

IPC J-STD-001H
September 2020
Supersedes IPC J-STD-001G
October 2017

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Requirements for
Soldered Electrical
and Electronic
Assemblies



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Requirements for Soldered Electrical and Electronic Assemblies

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Developed by the J-STD-001 Task Group (5-22A), J-STD-001 Task Group – Europe (5-22A-EU), J-STD-001 Task Group – China (5-22ACN) of the Assembly and Joining Committees (5-20) of IPC

Supersedes:

J-STD-001G - October 2017
J-STD-001F WAM1 -
February 2016
J-STD-001F - July 2014
J-STD-001E - April 2010
J-STD-001D - February 2005
J-STD-001C - March 2000
J-STD-001B - October 1996
J-STD-001A - April 1992

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J-STD-001, "Requirements for Soldered Electrical and Electronic Assemblies", was adopted on 19-JUL-01 for use by the Department of Defense (DoD). Proposed changes by DoD activities must be submitted to the DoD Adopting Activity: Commander, US Army Tank-Automotive and Armaments Command, ATTN: AMSTA-TR-E/IE, Warren, MI 48397-5000. Copies of this document may be purchased from The Institute for Interconnecting and Packaging Electronic Circuits, 2215 Sanders Road, Northbrook, IL 60062-6135. <http://www.ipc.org/>

Custodians:

Army - AT
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Army - AT
(Project SOLD-0059)

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Acknowledgment

Any document involving a complex technology draws material from a vast number of sources across many continents. Shown below are the principal members of the J-STD-001 Task Group (5-22A), J-STD-001 Task Group – Europe (5-22A-EU), J-STD-001 Task Group – China (5-22ACN) of the Assembly and Joining Committees (5-20). It is not possible to include all of those who assisted in the evolution of this standard. To each of them, the members of IPC extend their gratitude.

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Requirements for Soldered Electrical and Electronic Assemblies

1.0 GENERAL

1.1 Scope This standard describes materials, methods and acceptance criteria for producing soldered electrical and electronic assemblies. The intent of this document is to rely on process control methodology to ensure consistent quality levels during the manufacture of products. It is not the intent of this standard to exclude any procedure, such as for component placement or for applying flux and solder used to make the electrical connection.

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, Fabrication and Acceptability Specifications

Board Type	Design	Fabrication/Acceptability 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-2222 IPC-2223	IPC-6013

1.2 Purpose This standard prescribes material requirements, process requirements, and acceptability requirements for the manufacture of soldered electrical and electronic assemblies. For a more complete understanding of this document's recommendations and requirements, one may use this document in conjunction with IPC-HDBK-001, IPC-AJ-820 and IPC-A-610. Standards may be updated at any time, including with the addition of amendments. The use of an amendment or a newer revision is not automatically required.

1.3 Classification This standard recognizes that electrical and electronic assemblies are subject to classifications by intended end-item use. Three general end-product classes have been established to reflect differences in manufacturability, complexity, functional performance requirements, and verification (inspection/test) frequency.

Use of this standard requires agreement on the class to which the product belongs. The User has the responsibility for identifying the class to which the assembly is produced. The product class should be stated in the procurement documentation package. If the User does not establish and document the acceptance class, the Manufacturer may do so.

CLASS 1 General Electronic Products

Includes products suitable for applications where the major requirement is function of the completed assembly.

CLASS 2 Dedicated Service Electronic Products

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

CLASS 3 High Performance/Harsh Environment Electronic Products

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

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

Note: This standard uses other SI prefixes (ASTM SI10, Section 3.2) to eliminate leading zeroes (for example, 0.0012 mm becomes 1.2 µm) or as alternative to powers-of-ten (3.6 x 10³ mm becomes 3.6 m).

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

1.5 Definition of Requirements The words **shall** or **shall not** are used in the text of this document wherever there is a requirement for materials, preparation, process control or acceptance of an electrical or electronic assembly.

Where the word **shall** is used in this standard, the requirements for each class are in brackets next to the requirement.

N = No requirement has been established for this Class, but may require separate criteria as agreed between the Manufacturer and User.

A = Acceptable

P = Process Indicator

D = Defect

Examples:

[A1P2D3] is Acceptable Class 1, Process Indicator Class 2 and Defect Class 3

[N1D2D3] is No requirement has been established Class 1, Defect Classes 2 and 3

[A1A2D3] is Acceptable Classes 1 and 2, Defect Class 3

[D1D2D3] is Defect for all Classes

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. The text takes precedence over the figures.

IPC-HDBK-001, a companion document to this specification, contains 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.

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.

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 1.8.8 Manufacturer. Defects **shall [D1D2D3]** be identified, documented, and dispositioned by the Manufacturer based on the design, service, and User requirements.

A process indicator is a condition (not a defect) attributable to variation in material, equipment operation, workmanship or processes, but it 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 but the hardware need not be dispositioned.

It is the responsibility of the User to define additional defect categories applicable to the product. It is the responsibility of the Manufacturer to identify defects and process indicators that are unique to the assembly process, see 1.5.3 Procedures for Specialized Technologies.

1.5.2 Material and Process Nonconformance Material and process nonconformance differs from hardware defects or hardware process indicators in that the material/process nonconformance often does not result in an obvious change in the hardware’s appearance but can impact the hardware’s performance, e.g., contaminated solder, incorrect solder alloy (per engineering documentation).

