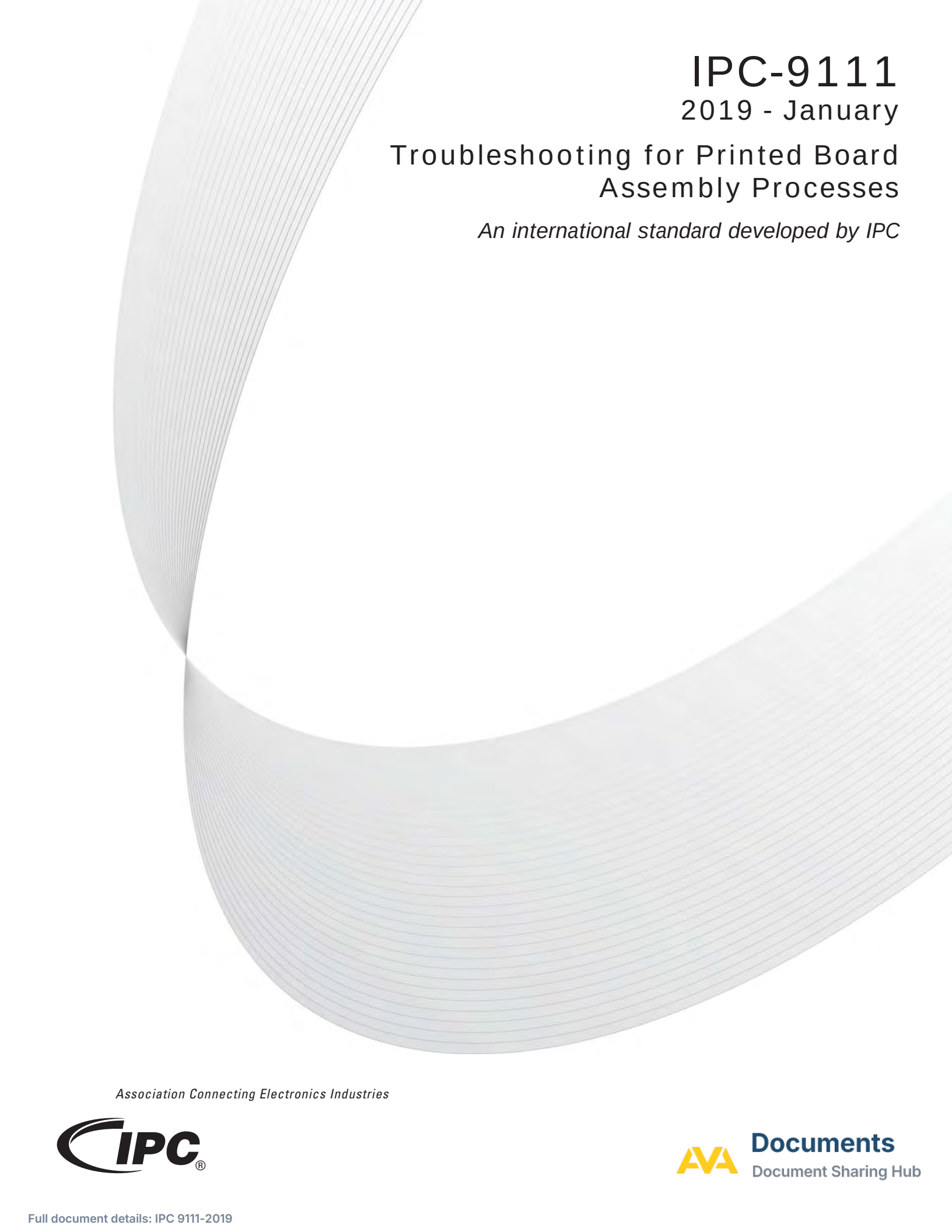




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Troubleshooting for Printed Board Assembly Processes

An international standard developed by IPC

Association Connecting Electronics Industries



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Troubleshooting for Printed Board Assembly Processes

Developed by Assembly Process Effects Handbook Subcommittee (7-23)
of the Process Control Management Committee (7-20) of IPC

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

Contact:

IPC
3000 Lakeside Drive, Suite 105N
Bannockburn, Illinois
60015-1219
Tel 847 615.7100
Fax 847 615.7105

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Raiyomand Aspandiar, Intel Corporation	Bhanu Sood, NASA Goddard Space Flight Center	Rachel Grinvalds, Rockwell Collins
Ife Hsu, Intel Corporation		David Hillman, Rockwell Collins
		Douglas Pauls, Rockwell Collins
		Casimir Budzinski, Safari Circuits Inc.

Vern Solberg, Solberg Technical
Consulting

Andy Bester, U.S. Army Aviation &
Missile Command

David Carlton, U.S. Army Aviation &
Missile Command

Calette Chamness, U.S. Army
Aviation & Missile Command

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Troubleshooting for Printed Board Assembly Processes

Section 1 – General Introduction

1 GENERAL INTRODUCTION

The Process Effects Committee of the IPC has developed this Process Control Handbooks for Printed Board Manufacture and Assembly, which is a documentation of problems, process causes, and the possible corrective action that may be taken. The inputs were voluntarily established by technical representatives of IPC member companies and have been reviewed in open discussion at the Process Effects Handbook meetings prior to publication.

New inputs are encouraged to help assure that the future Process Control Handbooks are complete and match the latest state-of-the-art in a particular subject.

1.1 Purpose and Format

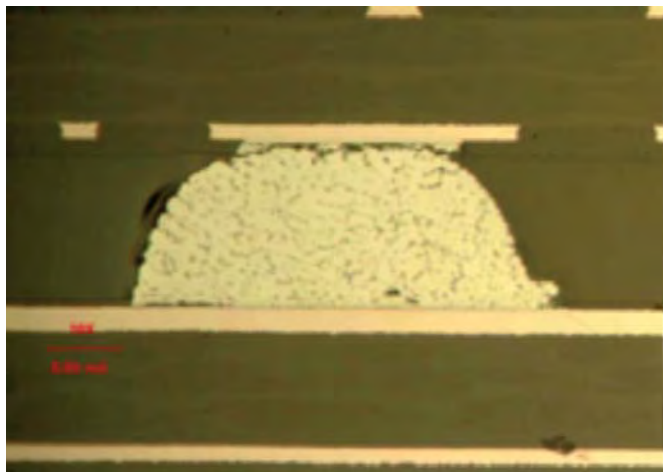
The purpose of this Handbook is to provide guidance in the form of troubleshooting examples, process cause and effect information and statistical methods for correcting problems in all areas relating to the design, manufacture, assembly, and test of printed wiring products. A comprehensive Table of Contents deals with all of the various aspects of the design through delivery cycle.

