



ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

IPC-S-816

SMT Process Guideline and Checklist

IPC-S-816

A standard developed by IPC

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Developed by the Soldering Surface Mount Devices Task Group
of the Joining Processes Committee of IPC

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

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Acknowledgment

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SMT Process Guideline and Checklist

1.0 SCOPE

This document is intended to provide guidelines and assistance in performing and troubleshooting the steps involved in the process of producing printed wiring assemblies incorporating surface mounting attachment of components.

Each section contains a list of problems often observed during a specific part of the surface mount assembly process. The list of observed symptoms is matched by a description of causes often associated with the symptoms. Suggestions for correction are also included. These solutions may be related to the equipment, materials, or design. Accordingly, some of these corrective measures cannot be implemented on the shop floor.

1.1 Environmental, Safety, and Industrial Hygiene Considerations The use of some of the materials referenced in this document may be hazardous. Precautions should be taken to safeguard personnel and the environment, as outlined in the appropriate data supplied with the materials used. In addition, equipment and procedures should adhere to applicable local and federal regulations.

1.2 Applicable Documents The following documents, of the issue currently in effect, are applicable to the extent specified herein.

1.2.1 IPC¹

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

IPC-OI-645 Standard for Visual Optical Inspection Aids

IPC-R-700 Suggested Guidelines for Modification, Rework, and Repair of Printed Boards and Assemblies

IPC-SM-782 Surface Mount Land Patterns (configurations and Design Rules)

IPC-SM-786 Recommended Procedures for handling of Moisture Sensitive Plastic IC Packages

IPC-SM-840 Qualification and Performance of Permanent Polymer Coating (Solder Mask) For Printed Boards

1.2.2 Joint Industry Standards¹

J-STD-002 Solderability Test for Component Leads, Termination, Lugs, Terminals and Wires

J-STD-003 Solderability Tests for Printed Boards

J-STD-004 Requirements for Soldering Fluxes

J-STD-005 General Requirements and Test Methods for Electronic Grade Solder Paste

2.0 HANDLING

Handling is one topic that is not confined to a specific area of the manufacturing operation. Handling problems are a “cradle to grave” issue for which no one will claim responsibility; yet the impact on the surface mount process yield is substantial. Every major step covered in this guideline, from adhesive application to cleaning of surface mount assemblies, relies on a comprehensive component and assembly handling strategy. Handling can’t be the concern of a single group in the manufacturing environment and must be an integral part of each process step in the surface mount assembly line. Although the general format of this document is problem-cause-corrective action, the following handling items need to be considered throughout the entire surface mount assembly process.

2.1 Electrostatic Discharge (ESD) Concerns The following are ESD concerns:

- 1) Has process machinery been properly grounded?
- 2) Have work stations and storage areas been properly grounded?
- 3) Are other environmental controls (i.e., ionizers, humidifiers, etc.) in place to reduce the occurrence of ESD?
- 4) Have operators and all other employees who may handle components or surface mount assemblies been properly trained to use ESD precautions such as wrist straps or other similar preventative measures?
- 5) Have the component packaging and assembly containers been reviewed for potential ESD problems?
- 6) Have ESD sensitive parts been identified and sufficiently protected?

2.2 Component Leads The following are concerns regarding component leads:

- 1) Has component lead coplanarity been addressed following manual or automatic lead forming operations?
- 2) Has component lead solderability concerns in relation to handling been reviewed and precautions taken where deemed necessary?

2.3 Storage The following are concerns regarding storage:

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- 1) Have the effects of the storage environment on components, materials or assemblies been reviewed within your manufacturing environment?
- 2) Does your handling system have a method of monitoring shelf life issues of stored components or assembly materials to prevent unacceptable material from being issued into the manufacturing environment?
- 3) Would the use of date codes on assembly materials and components be beneficial in ensuring timely usage?

2.4 Interim Handling The following are concerns regarding interim handling:

- 1) Would the use of dedicated assembly or component carriers prevent handling defects between process operations?
- 2) Have operators and assembly routers who handle components or surface mount assemblies between process operations been properly trained and made aware of their potential impact on the assembly process?

3.0 INCOMING INSPECTION OF MATERIALS AND COMPONENTS

Surface mount assembly complexity can range from just a few components to several hundred on one printed wiring board (PWB). Adhesives, solder, flux, printed circuit boards, heat sinks, and components are just some of the variety of "building blocks" used in surface mount technology (SMT) assembly. The breakdown of form, fit, or function of just one of these building blocks can result in a rework operation or even the rejection of a completed assembly. Incoming inspection of the materials and components which comprise an assembly is one method of reducing, or eliminating, the possibility of this situation occurring. Incoming inspection can accomplish two purposes:

1. **Conformance of Material to Specification Requirements** Surface mount assembly costs rise sharply when nonconforming materials find their way into the manufacturing process. Important key material characteristics can be identified and checked prior to the release of the material to the manufacturing floor. Conformance testing can also be utilized for evaluating materials which can degrade over time, such as solderability or adhesive shelf life.
2. **Vendor Evaluation** When a particular material or component is procured from several different sources, incoming inspection can be used for evaluation comparisons. The comparison may reveal one particular vendor which supplies a material more consistently and with less variation between different material lots. This type of data can be shared with vendors to improve a particular assembly manufacturing process or be incorporated into a vendor rating system.

Incoming inspection of materials and components should have a defined purpose and be performed in conjunction with a good statistical process control plan. Emphasis on a well-planned incoming inspection system results in lower manufacturing costs through fewer surface mount assembly defects and a reduction in the number of surface mount assembly scrapped.