Hardware found to be produced using either materials or processes that do not conform to the requirements of this standard **shall [D1D2D3]** be classified as defects and dispositioned. This disposition **shall [D1D2D3]** address the potential effect of the nonconformance on functional capability of the hardware such as reliability and design life (longevity).

1.5.3 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. 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. Mounting and soldering for specialized processes and/or technologies not specified herein **shall [N1D2D3]** be performed in accordance with documented procedures which are available for review.

These criteria should be submitted to the IPC Technical Committee to be considered for inclusion in upcoming revisions of this standard.

1.5.3.1 Manufacture of Devices Incorporating Magnetic Windings This standard is very limited in its applicability to the manufacturing processes associated with the mounting of internal electronic elements and the soldering of the internal connections of transformers, motors, and similar devices. Unless a User has a specific need for the controls provided by this standard, it should not be imposed relative to the manufacture of the internal elements of these devices. The external interconnect points, e.g., terminals, pins, **shall [D1D2D3]** meet the solderability requirements of 4.1 Solderability.

1.5.3.2 High Frequency Applications High frequency applications, i.e., radio wave and microwaves, may require part clearances, mounting systems, and assembly designs that vary from the requirements stated herein.

1.5.3.3 High Voltage Applications High voltage applications may require part clearances, mounting systems, and assembly designs that vary from the requirements stated herein.

There **shall [D1D2D3]** be no broken strands for wires used at a potential of 6 kV or greater.

1.6 Process Control Requirements The primary goal of process control is to continually reduce variation in the processes, products, or services to provide products or processes meeting or exceeding User requirements. Process control tools such as IPC-9191, JESD557 or other User-approved system may be used as guidelines for implementing process control.

Manufacturers of Class 3 products **shall [N1N2D3]** develop and implement a documented process control system.

A documented process control system, if established, **shall [N1D2D3]** define process control and corrective action limits. This may or may not be a statistical process control system. The use of statistical process control (SPC) is optional and should be based on factors such as design stability, lot size, production quantities, and the needs of the Manufacturer, see 1.6.2 Statistical Process Control.

Process control methodologies **shall [N1D2D3]** be used in the planning, implementation and evaluation of the manufacturing processes used to produce soldered electrical and electronic assemblies. The philosophy, implementation strategies, tools and techniques may be applied in different sequences depending on the specific company, operation, or variable under consideration to relate process control and capability to end product requirements.

When a decision or requirement is to use a documented process control system, failure to implement process corrective action and/or the use of continually ineffective corrective actions **shall [N1D2D3]** be grounds for disapproval of the process and associated documentation.

1.6.1 Opportunities Determination Unless otherwise specified in the process control plan, the total number of interconnection sites is used as the measure to which the percentage of defects or process indicators is applied. These calculations consider each surface mount termination, each through-hole termination, and each terminal termination as a single opportunity in determining the total number of opportunities for a given assembly. For corrective action calculations, not more than one defect characteristic or process indicator can be attributed to a particular interconnection site, e.g., via, lead-in-hole, lead-to-land. For more information, see IPC-9261.

1.6.2 Statistical Process Control The use of statistical process control is encouraged but not mandatory, see 1.6 Process Control Requirements. When a statistical process control system process is used, it **shall [D1D2D3]** include the following elements at a minimum:

- a. Training is provided to personnel with assigned responsibilities in the development, implementation, and utilization of process control and statistical methods that are commensurate with their responsibilities.
- b. Quantitative methodologies and evidence are maintained to demonstrate that the process is capable and in control. Improvement strategies define initial process control limits and methodologies leading to a reduction in the occurrence of process indicators to achieve continual process improvement.

- c. Criteria for switching to sample based inspection is defined. When processes exceed control limits, or demonstrate an adverse trend or run, the criteria for reversion to higher levels of inspection (up to 100%) is also defined.
- d. When defect(s) are identified in the lot sample, and the number exceeds the limit allowed by the sampling plan, the entire lot is 100% inspected for the occurrence(s) of the defect(s).
- e. A system is in place to initiate corrective action for the occurrence of process indicators, out-of-control process(es), and/or discrepant assemblies.
- f. A documented audit plan is defined to monitor process characteristics and/or output at a prescribed frequency.
- g. Objective evidence of process control may be in the form of control charts or other tools and techniques of statistical process control derived from application of process parameter and/or product parameter data, see IPC-HDBK-001.

1.7 Order of Precedence The contract shall [D1D2D3] take precedence over this standard, referenced standards and engineering documentation.

In the event of a conflict between the requirements of this standard and the applicable engineering documentation, the applicable User-approved engineering documentation governs, see 1.8.5 Engineering Documentation. 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.

When 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 J-STD-001 the order of precedence should be defined in the procurement documents.

Note: IPC-A-610 may be used as a companion document to J-STD-001 for visual reference of J-STD-001 requirements.

Note: When using IPC-A-610 and J-STD-001 together, the revisions of both should be the same, e.g., J-STD-001H and IPC-A-610H. The likelihood of criteria not aligning increases when using different revisions.

1.7.1 Appendices Appendices to this standard are not binding requirements unless separately and specifically required by the applicable contracts, engineering documentation or purchase orders.

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 Circumferential Solder Separation (Area Void of Solder) An internal void in the solder fillet extending around the entire circumference of a plated through-hole and lead/wire. There is no continuous solder between the solder source side fillet and the solder destination side fillet, see 6.2.1 Solder Application.

1.8.2 Diameter

1.8.2.1 Conductor Diameter The outside diameter of wire, either stranded or solid, without the insulation.

1.8.2.2 Wire Diameter The outside diameter of wire, either stranded or solid, including insulation, if present.

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

1.8.4 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. In the absence of a known design standard use Appendix B (derived from IPC-2221).