The Guideline has been segmented into 16 major sections:

Section	Topic Descriptions	Comments
1	General information	Terminology
2	Documentation	Assembly drawing, Bill of Materials (BOM), Specification Control details, work instructions, routers, Specifications
3	Tooling and Fixturing	Stencils, Holding devices, Calipers, Torque devices
4	Handling and Storage	Materials, PWBs, and components
5	Assembly Material	Solder, flux, paste, adhesive, encapsulation
6	Mechanical Operation	Stenciling, paste deposition, conveyerization
7	Component Preparation	Lead forming and trimming, verification, and kitting
8	Component Mounting Site Preparation	Land pattern redressing, solder dotting, adhesive application, solder jetting
9	Component Placement	Insertion, SMT, bare die
10	Component Attachment	Reflow, wave solder, fountain soldering, hand soldering, welding, surface contact, press fit
11	Cleaning	Manual and automated; in-process and final
12	Coating and Marking	Conformal coating, assembly serialization, and labels
13	Inspection	Visual, magnification, measurement, go/no-go, x-ray
14	Testing	In-circuit, physical, end-use, material testing
15	Reliability Stress Conditioning	Thermal Cycling, Vibration, Humidity Testing

The Handbook follows this format:

Issue: Solder Mask-Defined and Non-Defined Lands



CAUSE	ACTION
Interposer is solder mask defined; board is metal-defined. If the two areas are very different the stresses are not uniform and cracks may occur at the solder mask defined side. Board land pattern too large.	Area of the two attachment conditions should be similar or identical. In addition, solder mask defined lands create additional stress and should be avoided on both the interposer and the printed board land.
Potential test methods (discover)	Potential test method (verification)
X-Ray	Cross section – Visual inspection

Where available, an illustration is included to aid in clearly identifying the problem.

General instruction may at times be provided. Text will be printed across the page, dealing with the subject in general, and not highlighting a problem, cause, or corrective action.

1.2 Guidelines for Effective Troubleshooting and Process Control

One of the keys to effective problem solving is a structured routine that addresses key points each time a major problem is encountered. This section suggests steps to be taken in order to effectively find the cause of a problem and to solve it permanently. Refer to IPC-9191 for greater detail to suggested methodology for Statistical Process Control.

1. Problem Identification before beginning a detailed troubleshooting project, use common sense in defining the problem. Verify that there is a problem. Observe the defective product and compare to the standard. Identify the standard process and product, and then determine any present deviation from the standard, or any change in the product.
2. Establish whether operating procedures were followed and whether an assignable cause can be quickly identified as the reason behind the problem. Only continue into more detailed analysis if the initial questions do not lead to an obvious answer. Even if the answer appears to be obvious, confirm the answer by operation of the process before closing the project.
3. Develop a clear, concise problem statement that quantifies the problem whenever possible and reduces the scope of the investigation to a manageable size.
4. Gather all pertinent data and facts. Use SPC, historical data, records, logs, etc. This includes temperature charts, analysis records, maintenance logs and the like.
5. Use root cause analysis.
6. Producing out-of-specification parts require immediate action, i.e., shut down the process.
7. Out-of-control processes require determination as to whether the process can continue to operate.
8. Severe process variation requires evaluation of the severity and effect of the problem on the final product.

9. The action plan should include the procedures for addressing products produced during out-of-specification or out-of-control conditions. The plan should also indicate who should make those decisions. These issues include but are not limited to:
 - a. Disposition of the defective material (repair, scrap, replace, etc.)
 - b. Checking the effect on scheduled delivery.
 - c. Informing the effect on scheduled delivery.
 - d. Request for non-conformance authority or Material Review Board (MRB) action.
 - e. Establish a Corrective Action Plan to reduce or eliminate the likelihood of recurrence.
10. Measurement System Evaluation “Measurement System” in this context refers to the means used to detect and identify the problem. This includes not only the measuring apparatus, but also the sampling method, the operator (and their instructions), accuracy and calibration of equipment, and environmental factors, i.e., lighting, temperature, and relative humidity.
11. The variation inherent in the measurement of attribute data and responses that are subjective in nature can be addressed. The evaluation is more complex in nature, but it is still an essential part of the analysis of the problem. IPC-9191 discusses this subject in greater detail.

1.3 Parameter Analysis The purpose of Parameter Analysis, as detailed in IPC-9191 is to establish cause-effect relationships, identify, isolate and rank major sources of variation. Common sources are Positional Variation (within a piece), Cyclical Variation (piece to piece) and Temporal Variation (over time).

1.3.1 Brainstorming The development of a cause-and-effect diagram by a cross-functional problem-solving team is critical to the identification of variables to be studied. Care should be taken to include representatives of the disciplines that are part of the process being studied, such as engineering, quality, manufacturing operators, analysis laboratory, etc.

Identify all possible causes of the problem, including process steps, raw materials, materials handling, inspection and personnel, i.e., Fishbone. The ranking of these factors by the problem-solving team should be used to establish those factors that will be studied experimentally. The troubleshooting team should at a minimum include manufacturing engineers, quality engineering, and operators that are intimate with the process. The team should take care to openly consider new ideas on the problem.

Situations may occur where the formation of a team for brainstorming is inappropriate. Only someone with experience at troubleshooting should make the decision to approach a problem alone. Considerable time and effort can be wasted by failure to get input from all knowledgeable sources.

1.3.2 Process Audit A process audit by reviewing the entire operation, e.g., documentation, transfer, handling, processing, etc. Identify current conditions and compare to the standard. Define process windows. An audit is best conducted by someone not directly involved in the day-to-day operation of the process.

1.3.3 Initial Capability Study Ideally are done before the process is accepted for production. This means creating a match between the process and the product, and results in a process control window that is capable of producing the product.

One approach to troubleshooting that quantifies improvement for reporting to management involves the use of Capability Assessment. IPC-9191 discusses the generation of capability indices in greater detail. This step promotes the clear understanding of the process matrices but does require time and resources.

1.3.4 Optimization This step includes the variety of techniques used to isolate factors that affect the response being studied. The most important technique is to alter one-factor-at-a-time change. Comparison of the output at both settings is mandatory to establish the real effect of the process change. Outside factors that are not controlled when a new factor setting is evaluated can cause incorrect conclusions to be drawn.

1.3.5 Confirmation and Final Capability Assessment After determination of preferred settings for those factors studied, a confirmation run must be performed to establish the performance of the modified process. This step often consists of a Short-Term Capability Analysis for comparison with the initial capability assessment. A quantitative comparison of indices can be easily understood by uninvolved parties such as management. Only after confirmation of the test results should process changes implemented.

1.3.6 Parameter Control At this point, the factors that significantly impact the identified problem are understood and must be controlled. IPC-9191 discusses Parameter Control in detail. If the Tolerance band for these parameters is not clearly understood, more advanced experimental techniques can be used to establish specification limits.

