.	
Maximum Side Overhang	A	See 7.6.7.5.7 The mounting and solder requirements for SMT terminations **shall [D1D2D3]** meet the criteria for the type of lead termination being used.
Toe Overhang (outside edge of component termination)	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	
Feature (only for the thermal plane connection)		**Class 1,2,3**
Thermal Plane Side Overhang (Figure 7-16)		Not greater than 25% of termination width.
Thermal Plane End Overhang		No overhang.
Thermal Plane End Joint Width		100% wetting to land in the end-joint contact area.

Figure 7-16 new

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7.5.17 Flatten Post Connections/Square Solder Land, Round Flatten Post

Criteria have not been established for Class 3 for this termination style.

Connections formed to components with flatten post connections, Figure 7-17, **shall [D1D2D3]** meet the dimensional and solder fillet requirements of Table 7-19.

Table 7-19 Dimensional Criteria Flatten 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.

Figure 7-17 IPC action to add drawings with keys showing specific features

7.6 Specialized SMT Terminations The IPC committee that maintains this standard has received requests to include a number of specialized SMT termination styles. 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 1.13.2 of this standard is repeated here.

> ***1.13.2 Procedures for Specialized Technologies*** *As an industry consensus standard, this document cannot address all of the possible components and product design combinations, e.g., magnetic windings, high frequency, high voltage, etc. Where uncommon or specialized technologies are used, it may be necessary to develop unique process and/or acceptance criteria. Often, unique definition is necessary to consider the specialized characteristics while considering product performance criteria.*
>
> *The development should include user involvement. The acceptance criteria* ***shall [N1N2D3]*** *have user agreement. Mounting and soldering requirements for specialized processes and/or technologies not specified herein* ***shall [N1D2D3]*** *be performed in accordance with documented procedures which are available for review.*
>
> *Whenever possible these criteria should be submitted to the IPC Technical Committee to be considered for inclusion in upcoming revisions of this standard.*

8 CLEANING PROCESS REQUIREMENTS<no change>

8.1 Cleanliness Exemptions <no change>

8.2 Ultrasonic Cleaning <no change>

8.3 Post-Solder Cleanliness <no change>

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8.3.1 Particulate Matter Assemblies **shall [D1D2D3]** be free of dirt, lint, solder ~~splash,~~ webbing, dross, wire clippings, etc. Solder balls or solder splash **shall [D1D2D3]** neither be loose (i.e., be dislodged in the normal service environment of the product) nor violate minimum electrical clearance.

8.3.2 Flux Residues and Other Ionic or Organic Contaminants <no change>

8.3.3 Post-Soldering Cleanliness Designator <no change>

8.3.4 Cleaning Option <no change>

Table 8-1 Designation of Surfaces to be Cleaned<no change>

8.3.5 Test for Cleanliness <no change>

Table 8-2 Cleanliness Testing Designators<no change>

8.3.6 Testing <no change>

8.3.6.1 Rosin Flux Residues <no change>

8.3.6.2 Ionic Residues (Instrument Method) <no change>

8.3.6.3 Ionic Residues (Manual Method) <no change>

8.3.6.4 Surface Insulation Resistance (SIR) <no change>

8.3.6.5 Other Contamination <no change>

9 PCB REQUIREMENTS

This section applies to PCB defects regardless of when they occur.

9.1 Printed Circuit Board Damage

9.1.1 Blistering/Delamination <no change>

9.1.2 Weave Exposure/Cut Fibers Weave exposure **shall not [D1D2D3]** reduce the clearance between noncommon conductive patterns to less than the minimum electrical clearance. There **shall [N1D2D3]** be no surface damage that cuts into laminate fibers.

9.1.3 Haloing <no change>

9.1.4 Land Separation The outer, lower edge of land areas **shall not [D1D2D3]** be lifted or separated more than the thickness (height) of the land. For Class 3 assemblies, the land areas **shall not [N1N2D3]** be lifted when there is an unfilled via or via with no lead in the land.

9.1.5 Land/Conductor Reduction in Size <no change>

9.1.6 Flexible Circuitry Delamination <no change>

9.1.7 Flexible Circuitry Damage There **shall not [D1D2D3]** be evidence of tearing, blistering, charring, or melting of the insulation. Nicks ~~and~~ ~~tears~~ **shall not [D1D2D3]** be more than 50% of the distance from the edge to the nearest conductor or 2.5 mm, whichever is less.~~on flexible printed circuit boards or assemblies.~~

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Note: Mechanically created indentions 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.

9.1.8 Burns Burns **shall not [D1D2D3]** physically damage the surface of the assembly.

9.1.9 Solder on Gold Contacts <no change>

9.1.10 Measles ~~Measled areas in laminate substrates **shall not [N1P2D3]** exceed 50% of the physical spacing between internal conductors.~~ Measling is acceptable for Class 1, 2 and 3 end printed board assemblies. Measled areas in laminate substrates **shall not [N1N2P3]** exceed 50% of the spacing between non-common conductors.

Note: 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. Users who wish to incorporate additional criteria for measle conditions may consider incorporating the provisions of IPC-6012, Class 3A which does not allow measles for Class 3 product.