1.8.5 Engineering Documentation Drawings, specifications, technical illustrations, and other documents, prepared and released by the design activity in any form of media, that establish the design and design requirements.

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

1.8.7 High Voltage The term “high voltage” will vary by design and application. The high voltage criteria in this document are only applicable when specifically required in the engineering/procurement documentation.

1.8.8 Manufacturer The individual, organization, or company responsible for the assembly process and verification operations necessary to ensure full compliance of assemblies to this standard.

1.8.9 Objective Evidence Documentation in the form of hard copy, computer data, video, or other media that demonstrates the requirements in the standard have been met (for examples, see Appendix C). Such documentation may include, but is not limited to:

- a. Work instructions.
- b. Procedures and records required by the quality management system.
- c. Chemical and physical test data.
- d. Reliability calculations based on recognized industry reliability standards.
- e. Manufacturer data sheets/reports, known acceptable record of performance by selected suppliers.
- f. External and/or internal audit reports.
- g. Test/Inspection reports including actual measured values.
- h. Training records.
- i. Soldering temperature versus time profiles.
- j. Technical basis for changes in materials and/or processes (as an example, see Appendix C).
- k. Historical data.
- l. Competency matrix (skills checklist).

1.8.10 Process Control A system or method to continually steer an operation in reducing variation in the processes or products to meet or exceed the goal in quality and performance.

1.8.11 Proficiency The capability to perform tasks in accordance with the requirements and verification procedures detailed in this standard.

1.8.12 Solder Destination Side That side of the printed board that the solder flows toward in a plated through-hole application.

1.8.13 Solder Source Side The side of the printed board to which solder is applied.

1.8.14 Solder Void The absence of solder in a localized area inside a solder fillet. A void is not identifiable during a visual solder inspection.

1.8.15 Supplier The individual, organization, or company which provides the Manufacturer components (electronic, electromechanical, mechanical, printed boards, etc.) and/or materials (solder, flux, cleaning agents, etc.).

1.8.16 Tempered Leads Component terminations or pins heat treated to increase hardness or that incorporate hard, brittle plating layers.

1.8.17 User The individual, organization, company, contractually designated authority, or agency responsible for the procurement or design of electrical/electronic hardware, and having the authority to define the Product Class and any variation or restrictions to the requirements of this standard, i.e., the originator/custodian of the contract detailing these requirements.

1.8.18 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 1-1.

1.8.19 Wire Overwrap Wire overwrap occurs when a wire/lead is wrapped more than 360° and remains in contact with the terminal post, see Figure 1-2.

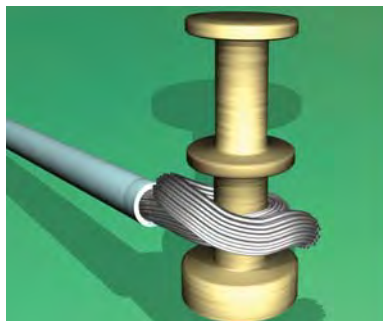


Figure 1-1 Wire Overlap

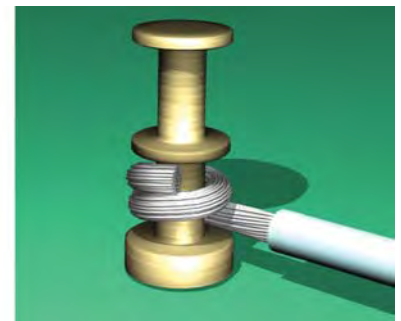


Figure 1-2 Wire Overwrap



Documents

Document Sharing Hub

1.9 Requirements Flowdown When this standard is contractually required, the applicable requirements of this standard (including Product Class, see 1.3 Classification) **shall [D1D2D3]** be imposed on all applicable subcontracts, engineering 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 Manufacturer of that part only when necessary to meet end-item requirements. When it is unclear where flowdown should stop, it is the responsibility of the Manufacturer to establish that determination with the User.

When an assembly, e.g., daughterboard, is procured, that assembly should meet the requirements of this standard. The connections from the procured assembly to the manufactured assembly **shall [D1D2D3]** meet the requirements of this standard. If the assembly is manufactured by the same Manufacturer, the solder requirements are as stated in the contract for the entire assembly.

The design and workmanship of COTS items should be evaluated and modified as required to ensure the end-item meets contract performance requirements. Modifications to COTS items **shall [D1D2D3]** meet the applicable requirements of this standard.

1.10 Personnel Proficiency All instructors, operators, and inspection personnel **shall [D1D2D3]** be proficient in the tasks to be performed. Objective evidence of that proficiency, e.g., records of training to the applicable job functions being performed, work experience, testing to the requirements of this standard, or results of periodic reviews of proficiency, **shall [D1D2D3]** be maintained and be available for review. Supervised on-the-job training is acceptable until proficiency is demonstrated.

1.10.1 X-Ray Specific Personnel Proficiency Certification to NAS 410 or other nondestructive certifications is not applicable to solder joint or electronic assembly x-ray evaluation, and therefore is not necessary or required.

1.11 Acceptance Requirements All products **shall [D1D2D3]** meet the requirements of the contracts, engineering documentation, applicable standards, and the requirements for the applicable Product Class specified herein.

Manufacturers **shall [N1D2D3]** perform 100% inspection unless sampling inspection is defined as part of a documented process control plan, see 1.6.2 Statistical Process Control.