1.3.7 Corrective Action Plan When a problem is identified, you must recommend the required course of action, and then follow it up to assure that it is understood and implemented. This may include:

1. Document the problem and solution.
2. Determine what measures must be taken to prevent recurrence.
3. Redefine the process control window.
4. Set up permanent controls to keep the variables within the set limits. These may include:
 - a. Process audits at specified intervals.
 - b. Process control or parameter measurement reporting (control charts, etc.).
 - c. Preventative maintenance to keep equipment functioning at established levels.
 - d. Report the problem and the corrective action to the appropriate people.

1.4 Applicable Documents

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

1.4.1 IPC

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

IPC-A-610 Acceptability of Printed Board Assemblies

IPC-TM-650 IPC Test Methods Manual

IPC-AJ-820 Assembly and Joining Handbook

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

IPC-2221 Generic Standard on Printed Board Design

IPC-2222 Sectional Standard on Rigid PWB Design

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

IPC-7525 Stencil Design Guidelines

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

IPC-9191 General Guidelines for Implementation of Statistical Process Control

IPC/JEDEC-9704 Printed Wiring Board Strain Gage Test Guideline

IPC-9708 Test Methods for Characterization of Printed Board Assembly Pad Cratering

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

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

J-STD-003 Solderability Tests for Printed Boards

J-STD-005 Requirements for Soldering Pastes

IPC/JEDEC J-STD-020 Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices

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Troubleshooting for Printed Board Assembly Processes

Section 2 – Design and Documentation

2 DESIGN AND DOCUMENTATION

This section provides information on those assembly conditions that are affected by the design and documentation provided to the assembly manufacturer. Included in the descriptions is information provided related to specific user manufacturing instructions. Although the recommended solutions must be implemented during the design and documentation phase they are useful in identifying those conditions that lead to defects or anomalies in the final assembled product. This section would include Assembly drawing, BOM, Specification Control details, work instructions, routers and specifications.

Printed board assembly documentation should adequately define the following:

- Lead bend criteria.
- Clearance of components between the board and the bottom of the component.
- Cleaning requirements and test for cleanliness.
- Type of solder mask and conformal coating and imperfections that are allowed.
- Requirements for complete filling in the solder hole, or solder filling around the lead.
- The use of jumper or haywires and how they must be secured to the boards.
- The masking of components or areas of the board that do not get conformal coating.
- Requirements for stress relief bends on wires, components, etc.
- Location, identification and orientation of all components.
- The definition of projection or lead projection of straight through leads.
- For surface mounted components, the thickness of solder paste, solder callout, flux, inadequately defined, including all locations of solder paste/creams.
- For connectors that require keys, the assembly drawing should show the exact key position and assembly instructions.
- Any hardware that becomes part of the assembly and the torque requirements necessary to prevent damage to the printed board assembly.
- Bow and twist end product requirements after assembly.
- Electrical requirements for end product testing of the assembly, including go/no-go tests as well as diagnostics.
- Applicable ordering data.
- Structural details when required for support and rigidity.
- Markings (serial number, dash number, etc.) to be added as a result of the assembly operation.

2.1 Component Positioning

Issue: SMT chip components twist off lands during reflow

CAUSE	ACTION
Improper land pattern design.	Redesign land pattern per IPC-7351.
Potential test methods (discover)	Potential test method (verification)

Issue: Insufficient toe and heel fillets

CAUSE	ACTION
Improper land design.	Redesign land pattern per IPC-7351.
Over-etched board.	Refer problem to PWB supplier.
Potential test methods (discover)	Potential test method (verification)

Issue: Through hole components do not consistently go into mounting holes during automatic assembly

CAUSE	ACTION
Component mounting holes too small.	Increase mounting hole size in accordance with IPC-2221 and IPC-2222.
Hole patterns not located to datum planes.	Locate hole pattern to datum planes.
Assembly equipment not properly maintained.	Maintain assembly equipment within operational specifications.
Potential test methods (discover)	Potential test method (verification)

Issue: Cannot access component for repair

CAUSE	ACTION
Incorrect component placement.	Provide sufficient spacing between components to facilitate repair equipment and tools.
Potential test methods (discover)	Potential test method (verification)

Issue: Delicate component bodies crack during the thermal cycles of assembly

CAUSE	ACTION
Insufficient lead stress relief for through-hole components.	Redesign through-hole component lead spacing to provide additional lead stress relief.
Improper land design for surface mount components.	Redesign SMT land per IPC-7351.
Potential test methods (discover)	Potential test method (verification)

Issue: Small components exhibit poor solder joint formation

CAUSE	ACTION
Small components shadowed by larger components.	Relocate smaller components so that they are not shadowed by larger components.
Improper land design.	Redesign land pattern per IPC-2221, IPC-2222 and IPC-7351.
Potential test methods (discover)	Potential test method (verification)

Issue: Unable to maximize manufacturing capability, or optimize construction and assembly choices to obtain best solutions for end product functionality and performance

CAUSE	ACTION
User defined manufacturing and process specifications attempt to define too many details and are therefore restrictive or prohibitive to supplier technology for optimization.	User/customer and supplier/vendor should work together in developing specifications, in order to cover basic minimum requirements, while allowing flexibility in manufacturing and processing for optimization. Use industry standards, such as IPC, "as is," or draw from these standards when developing user specifications.
Potential test methods (discover)	Potential test method (verification)

Issue: Unable to determine acceptance criteria.

CAUSE	ACTION
Specification requirements are in conflict with Master Drawing requirements.	Contact user/customer to resolve conflicts; determine if deviations are needed; request an update to documentation and purchase order or shop order.
Acceptance, test, and inspection requirements are not defined.	Contact user/customer to determine if this is an omission. If specific actions are required, request update to documentation. Otherwise, acceptance, test, and inspection actions by the manufacturer should be based on statistically based process control.
Potential test methods (discover)	Potential test method (verification)

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Troubleshooting for Printed Board Assembly Processes

Section 3 – Tooling and Fixturing

3 TOOLING AND FIXTURING

This section provides information on those assembly conditions that are affected by the tools and fixtures used to produce the final assembly. Included in the descriptions are the methods employed for palletization and any fixtures used to transport the assembly from one workstation to another. The solutions must be implemented by process engineering in order to avoid the potential defects or to make for a smoother work flow in the assembly of the product. This section would include stencils, holding devices, calipers and torque devices.