Note: Visual aids can be found in IPC-A-610 and IPC-HDBK-001.

9.2 Marking <no change>

9.3 Bow and Twist (Warpage) <no change>

~~**10 COATING AND ENCAPSULATION**~~
10 COATING, ENCAPSULATION and STAKING (ADHESIVE)

When coating or encapsulation materials are applied to glass body components, the components **shall [D1D2D3]** be sleeved to prevent cracking, unless the material has been selected so as not to damage the components/assembly in its service environment.

The material specification or other documented procedure **shall [D1D2D3]** be followed for mixing and curing. The material **shall [D1D2D3]** be used within the time period specified (both shelf life and pot life) or used within the time period indicated by a documented system the manufacturer has established to mark and control age-dated material.

Equipment used for measuring viscosity, mixing, applying and curing silicone material **shall not [D1D2D3]** be used for applying other material.

10.1 Conformal Coating <no change>

10.1.1 Application <no change>

10.1.1.1 Components Required to be Uncoated <no change>

10.1.1.2 Conformal Coating on Connectors Mating connector surfaces of printed circuit assemblies **shall ~~not~~ [D1D2D3]** be free of ~~coated with~~ conformal coating. ~~The conformal coating specified on the assembly drawing(s)/documentation should, however, provide a seal around the perimeter of all connector/board interface areas.~~

10.1.1.3 Conformal Coating on Brackets <no change>

10.1.2 Performance Requirements

10.1.2.1 Thickness <no change>

Table 10-1 Coating Thickness<no change>

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10.1.2.2 Coating Coverage <no change>

10.1.3 Conformal Coating Inspection ~~Visual~~ Inspection of conformal coating **shall [A1P2D3]** be performed (see Table 11-2) and~~Visual inspection of conformal coating~~ may be performed without magnification. Inspection for conformal coating coverage may be performed under an ultraviolet (UV) light source when using conformal coating material containing a UV tracer. Magnification up to 4X may be used for referee purposes.

10.1.4 Rework of Conformal Coating Procedures which describe the removal and replacement of conformal coating **shall [N1D2D3]** be documented and available for review.

10.2 Encapsulation <no change>

10.2.1 Application <no change>

10.2.1.1 Encapsulant Free Surfaces <no change>

10.2.2 Performance Requirements The applied encapsulant **shall [N1D2D3]** be completely cured, homogeneous, and cover only those areas specified on the assembly drawing(s)/documentation. The encapsulant **shall [D1D2D3]** be free of bubbles, blisters, or breaks that affect the ~~printed circuit~~ assembly operation or sealing properties of the encapsulant material. There **shall [N1P2D3]** be no visible cracks, crazing, mealing, peeling, and/or wrinkles in the encapsulant material. Minor surface swirls, striations, or flow marks are not considered defects.

10.2.3 Rework of Encapsulant Material <no change>

10.2.4 Encapsulant Inspection <no change>

10.3 Staking (Adhesive) The criteria below **shall [D1D2D3]** be used when staking is required and criteria are not provided on the drawing.

a. Placement Staking materials **shall not [P1D2D3]** contact component lead seals unless the material has been selected so as not to damage the components/assembly in its service environment.

b. Unsleeved axial leaded components mounted horizontally– Staking material **shall [N1N2D3]** be applied to both sides of the component. The length of the fillets of the staking material **shall [D1D2D3]** extend between 50% and 100% of the component length. Minimum fillet height **shall [D1D2D3]** be 25% of the height of the component. For maximum fillet height, the top of the component **shall [N1P2D3]** be visible for the entire length of the component body.

c. Unsleeved axial leaded components mounted vertically - A minimum of two beads of staking material **shall [N1D2D3]** be placed approximately evenly around the periphery of the component. For each bead, the staking material **shall [N1 D2 D3]** contact a minimum-25% to maximum-100% of the height of the component body. Slight flow of staking material under the component body is acceptable provided it does not violate 10.3a. **Adhesive shall [D1D2D3]** adhere to at least 25% of the component circumference.

d. Sleeved axial leaded components - Staking material **shall [N1D2D3]** be in contact with both end-faces of the component and the surface it is being staked to. Minimum fillet height **shall [N1D2D3]** be at least 25% of the component height. Maximum fillet height **shall [P1D2D2]** be no greater than 50% of the component height, and **shall [N1D2D3]** meet the requirements of 10.3.a. This clause does not apply to sleeved glass bodied axial leaded components (see 10.3e).

e. Glass bodied components – Sleeved glass bodied components **shall [N1D2D3]** be free from staking material on any exposed glass surface, such as the component end face. Staking material **shall [N1N2D3]** be applied to both sides of the component. Staking material fillet **shall [N1D2D3]** extend between 50% and 100% of the component length. Minimum fillet height **shall [D1D2D3]** be 25% of the component height. Maximum fillet height **shall [N1P2D3]** allow the top of the component to be visible for the entire length of the component body.

f. Radial leaded components whose longest dimension is their height (e.g., CKR capacitors, Single In-Line (SIP) resistor networks) The staking material **shall [N1D2D3]** be applied to a minimum height of 25% to a maximum of 100% of each individual component's body height.