The User has the responsibility to specify acceptance criteria. If no criteria are specified, required, or cited, then best manufacturing practice applies.

1.12 Inspection Methodology

1.12.1 Process Verification Inspection Process verification inspection **shall [N1N2D3]** include:

- a. Surveillance of the operation to determine that practices, methods, procedures and a written inspection plan are being properly applied.
- b. Inspection to measure the quality of the product.

1.12.2 Visual Inspection The assembly **shall [N1D2D3]** be evaluated either by sample-based inspection in accordance with a documented process control plan, see 1.6 Process Control Requirements, or by 100% visual inspection. Inspection of soldering and post-solder cleanliness may be performed in the same operation using Tables 1-2, 1-3, and 1-4. Inspection of soldering and cleanliness **shall [N1D2D3]** be performed prior to conformal coating, staking or encapsulation. Inspection for damage should be performed prior to conformal coating, when applicable, may be combined with solder and/or cleanliness inspections, and as part of the final inspection process.

The use of any non-visual inspection methods, other than those already detailed in this standard, are not specifically covered and **shall [D1D2D3]** be used as established between Manufacturer and User.

See Appendix D for x-ray Guidelines.

1.12.2.1 Lighting Illumination at the surface of workstations should be at least 1000 lux [approximately 93 foot candles]. 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 assembly features and contaminants with increased clarity.

1.12.2.2 Magnification Aids Magnification power for visual inspection shall [A1P2D3] be in accordance with Tables 1-2, 1-3, and 1-4. The magnification power requirement shall [D1D2D3] be based on the size of the land or wire being inspected. Any magnification power within the applicable inspection range may be used. For assemblies with mixed land sizes, the greater magnification power may be used for the entire assembly. For assemblies with mixed wire sizes, the greater magnification power may be used.

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

The tolerance for magnification aids is $\pm 15\%$ 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, see 1.12.2.1 Lighting.

Inspection magnification powers in Tables 1-2, 1-3 and 1-4 are specific to visual inspection and not applicable to the use of x-ray inspection.

Table 1-2 Magnification Aid Applications for Solder Connections

Land Widths or Land Diameters ¹	Magnification Power	
	Inspection Range	Maximum Referee
> 1.0 mm [0.04 in]	1.5X to 3X	4X
> 0.5 to $\leq$ 1.0 mm [0.02 to 0.04 in]	3X to 7.5X	10X
$\geq$ 0.25 to $\leq$ 0.5 mm [0.01 to 0.02 in]	7.5X to 10X	20X
< 0.25 mm [0.01 in]	20X	40X

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

Table 1-3 Magnification Aid Applications for Wires and Wire Connections, Note 1

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

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

Table 1-4 Magnification Aid Applications – Other

Cleanliness (with or without cleaning processes)	Magnification not required, Note 1
Cleanliness (no-clean processes)	Magnification not required, Note 1
Conformal Coating/Encapsulation, Staking	Magnification not required, Notes 1, 2
Other (Component damage, etc.)	Magnification not required, Note 1
Marking	Magnification not required, 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 also be needed to determine if contamination affects form, fit or function.

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

1.13 Facilities Cleanliness and ambient environments in all work areas shall [D1D2D3] be maintained at levels that prevent contamination or deterioration of tools, materials, and surfaces to be soldered or conformally coated. Eating, drinking, smoking, including use of e-cigarettes, and/or use of tobacco products shall [D1D2D3] be prohibited in the work area.

1.13.1 Environmental Controls The soldering facility should be enclosed, temperature and humidity controlled, and maintained at a positive pressure.

1.13.1.1 Temperature and Humidity When humidity decreases to a level of 30% or lower, the Manufacturer **shall [N1D2D3]** verify that electrostatic discharge control is adequate. For process control, more restrictive temperature and humidity limits may be required.

1.13.1.1.1 Temperature For operator comfort and solderability maintenance, the temperature should be maintained between 18 °C [64.4 °F] and 30 °C [86 °F].

1.13.1.1.2 Humidity The range (lower and upper limits) of humidity in the assembly area **shall [N1D2D3]** allow soldering (including solderability maintenance) and assembly materials, e.g., conformal coating, to function correctly in the process, based on Material Manufacturer recommendations or documented evidence of process performance. For operator comfort the relative humidity should not exceed 70%.

See 3.6 Components for humidity control requirements for moisture sensitive devices/assemblies.

1.13.2 Field Assembly Operations In field assembly operations on Class 3 products where the controlled environmental conditions required by this standard cannot be effectively achieved, precautions **shall [N1N2D3]** be taken to maximize the quality of solder connections and minimize the effects of the uncontrolled environment on the operation being performed on the hardware.

1.13.3 Health and Safety The use of some materials referenced in this standard may be hazardous. To provide for personnel safety, follow the applicable local and Federal (National) occupational, safety and health regulations.

1.14 Electrostatic Discharge (ESD) If there are any assemblies that contain components or parts sensitive to ESD, the Manufacturer **shall [D1D2D3]** implement a documented ESD control program in accordance with ANSI/ESD S20.20, IEC 61340-5-1, MIL-STD-1686, or as established between Manufacturer and User. Documentation necessary for an effective program **shall [D1D2D3]** be available for review.

2.0 APPLICABLE DOCUMENTS

The following documents of the issue in effect on the invitation for bid form a part of this specification to the extent specified herein.