3.1 Terminals

Issue: Terminals and eyelets, swaged base split

CAUSE	ACTION
Terminal/eyelet material is too hard.	Terminals/eyelets must be annealed.
Tooling is incorrect for particular hardware.	Check supplier's literature for correct tooling.
Board is delaminated around plated-through hole.	Install proper length hardware.
Potential test methods (discover)	Potential test method (verification)

Issue: Terminal and eyelets, mounts are cracked

CAUSE	ACTION
Hardware torqued too tightly.	Torque to allow for heat expansion.
Potential test methods (discover)	Potential test method (verification)

Issue: Incorrect stress relief

CAUSE	ACTION
Improper employee training.	Re-train employee. Replace equipment.
Worn equipment.	Re-train/adjust tool.
Potential test methods (discover)	Potential test method (verification)

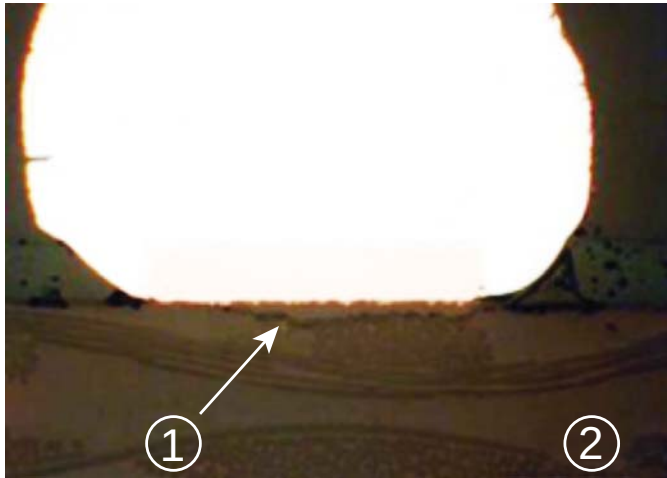
Issue: Cracked or fractured meniscus

CAUSE	ACTION
Tool too close to body.	Adjust tool.
Potential test methods (discover)	Potential test method (verification)

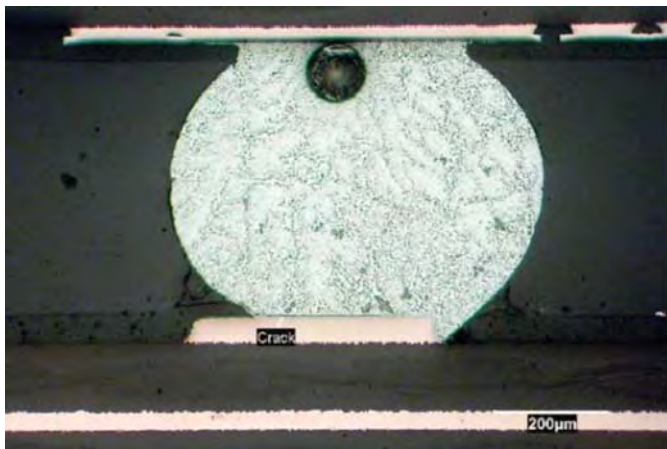
3.2 Assembly Fixture

Issue: Components damaged by assembly fixturing

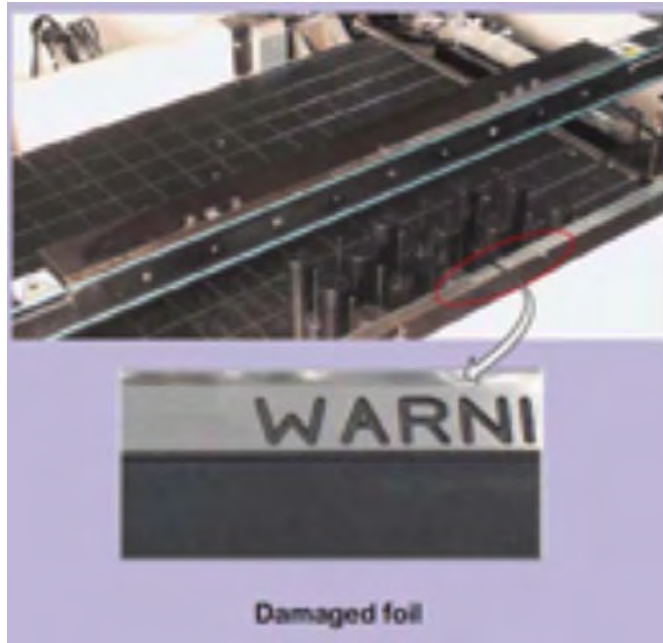
CAUSE	ACTION
Components intrude in assembly fixturing area.	Add a breakaway portion of board material to facilitate assembly fixturing.
Potential test methods (discover)	Potential test method (verification)

Issue: Board Pad Cratering

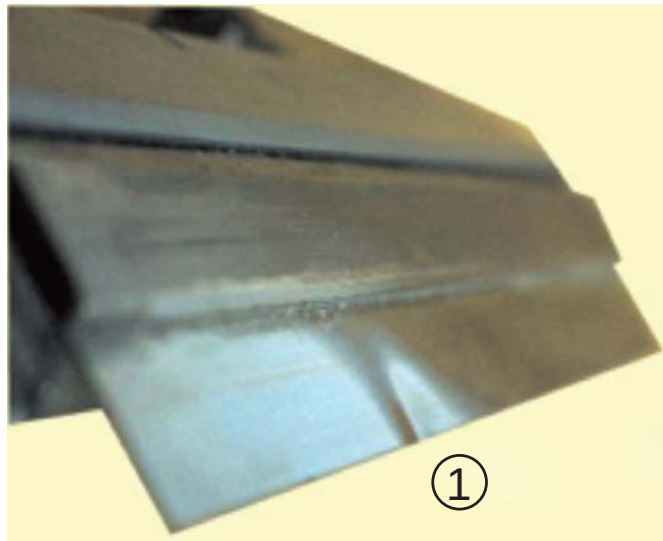
CAUSE	ACTION
Board Pad cratering due to mechanical strain at corner solder joint from fixture strain.	Reduce fixture strain.
Potential test methods (discover)	Potential test method (verification)
	IPC/JEDEC-9704 and IPC-9708.

Issue: Solder Joint Cracking

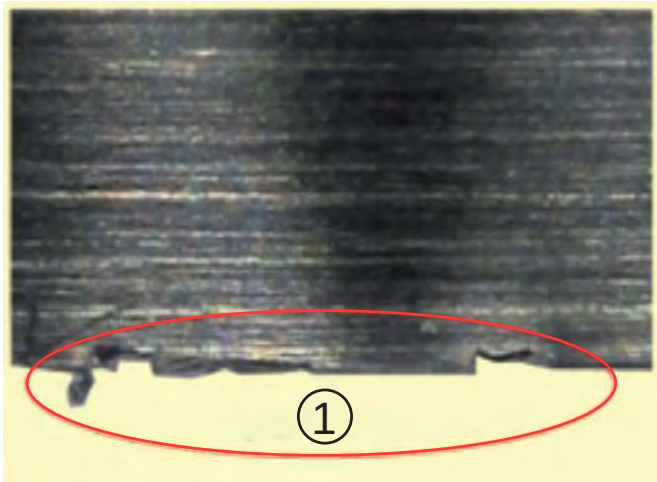
CAUSE	ACTION
Solder Joint due to mechanical strain at corner solder joint from fixture strain.	Reduce fixture strain.
Potential test methods (discover)	Potential test method (verification)
	IPC/JEDEC-9704.