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For closely spaced arrays consisting of up to four components fillet height requirements for the two outer end-faces **shall [N1D2D3]** be the same as for an individual component. In addition, the top inner surfaces **shall [N1D2D3]** be bonded to each other for 50% of the components' width.

For closely spaced arrays consisting of more than four components staking **shall [N1D2D3] be** applied in the same manner as arrays up to four components, with the additional requirement that every other internal component **shall [N1D2D3] have** their sides staked to the board surface.

g. Radial leaded components whose longest dimension is their diameter or length (e.g., TO5 semiconductors, etc.). Cylindrical components **shall [N1D2D3]** be staked with at least three beads of staking material placed approximately evenly around the periphery of the component. For each bead, the staking material **shall [N1D2D3]** contact a minimum-25% to maximum-100% of the height of the component body. Slight flow of staking material under the component body is acceptable provided it does not violate 10.3a.

Rectangular components **shall [N1D2D3]** be staked with a bead of staking material placed at each corner of the component. For each bead, the staking material **shall [N1D2D3]** contact a minimum-25% to maximum-100% of the height of the component body. Slight flow of staking material under the component body is acceptable provided it does not violate 10.3a.

h. Fasteners identified on the drawing to be staked **shall [D1D2D3]** be staked either:

a. At two places spaced approximately opposite of each other, with bead of staking material covering at least 25% of the perimeter of the fastener.
b. With one bead of staking material covering at least 50% of the perimeter of the fastener.

10.3.1 Staking

Staking **shall [D1D2D3]:**

a. Be completely cured and homogeneous.
b. Be free of voids or bubbles that expose component conductors, bridge noncommon conductors and/or violate design electrical clearance.
c. Not bridge between the substrate and the bottom of radial leaded components. This does not apply to bonding or underfilling when used as part of a documented process.
d. Be free of contamination.
e. Not negate stress relief.

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

11 PRODUCT ASSURANCE

11.1 Hardware Defects Requiring Disposition Hardware defects that require disposition are annotated throughout the standard. ~~and are summarized in Appendix A. A defect **shall not [N1N2D3]** be reworked before it is documented per 12.1. Touch-up processes that include reheating are examples of rework operations.~~ Rework is covered in 12.1.

11.2 Inspection Methodology

11.2.1 Process Verification Inspection <no change>

11.2.2 Visual Inspection The assembly **shall [N1D2D3]** be evaluated in accordance with the established process control plan (see 11.3) or by 100% visual inspection (see 1.11). Inspection of conformal coating, staking or encapsulation **shall [N1D2D3]** be performed after and not combined with, soldering and cleaning process inspections.

11.2.2.1 Magnification Aids Magnification power for visual inspection **shall [A1P2D3]** be at least the minimum inspection power specified in Tables 11-1 and 11-2. Other magnification powers within the inspection range may be used. The magnification power requirement **shall (D1D2D3)** be ~~is~~ based on the size of the device being inspected. For assemblies with mixed land widths, the greater magnification may be used for the entire assembly. If the presence of a defect cannot be determined at the inspection power, 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.

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The tolerance for magnification aids is ± 15% of the selected magnification power. Magnification aids should be maintained and calibrated as appropriate (see IPC-OI-645). Supplemental lighting may be necessary to assist in visual assessment.

11.2.2.2 Lighting See 4.2.3 ~~Supplemental lighting may be necessary to assist in visual inspection. Light sources should be selected to prevent shadows on the item being inspected except those caused by the item being inspected.~~

Table 11-1 Magnification Aid Applications for Solder Connections<no change>

Table 11-2 Magnification Aid Applications - Other

Cleanliness (cleaning processes per 8.3.4)	Magnification not required, see Note 1
Cleanliness (no-clean processes per 8.3.4)	Note 1
Conformal Coating/ Encapsulation (10.1 and 10.2)	Notes 1,2
Other (Component and wire damage, etc.)	Note 1
Marking	Note 2

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.

11.2.3 Sampling Inspection <no change>

11.3 Process Control Requirements <no change>

11.3.1 Opportunities Determination <no change>

11.4 Statistical Process Control <no change>

12 REWORK AND REPAIR

12.1 <Replaced with the following>
12.1 Rework ~~of~~ ~~Unsatisfactory~~ ~~Solder~~ ~~Connections~~ Hardware defects **shall [N1N2D3]** be documented before rework. Rework for Classes 1 or 2 should and for Class 3 **shall [N1N2D3]** be documented. Rework includes hand solder touchup after mass soldering operations. Rework does not include a second application of a soldering iron during a hand soldering operation on a single connection.

Proper soldering technique, including limiting the time on the connection and the amount of heat applied, is critical in preventing delamination or other damage to the assembly. Control of hand soldering **shall [N1N2D3]** include operator training, process controls, and management. See 1.10 personnel proficiency.

Rework **shall [D1D2D3]** meet all applicable requirements of this standard.

12.2 Repair <no change>

12.3 Post Rework/Repair Cleaning <no change>