2.1 IPC¹

- IPC 1602** Standard for Printed Board Handling and Storage
- IPC-2221** Generic Standard on Printed Board Design
- IPC-2222** Sectional Standard on Rigid PWB Design
- IPC-2223** Sectional Design Standard for Flexible Printed Boards
- IPC-6011** Generic Performance Specification of Printed Boards
- IPC-6012** Qualification and Performance Specification for Rigid Printed Boards
- IPC-6013** Qualification and Performance for Flexible Printed Boards
- IPC-7093** Design and Assembly Process Implementation for Bottom Termination Components (BTC)
- IPC-7095** Design and Assembly Process Implementation for BGAs
- IPC-7530** Guidelines for Temperature Profiling for Mass Soldering Processes (Reflow & Wave)
- IPC-9191** General Guidelines for Implementation of Statistical Process Control (SPC)
- IPC-7711/7721** Rework, Modification and Repair of Electronic Assemblies
- IPC-9201** Surface Insulation Resistance Handbook
- IPC-9202** Material and Process Characterization/Qualification Test Protocol for Assessing Electrochemical Performance
- IPC-9203** Users Guide to IPC-9202 and the IPC-B-52 Standard Test Vehicle
- IPC-9261** In-Process DPMO and Estimated Yield for PWAs
- IPC-9691** User Guide for the IPC-TM-650, Method 2.6.25, Conductive Anodic Filament (CAF) Resistance and Other Internal Electrochemical Testing
- IPC-9701** Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments
- IPC-A-600** Acceptability of Printed Boards
- IPC-A-610** Acceptability of Electronic Assemblies
- IPC-AJ-820** Assembly and Joining Handbook
- IPC-CC-830** Qualification and Performance of Electrical Insulating Compound for Printed Board Assemblies
- IPC-CH-65** Guidelines for Cleaning of Printed Boards and Assemblies
- IPC-D-279** Design Guidelines for Reliable Surface Mount Technology Printed Board Assemblies
- IPC-HDBK-001** Handbook and Guide to Supplement J-STD-001
- IPC-OI-645** Standard for Visual Optical Inspection Aids
- IPC-SM-785** Guidelines for Accelerated Reliability Testing of Surface Mount Attachments
- IPC-SM-817** General Requirements for Dielectric Surface Mounting Adhesives
- IPC-T-50** Terms and Definitions for Interconnecting and Packaging Electronic Circuits
- IPC-TM-650** Test Methods Manual²
 - 2.3.25 Detection and Measurement of Ionizable Surface Contaminants
 - 2.3.39 Surface Organic Contamination Identification Test (Infrared Analytical Method)
 - 2.4.22 Bow and Twist
 - 2.6.9.1 Test to Determine Sensitivity of Electronic Assemblies to Ultrasonic Energy
 - 2.6.9.2 Test to Determine Sensitivity of Electronic Components to Ultrasonic Energy
 - 2.6.25 Conductive Anodic Filament (CAF) Resistance Test: X-Y Axis
- IPC-WP-019** An Overview on Global Change in Ionic Cleanliness Requirements

2.2 JEDEC³

- JESD557** Statistical Process Control Systems

1. www.ipc.org

2. www.ipc.org/test-methods.aspx

3. www.jedec.org

2.3 Joint Industry Standards⁴

J-STD-002 Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires

J-STD-003 Solderability Tests for Printed Boards

J-STD-004 Requirements for Soldering Fluxes

J-STD-005 Requirements for Soldering Paste

J-STD-006 Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications

J-STD-020 Moisture/Reflow Sensitivity Classification for Nonhermetic Circuit Surface Mount Devices

J-STD-033 Handling, Packing, Shipping and Use of Moisture, Reflow, and Process Sensitive Devices

J-STD-075 Classification of Non-IC Electronic Components for Assembly Processes

2.4 ASTM⁵

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

ASTM SI10, IEEE/ASTM SI 10 American National Standard for Metric Practice

2.5 EOS/ESD Association, Inc.⁶

ANSI/ESD-S20.20 Protection of Electrical and Electronic Parts, Assemblies and Equipment

2.6 International Electrotechnical Commission⁷

IEC 61340-5-1 Protection of Electronic Devices from Electrostatic Phenomena - General Requirements

2.7 SAE International⁸

GEIA-STD-0005-1 Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder

GEIA-STD-0005-2 Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems

SAE-AS6171/5 Techniques for Suspect/Counterfeit EEE Parts Detection by Radiological Test Methods

2.8 Military Standards⁹

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

2.9 Aerospace Industries Association / National Aeronautics Standards¹⁰

NAS 410 NAS Certification & Qualification of Nondestructive Test Personnel

4. www.ipc.org

5. www.astm.org

6. www.esda.org

7. www.iec.ch

8. www.sae.org

9. <http://quicksearch.dla.mil>

10. www.aia-aerospace.org

3.0 MATERIALS, COMPONENTS AND EQUIPMENT REQUIREMENTS

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, see Appendix C. They can also pertain to a change in bare boards, solder mask or metallization.

Manufacturers, when specified, **shall [N1N2D3]** have a Pb-free control plan (LFCP), which should be established between the Manufacturer and the User.

Note: GEIA-STD-0005-1 and GEIA-STD-0005-2 constitute examples for the implementation of LFCPs/tin whisker mitigation for Aerospace and other High Performance Electronic Systems.

The electrical and mechanical integrity of components and assemblies **shall [D1D2D3]** be retained after exposure to processes employed during manufacture and assembly, e.g., handling, baking, fluxing, soldering, and cleaning.