Issue: Stencil and Printer Tooling Issues

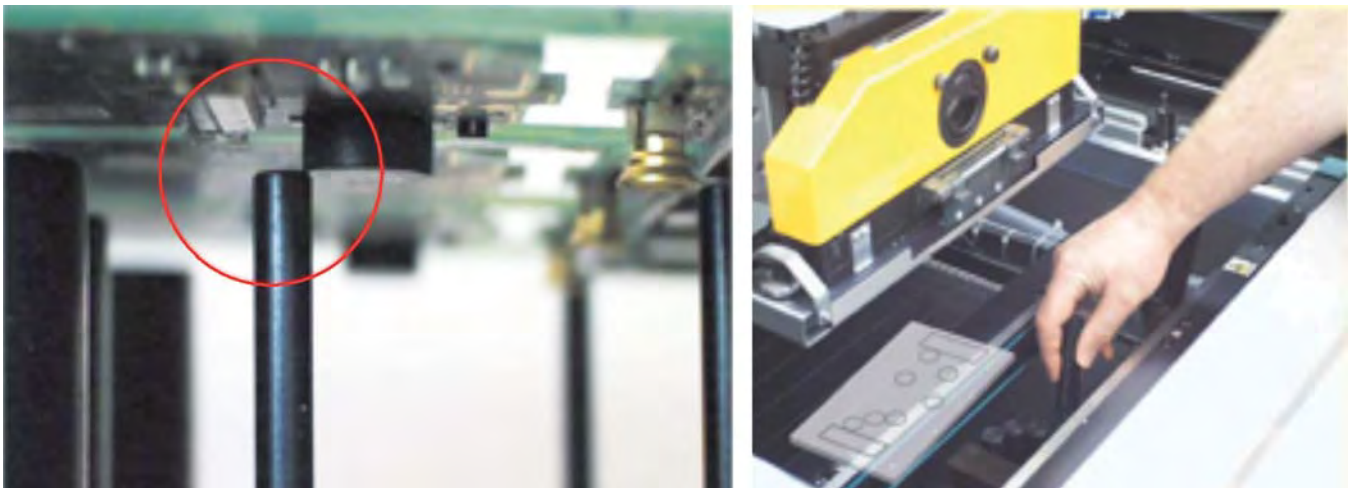
CAUSE	ACTION
Damaged board clamp.	Replace damaged board clamp.
Potential test methods (discover)	Potential test method (verification)

Issue: Damaged Squeegee Blade

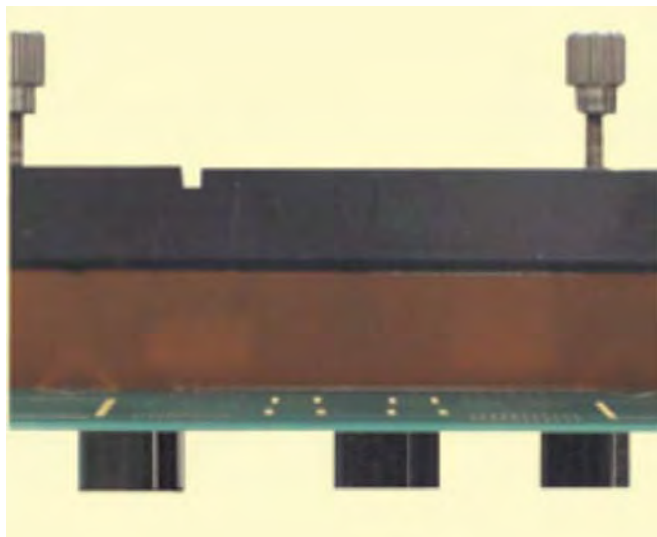
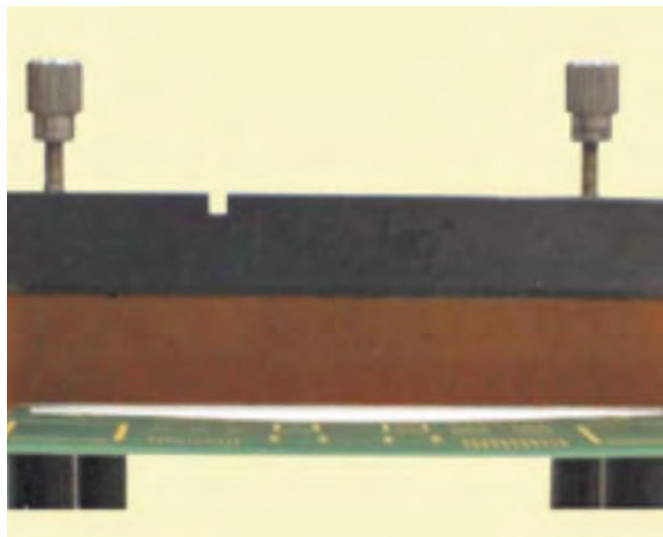
CAUSE	ACTION
Damaged squeegee blade.	Replace damaged squeegee blade.
Potential test methods (discover)	Potential test method (verification)

Issue: Damaged printer wiper

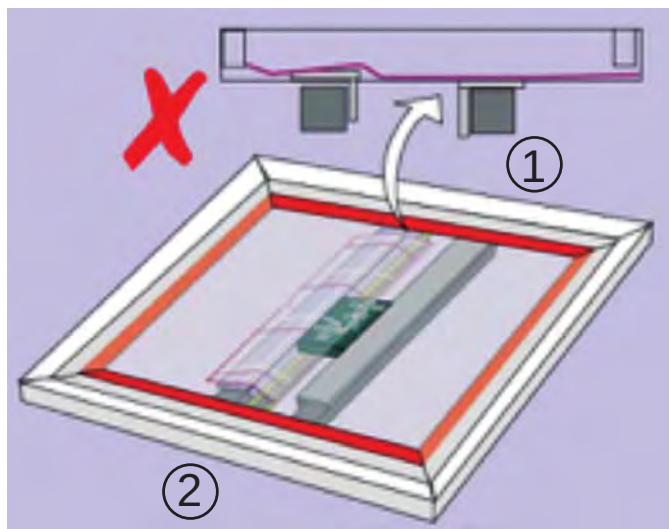
CAUSE	ACTION
Damaged printer wiper.	Replace damaged printer wiper.
Potential test methods (discover)	Potential test method (verification)