There **shall [N1D2D3]** be a documented process to control materials, including consumable materials that are subject to age degradation. Limited shelf life items **shall [N1D2D3]** be stored and controlled in accordance with the material manufacturer's recommendations, or in accordance with the manufacturer's documented procedures for controlling shelf life and shelf life extensions.

Unless otherwise specified on the engineering documentation, materials **shall [N1D2D3]** be processed (mixing, curing, etc.) per the material specification or other documented procedure. Material **shall [N1D2D3]** be used within the pot life (working time) specified by the material manufacturer or used within the time period indicated by a documented system.

When curing conditions (temperature, time, infrared (IR) intensity, etc.) vary from the material manufacturer's recommended instructions, they **shall [N1D2D3]** be documented and available for review.

Items exposed to uncured silicone material **shall not [D1D2D3]** be used for processing other material. An authorized exception is allowed only in cases where equipment is used for co-curing processes and the Manufacturer has demonstrated through system tests that non-silicone material properties have not changed and design requirements are met. Objective evidence **shall [N1N2D3]** be maintained and available for review.

3.2 Solder Solder alloys **shall [D1D2D3]** be in accordance with J-STD-006 or equivalent. Solder alloys other than Sn60Pb40, Sn62Pb36Ag2, and Sn63Pb37 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.

Solder paste **shall [D1D2D3]** be in accordance with J-STD-005 or equivalent.

Flux that is part of flux-cored solder wire or preforms **shall [D1D2D3]** meet the requirements of 3.3 Flux. Flux percentage is optional.

3.2.1 Solder – Pb-Free Solder alloys less than 0.1% Pb by weight not listed by J-STD-006 may be used when such use is established between the Manufacturer and the User. Pb-free processing **shall [N1D2D3]** be in accordance with a documented procedure that includes adequate controls to minimize the risk of cross-contamination (Pb and Pb-free products/processes).

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.

SnPb solder alloys other than Sn60Pb40, Sn62Pb36Ag2, or Sn63Pb37 **shall [N1D2D3]** be in compliance with equivalent documented limits.

If contamination exceeds the limits, intervals between the analyses, replacement or replenishment **shall [N1D2D3]** be shortened. The frequency of analysis should be determined based on 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 $\pm 1.5\%$ of the nominal alloy, e.g., 63 $\pm 1.5\%$ (i.e., 61.5% - 64.5%), 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 Pb and/or the items listed in Table 3-1.

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 SAC305 Pb-Free Alloys
Copper (Cu)	0.75	0.3	1.1, Note 2
Gold (Au)	0.5	0.2	0.2
Cadmium (Cd)	0.01	0.005	0.005
Zinc (Zn)	0.008	0.005	0.005
Aluminum (Al)	0.008	0.006	0.006
Antimony (Sb)	0.5	0.5	0.2
Iron (Fe)	0.02	0.02	0.02
Arsenic (As)	0.03	0.03	0.03
Bismuth (Bi)	0.25	0.25	0.25
Silver (Ag), Note 1	0.75	0.1	Note 3
Nickel (Ni)	0.025	0.01	0.05
Lead (Pb)	N/A	N/A	0.1
Total of Copper (Cu), Gold (Au), Cadmium (Cd), Zinc (Zn), Aluminum (Al) Contaminants	N/A	0.4	N/A

Note 1. Not applicable for Sn62Pb36Ag2: limits to be 1.75% to 2.25%.

Note 2. A maximum copper limit of 1.0% may be specified as established between Manufacturer and User. Printed boards 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.

Note 3. SAC305 silver content limits to be 2.5% - 3.5%. Alloys with different nominal silver content have different limits that may be applied as agreed between Manufacturer and User. Consult the alloy supplier for guidance.

Pb-free alloys used for preconditioning or assembly **shall [N1D2D3]** have a tin content maintained within $\pm 1\%$ of the nominal alloy being used. Tin content for Pb-free alloys **shall [N1D2D3]** be tested at the same frequency as testing for copper/silver contamination. The balance of a SAC305 Pb-free bath **shall [N1D2D3]** be the items listed in Table 3-1. Use of other Pb-free solder alloy contamination limits **shall [N1D2D3]** be as established between Manufacturer and User.

3.2.2.1 Solder Pot Purity and Maintenance Dross **shall [N1D2D3]** be removed from the solder surface in a manner that ensures the dross does not contact the items being tinned or soldered.

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

Flux **shall [N1D2D3]** conform to flux activity levels L0 and L1 of flux materials rosin (RO), resin (RE), or organic (OR). Flux ORL1 **shall not [N1D2D3]** be used for no-clean soldering.

When other activity levels or flux materials are used, data demonstrating compatibility **shall [N1D2D3]** be available for review, see 3.1 Materials and Appendix C.

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 When an external flux is used in conjunction with flux-cored solders, the fluxes **shall [D1D2D3]** be compatible both from a cleaning process standpoint and a chemical standpoint. Objective evidence of compatibility, e.g., surface insulation resistance testing, ion chromatography testing, **shall [N1D2D3]** be available for review, see 1.8.9 Objective Evidence and Appendix C. IPC-9202 and IPC-9203 are examples for qualification testing.

3.4 Adhesives Electrically nonconductive adhesive materials used for attachment of components should conform to an acceptable document or standard, e.g., IPC-SM-817, or as otherwise specified. The adhesives selected **shall not [D1D2D3]** be detrimental to the component or assembly they are used on. The material **shall [D1D2D3]** be cured. Additional criteria for polymeric materials and witness (torque/anti-tampering stripes) are in 10.0 Coating, Encapsulation and Staking (Adhesive) and 11.0 Witness (Torque/Anti-Tampering) Stripe.