Issue: Tooling incorrectly set or placed

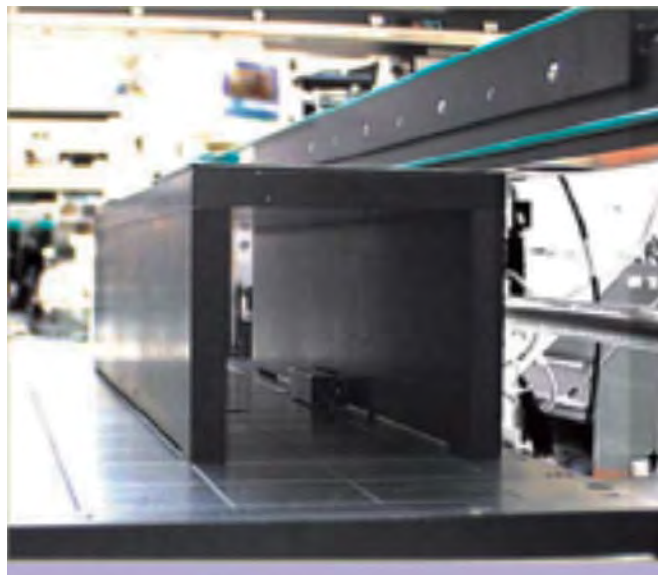
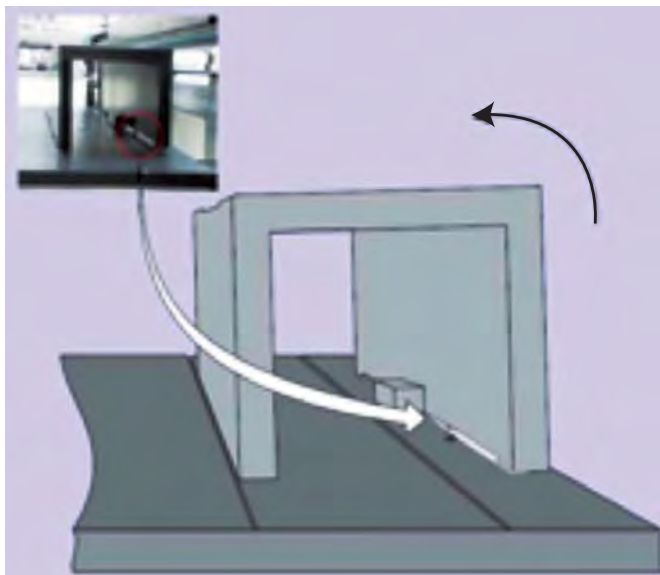
CAUSE	ACTION
Incorrect tooling during printing.	Use correct tooling and place tooling correctly.
Potential test methods (discover)	Potential test method (verification)

Issue: Tooling Missing

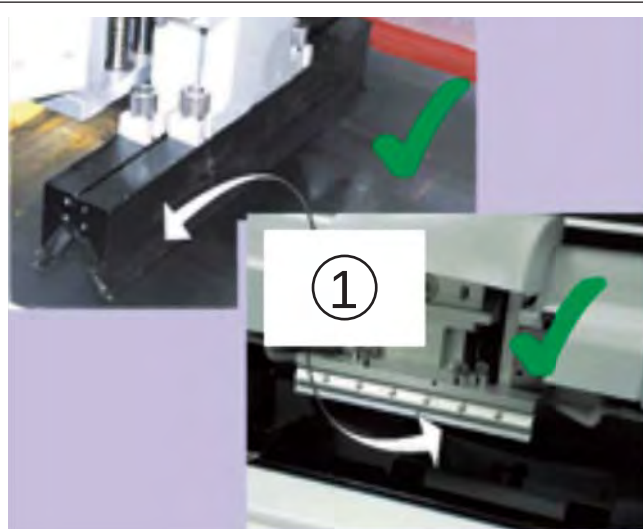
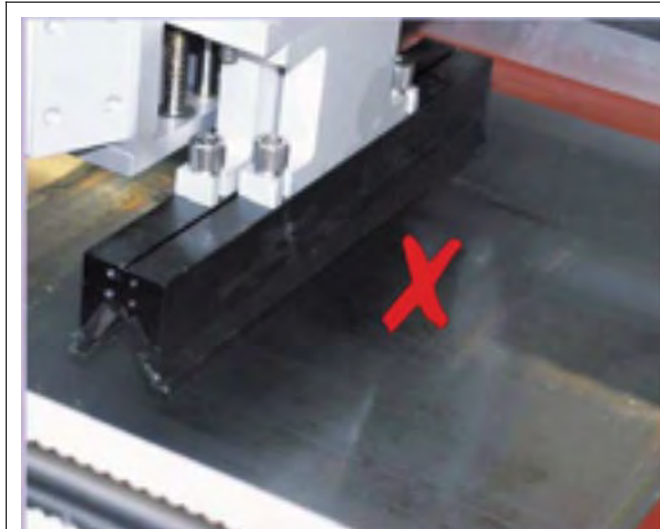
CAUSE	ACTION
Missing support tooling during printing.	
Potential test methods (discover)	Potential test method (verification)

Issue: Incorrect print height

CAUSE	ACTION
Board clamps set too high causing incorrect print height.	Set board clamps at correct height to avoid incorrect printing height.
Potential test methods (discover)	Potential test method (verification)

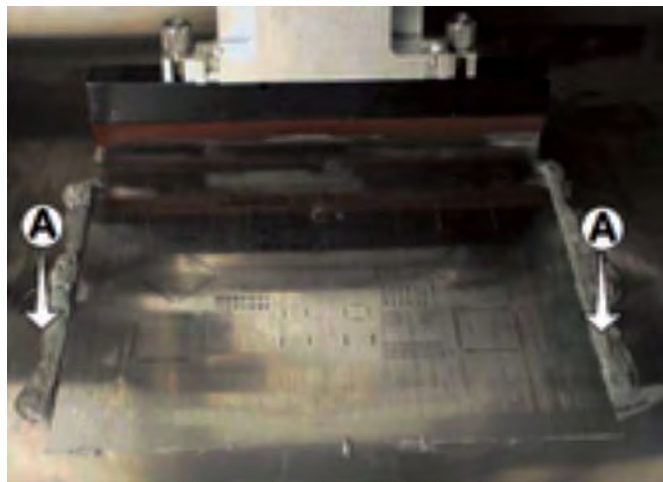
Issue: Tooling is not level

CAUSE	ACTION
Printer tooling block not level.	Level printer tooling block.
Potential test methods (discover)	Potential test method (verification)