3.5 Chemical Strippers Chemical solutions, pastes, and creams **shall not [D1D2D3]** cause damage or degradation.

3.6 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 J-STD-020, J-STD-075 or other documented classification procedure) **shall [D1D2D3]** be handled in a manner consistent with J-STD-033 or other documented procedure.

Note: See IPC-1602 for further information on moisture sensitive printed boards.

3.6.1 Component and Seal 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. Components **shall not [D1D2D3]** be charred. Component damage in excess of that determined to be a minor surface flaw **shall not [D1D2D3]** degrade the component below the part specification requirements, or as otherwise determined, to meet form, fit, function and life expectancy requirements. This may be determined through documented analysis.

Visual aids that define minor surface flaw limits for some component types can be found in IPC-A-610. Lead seals **shall not [D1D2D3]** be degraded below the part specification requirements.

Loss of metallization as a result of processing **shall not [D1D2D3]**:

- Expose ceramic on the terminal end face.
- Be greater than 25% of width or thickness on any termination side (not the end face).
- Be greater than 50% on top of a 5- or 3-sided termination component.

3.6.2 Coating Meniscus Component coating meniscus **shall not [N1D2D3]** be trimmed.

3.7 Tools and Equipment Tools and equipment **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 would 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 1.14 Electrostatic Discharge (ESD). See Appendix A for guidelines on tool selection and maintenance.

A tool used to cut leads **shall not [D1D2D3]** impart shock that damages a component lead seal or internal connection.

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4.0 GENERAL SOLDERING AND ASSEMBLY REQUIREMENTS

4.1 Solderability At the start of soldering operations, components 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 is performed as part of the documented assembly process, before or after soldering, that operation may be used in lieu of solderability testing.

4.2 Solderability Maintenance The Manufacturer should establish procedures to minimize part solderability degradation, see IPC-HDBK-001 or IPC-AJ-820 for guidance.

4.3 Removal of Component Surface Finishes Certain surface finishes on component terminations or printed board lands may affect the quality of the solder connection.

The printed boards or parts are exempt from the requirements for finish removal stated in 4.3.1 Gold Removal and 4.3.2 Other Metallic Surface Finishes Removal when either:

- 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 for guidance.
- There are electroless-nickel-immersion gold (ENIG), nickel-palladium-gold (NiPdAu), or electroless nickel-electroless-palladium-immersion gold (ENEPIG) finishes.

4.3.1 Gold Removal Gold removal is performed to reduce the risk of failure associated with embrittled solder. Gold embrittlement is not visually inspectable. In cases where analysis has determined there is a gold embrittlement condition, the gold embrittlement **shall [N1D2D3]** be considered a defect, see IPC-HDBK-001 or IPC-AJ-820 for guidance.

Except as noted above, gold **shall [N1D2D3]** be removed:

- a. From at least 95% of the surfaces to be soldered of the through-hole component leads with $> 2.54 \mu\text{m}$ [100 μin] gold thickness.
- b. From at least 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 $> 2.54 \mu\text{m}$ [100 μin] gold thickness and from all solder cup terminals, regardless of gold thickness.

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

Note: Gold embrittled solder connections can occur regardless of gold thickness when solder volume is low or the soldering process dwell time is not sufficient to allow the gold to dissolve throughout the entire solder joint.

4.3.2 Other Metallic Surface Finishes Removal Other metallic surface finishes **shall [N1D2D3]** be removed from at least 95% of the surfaces to be soldered on components if it is determined that the solder joint integrity will be compromised.

4.4 Thermal Protection When hand soldering, tinning or reworking a component identified as heat sensitive, protective measures **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 soldering process. When heat sensitive components are exposed to manual soldering processes, e.g., tinning, hand soldering attachment or solder touch-up/rework, the manufacturer **shall [D1D2D3]** have a documented soldering process that will minimize risk of latent damage.

If a solder iron tip or other manual soldering heat source makes direct contact with the end termination of a heat sensitive component, the heat sensitive component **shall [D1D2D3]** be discarded and replaced with a new component. As an exception, tip to termination contact is permitted when intended in a documented soldering process or with a suitable thermal shunt.

The same thermal precautions **shall [D1D2D3]** apply when manual assembly modifications, such as jumper wires or the addition of a component on the same land, affect a heat sensitive component.

Note: Additional information and solder process examples can be found in IPC-HDBK-001 and IPC-AJ-820.

4.5 Rework of Nonsolderable Parts A component lead, termination, or board not conforming to the solderability requirements of 4.1 Solderability may be reworked, e.g., by dipping in hot solder, before soldering.

A reworked part **shall [D1D2D3]** conform to the requirements of 4.1 Solderability, less steam conditioning.

4.6 Preprocessing Cleanliness Requirements The assembly **shall [D1D2D3]** be clean of any matter that will inhibit compliance to the requirements of this standard.

4.7 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 should be mounted with sufficient clearances between the body and the printed board 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 8.0 Cleaning and Residue Requirements.

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

Minimum electrical clearance **shall not [D1D2D3]** be violated.

When sleeving is required as protection for glass, ceramic, or hermetic components that will be coated, encapsulated or staked, the sleeving **shall [D1D2D3]** be placed on the component prior to installation.