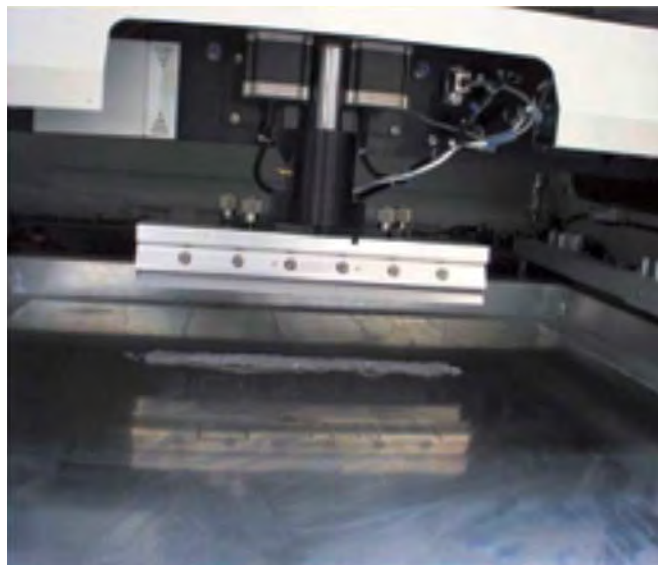
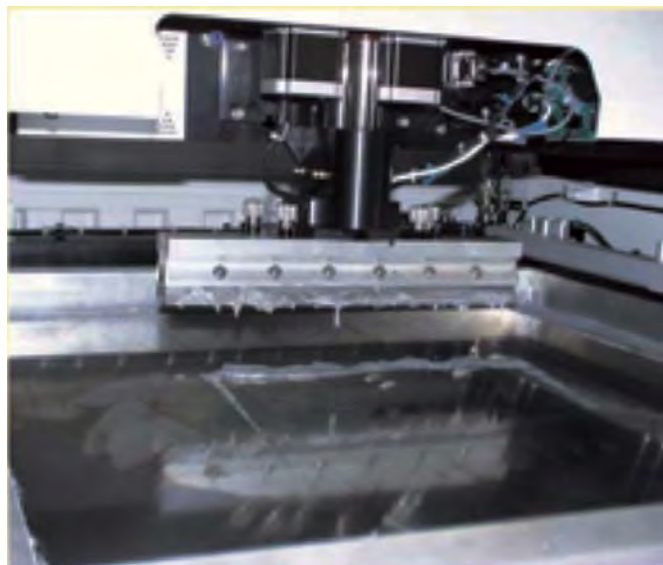
Issue: Incorrect squeegee type fitted

Note 1. Either type dependent upon process data sheet

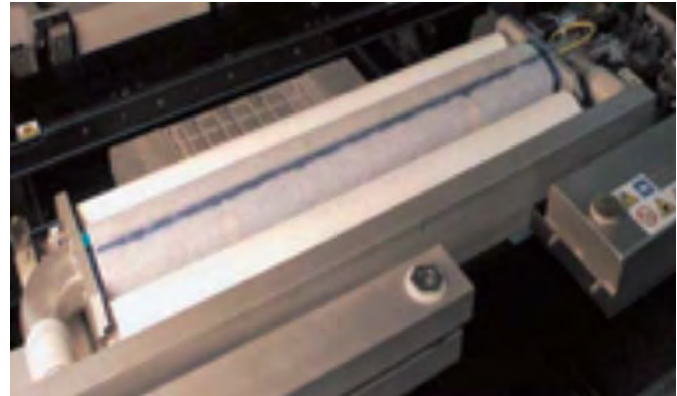
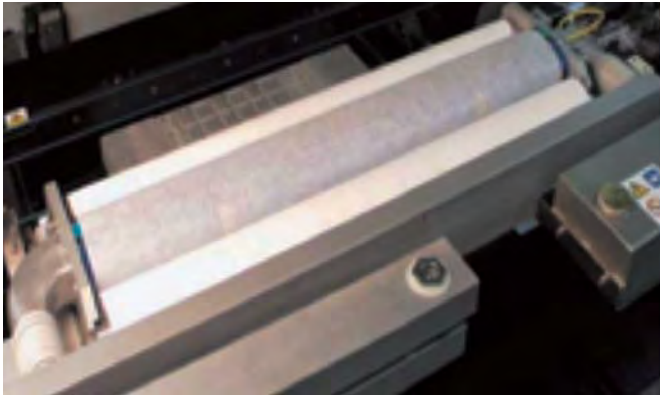
CAUSE	ACTION
Incorrect squeegee fitted.	Fit the correct squeegee type.
Potential test methods (discover)	Potential test method (verification)

Issue: Insufficient paste in print area

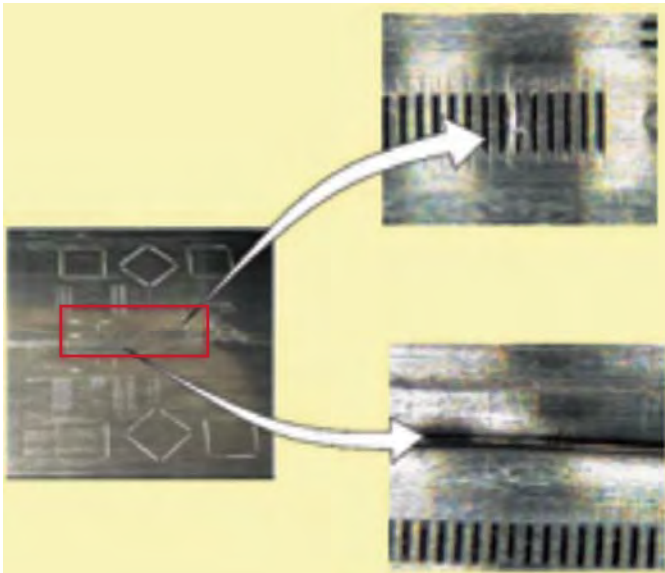
CAUSE	ACTION
Insufficient solder paste in print area.	Fit paste deflectors.
Potential test methods (discover)	Potential test method (verification)

Issue: Squeegees are dirty

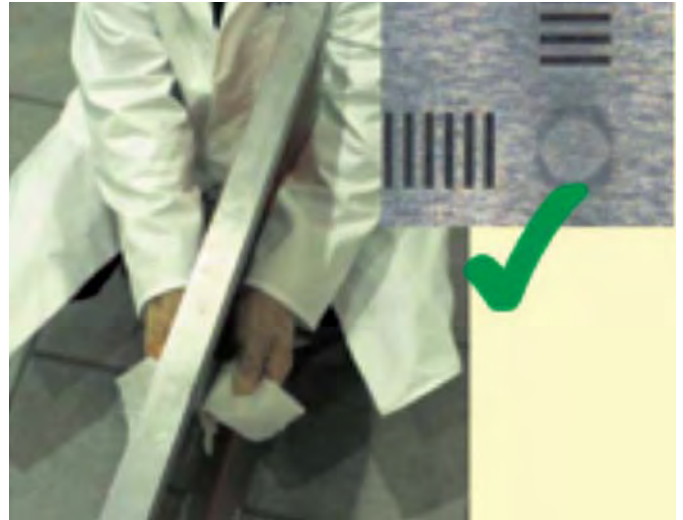
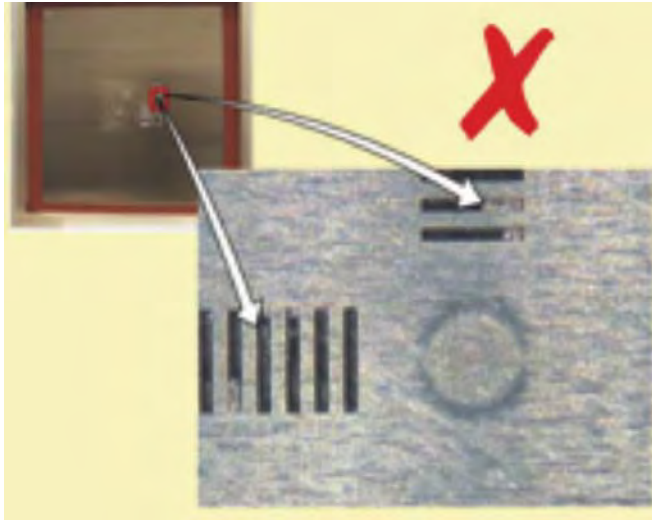
CAUSE	ACTION
Excessive solder paste on squeegee blades.	Clean the squeegee blades.
Potential test methods (discover)	Potential test method (verification)

Issue: Understencil cleaner

CAUSE	ACTION
Understencil cleaner runs out of solvent.	Replenish solvent in understencil cleaner.
Potential test methods (discover)	Potential test method (verification)

Issue: Damaged Screen/stencil

CAUSE	ACTION
Damaged screen/stencil.	Replace damaged screen/stencil.
Potential test methods (discover)	Potential test method (verification)

Issue: Screen Apertures Blocked with solder paste

CAUSE	ACTION
Screen/stencil apertures are blocked with solder paste.	Remove and clean screen/stencil apertures to remove solder paste.
Potential test methods (discover)	Potential test method (verification)

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Troubleshooting for Printed Board Assembly Processes

Section 4 – Handling and Storage

4 HANDLING AND STORAGE

This section provides information on those assembly conditions that are affected by the handling of materials, boards, and assemblies. Included in the descriptions are the methods for storage, Electrical Overstress (EOS), Electrostatic Discharge (ESD), Moisture Sensitive Devices (MSD), and packaging employed for the protection of the materials and assemblies. The solutions must be implemented by process engineering in order to avoid the potential defects or to make for a smoother work flow in the assembly of the product. This section includes materials, PWBs and components.

4.1 Component Mounting Solderability and Contamination

Issue: Leads do not accept solder

CAUSE	ACTION
Gold plate is too thin.	Verify gold thickness to meet specification requirements.
Lead is contaminated.	Degrease/clean. Use aggressive flux to pre-tin lead.
Potential test methods (discover)	Potential test method (verification)

Issue: Leads do not float

CAUSE	ACTION
Pins are contaminated inside of connector.	Clean connector pins of contamination by solvent; soak or degrease.
Potential test methods (discover)	Potential test method (verification)

4.2 Board Preparation

Issue: Residue at incoming inspection. Incoming residue may be associated with either the manufacture of the boards and components, or their handling and storage.

CAUSE	ACTION
Residue on components or boards.	Pre-clean components or boards. Work with supplier to eliminate residue.
Residue found after storage.	Pre-clean; modify storage conditions.
Potential test methods (discover)	Potential test method (verification)

Issue: Paste is dry

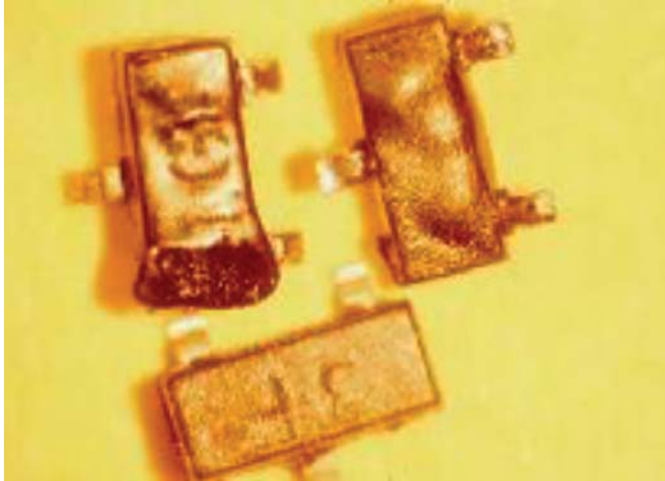


Note 1. Date OK

CAUSE	ACTION
Solder paste is dry causing issues during paste printing.	Check solder paste print medium has the correct storage conditions and date of manufacture.
Potential test methods (discover)	Potential test method (verification)

Issue: PWB warps or delaminates after reflow

CAUSE	ACTION
Moisture in PWB.	Pre-bake prior to reflow and/or store in dry cabinet. Require PWB Mfg. to dry & seal PWB with desiccant & Tag.
Potential test methods (discover)	Potential test method (verification)

Issue: Poor SOT 23 Component Compatibility

CAUSE	ACTION
Overheating.	Check reflow/rework profile.
Potential test methods (discover)	Potential test method (verification)

Ref: NPL Defect Database

Issue: QFP Cracking Popcorning

CAUSE	ACTION
Moisture ingress.	Check Packaging/Floor Life Controls per J-STD-033.
Potential test methods (discover)	Potential test method (verification)

Ref: NPL Defect Database

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Troubleshooting for Printed Board Assembly Processes

Section 5 – Assembly Material

5 ASSEMBLY MATERIAL

This section provides information on those assembly conditions that are affected by the materials used to produce the final assembly. Included in the descriptions are the methods employed when using adhesives, potting, encapsulation, conformal coating, flux, and solder materials used in the assembly process. The solutions must be implemented by process engineering in order to avoid the potential defects or to make for a smoother work flow in the assembly of the product. This section would cover solder, flux, paste, adhesive and encapsulation.

Issue: Flux on top of paste

CAUSE	ACTION
Formulation problem. (If flux collects on top of paste, it means that flux is liquid enough to allow powder to settle to bottom.)	Mix paste well, if still in jar (make sure that there is no crust on top). If paste is in dispensers, it can be squeezed into a jar and mixed, otherwise, a stir rod can be placed in nozzle end to mix paste inside canister. Work with paste supplier to correct problem. Separation can be slowed by storing paste in refrigerator.
Potential test methods (discover)	Potential test method (verification)

Issue: Crust on top of paste

CAUSE	ACTION
Packaging problem. Paste can develop crust on surface if caps are not screwed tightly.	Make sure that all paste containers are tightly sealed and all jars contain plastic plungers to reduce possible air contact area.
Exposure of paste to high temperatures during shipping/storage.	Have paste shipped overnight from supplier, to minimize exposure. Control storage conditions.
Improper storage after paste has been used.	Use plunger to keep air contact to a minimum. Keep all sides in jar clean of paste.
Poor paste flux formula	Monitor paste amount with crusting problems. If crusting is significant problem, notify supplier
Potential test methods (discover).	Potential test method (verification).

Issue: Dry solder paste

Note 1. Date OK

CAUSE	ACTION
Solder paste is dry causing issues during paste printing.	Check solder paste print medium has the correct storage conditions and date of manufacture.
Potential test methods (discover)	Potential test method (verification)

Issue: Conformal Coating bubbles

CAUSE	ACTION
Excessive mixing inducing bubbles or excessive spray pressure.	Avoid aggressive stirring or reduce pressure. If thinning, stir gently so as to not induce bubbles.
Potential test methods (discover)	Potential test method (verification)

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