Uninsulated parts mounted over exposed circuitry **shall [N1N2D3]** have their leads formed to provide a minimum of 0.25 mm [0.01 in] between the bottom of the component body and the exposed circuitry.

4.7.1 General Requirements Unless otherwise defined, the requirements for mounting apply to both wires and component leads.

4.7.2 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 7.1.6 Flattened Leads.

4.8 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 4.15.3 Partially Visible or Hidden Solder Connections.

4.9 Metal-Cased Component Isolation Metal-cased components **shall [D1D2D3]** be isolated from adjacent electrically conductive elements, see 1.8.4 Electrical Clearance.

4.10 Adhesive Coverage Limits Adhesive materials, when used, **shall not [D1D2D3]** preclude the formation of an acceptable solder connection. Adhesive materials extending from under SMT components **shall not [A1P2D3]** be visible in the termination area. Adhesives, e.g., staking, bonding, **shall not [D1D2D3]** contact an unsleeved area of a sleeved glass body component, see 10.3 Staking.

4.11 Mounting of Parts on Parts (Stacking of Components) When part stacking is permitted by the engineering documentation, parts **shall not [D1D2D3]** violate minimum electrical clearance between other parts or components.

4.12 Connectors and Contact Areas The mating surface(s) of connectors and contact areas intended for electrical connection **shall [D1D2D3]** be free of contaminants or foreign material.

4.13 Handling of Parts Parts **shall [D1D2D3]** be handled in a manner to preclude damage to terminations and to avoid the need for subsequent lead straightening operations. Once parts are mounted on printed boards, the unsoldered assembly **shall [D1D2D3]** be handled, transported, e.g., hand or conveyor, and processed in a manner to preclude movement that would detrimentally affect formation of acceptable solder connections. Assemblies with parts in solder paste should be handled in a manner to preclude damage to terminations and to avoid the need for subsequent lead straightening operations.

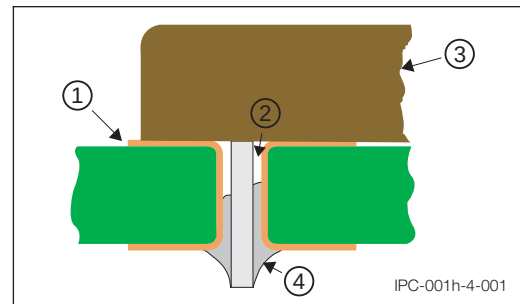


Figure 4-1 Hole Obstruction

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

handled to prevent parts from moving prior to reflow. After soldering operations have been performed, the assembly **shall** [D1D2D3] be sufficiently cooled so the solder is solidified prior to further handling.

4.13.1 Preheating For other than hand soldering, assemblies should be preheated to minimize the presence of volatile solvents, to reduce thermal shock to boards and components, to improve solder flow, and to reduce the solder dwell time. The preheat temperature exposure **shall not** [D1D2D3] degrade printed boards, components, or soldering performance.

4.13.2 Controlled Cooling Controlled cooling may be used. If used, controlled (accelerated or slowed ramp) cooling **shall** [N1D2D3] be in accordance with documented procedures.

4.13.3 Drying/Degassing Prior to soldering, the assembly may be treated to reduce detrimental moisture and other volatiles.

4.13.4 Holding Devices and Materials Equipment, devices, materials, or techniques used to handle boards or retain parts and components to the printed boards through any and all stages of soldering **shall not** [D1D2D3] contaminate, damage, or degrade printed boards or components or induce residual stress into the component body or solder connections, e.g., not constrain leads/terminations during solder solidification. The equipment, devices, materials or techniques should be adequate to maintain component positioning and permit solder flow through plated through-holes and/or onto terminal areas.

4.14 Machine Soldering IPC-7530 provides guidance on developing an appropriate profile. See IPC-AJ-820 for guidance on inert atmospheres.

4.14.1 Nonreflow Soldering

4.14.1.1 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 operating procedures **shall** [N1D2D3] define, as applicable, 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.

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

4.14.1.2 Solder Bath The period of exposure of any printed board to a solder bath **shall** [D1D2D3] be limited to a duration that will not degrade the board or parts mounted thereon. The solder bath temperature, based on the solder alloy in use, **shall** [N1D2D3] be set at a predetermined value with a tolerance of $\pm 5^\circ\text{C}$ [$\pm 9^\circ\text{F}$].

4.14.1.2.1 Solder Bath Maintenance Solder bath purity in machine soldering of printed board assemblies **shall** [N1D2D3] be maintained in accordance with 3.2.2 Solder Purity Maintenance. Dross **shall** [N1D2D3] be removed from the solder bath in a manner that ensures that dross does not contact the items being soldered. Automatic or manual methods for dross removal are acceptable.

4.14.2 Reflow Soldering See IPC-AJ-820 for guidance on inert atmospheres.

The Manufacturer **shall** [N1D2D3] develop and maintain operating procedures describing the reflow soldering process and the proper operation of the equipment. These procedures **shall** [N1D2D3] include, at a minimum, a reproducible time/temperature envelope including the flux and solder paste application procedures and coverage, drying/degassing operation (when required), preheating operation (when required), controlled atmosphere (if used), solder reflow operation, and a cooling operation, see 4.13.2 Controlled Cooling. These steps may be part of an integral or in-line system or may be accomplished through a series of separate operations.

4.14.2.1 Intrusive Soldering (Paste-in-Hole) The criteria of 6.2.2 Through-Hole Component Lead Soldering are applicable when using reflow processes to form plated through-hole connections (intrusive soldering).

4.15 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.