4.0 ADHESIVE APPLICATION

In surface mount technology the most prevalent use of adhesives is for component retention prior to, and during, bottom side wave soldering.

The most common method of adhesive application is automatic syringe dispensing. Hand syringe dispensing is also used for lower volumes and rework/repair operations. Pin transfer is another method often used in high volume, low mix operations.

Control of adhesive location and material properties for effective dispensing are the most common difficulties encountered.

This section presents a general listing of problems encountered in the adhesive application process, potential causes, and suggestions for corrective actions. These solutions may be related to equipment, materials, design, or prior processes. Accordingly some of the solutions cannot be immediately implemented on the shop floor.

4.1 Dispensing

4.1.1 Dispensing One Part Adhesive

4.1.1.1 Observed Condition: Stringing Most frequently related to both dispenser and adhesive.

A. Equipment/Process Related	
Potential Cause	Corrective Action
1. Dispenser pressure too high	Reduce pressure
2. Dispensing period too long	Increase nozzle tip size
3. Nozzle too far from substrate	Reduce distance of nozzle to substrate
4. Nozzle drools	Use vacuum suck back
5. Adhesive on soldering surface	Change direction of nozzle travel
6. Tip length too long	Shorten tip
B. Material/Prior-Process Related	
Potential Cause	Corrective Action
1. Viscosity of adhesive too high	Lower viscosity Increase reservoir temperature
2. Viscosity of adhesive too low	Reduce reservoir temperature
3. Plastic flow of adhesive (dribble)	Choose more thixotropic material
4. Air in adhesive	Remove air by centrifuging

4.1.1.2 Observed Condition: Nozzle Clogging Most frequently related to down time, curing, and foreign matter.

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Down time too long	Follow adhesive manufacturers' recommendation
2. Reaction with nozzle or tip	Anaerobic action— <i>do not</i> use copper or brass; use passivated stainless steel or plastic.
<i>B. Material/Prior-Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Reaction by absorption of moisture (epoxy)	Keep nozzle tip closed during down time
2. Mixing of two different adhesives	Thoroughly clean system when changing adhesives

4.1.1.3 Observed Condition: Skipping and Insufficient Adhesive Most frequently related to clogged nozzle.

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Clogged nozzle, bubbles, and foreign material	Remove cured adhesive, lumps, air
2. Worn or bent nozzle tip	Replace tip
3. Insufficient height	Dispense adhesive on top of original dot (double dispense)
4. Variation in dot size	Check dispenser output for consistency
<i>B. Material/Prior-Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. PWB not flat	Obtain flat boards Check hold down
2. Viscosity too high for nozzle tip and pulse rate	Reduce viscosity Heat reservoir Select another adhesive
3. Insufficient height and/or excessive spread	Increase viscosity Select a more thixotropic adhesive Cool reservoir

4.1.1.4 Observed Condition: Excessive Adhesive Most frequently related to thixotropic properties of adhesive, temperature of reservoir, and equipment controls.

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Low viscosity	Lower reservoir temperature
2. Dispenser pressure too high	Lower pressure
3. Tip size too large	Reduce tip size

<i>B. Material/Prior-Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Low viscosity	Increase adhesive viscosity Select adhesive with higher thixotropic ratio
2. Excessive spread	Select another adhesive

4.1.1.5 Observed Condition: Insufficient Cure Most frequently related to insufficient curing energy leaving soft, gummy, or tacky adhesive.

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Insufficient energy	Adjust cure time/temperature Check output of UV lamps
2. Too much energy which damages components	Reduce temperature Select another adhesive with different cure cycle
<i>B. Material/Prior-Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Local heat sinks	Move components on PWB
2. Heat sensitive components	Move components to bottom side, IR heat top side

4.1.1.6 Observed Condition: Lost Components Most frequently related to insufficient cure, poor bond or adhesive, or non-wetted component.

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Insufficient cure	Check time/temperature and energy level of cure cycle
2. Adhesive bond	Decrease time between placement and cure
3. Adhesive dot too low with insufficient component contact	Print second dot on top of original dot Increase tip size
4. Fast speed and stop in X-Y movement	Increase initial tackiness of adhesive Reprogram/reduce speed of placement
5. Poor placement of component	Realign equipment
6. Uncured adhesive (UV)	Place two dots either side of component
<i>B. Material/Prior-Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Adhesive bond/strength	Check PWB and component cleanliness/bondability with adhesive
2. Adhesive dot too low with insufficient component contact	Use high dot profile adhesive and high viscosity for initial tack
3. Adhesive shrinkage during cure	Select another adhesive

4.1.1.7 Observed Condition: Adhesive Voids Most frequently related to the presence of moisture in adhesive or on surfaces.

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
No information available	
<i>B. Material/Prior-Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Moisture in adhesive	Check adhesive for excess moisture If excessive, cease use and determine and eliminate source of moisture
2. Absorbed moisture on bare PWB	Bake PWB before using adhesive Check solder mask for porosity
3. Absorbed moisture on surface of component	Bake components before assembly

4.1.2 Dispensing Two Part Adhesive Similar to 4.1.1 with a requirement that if recommended mixture ratio is not met, the cure will not be satisfactory with a potential loss of components.

4.1.3 Pin Dip Transfer

4.1.3.1 Observed Condition: Stringing Most frequently related to withdrawal rate and viscosity.

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Rate of pin withdrawal	Correct speed of vertical travel
2. X-Y movement during withdrawal	Correct horizontal movement
<i>B. Material/Prior-Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Viscosity too high	Reduce viscosity
2. Flow properties do not match pin travel	Select adhesive with proper properties
3. Viscosity too low	Increase viscosity so adhesive does not drip

4.1.3.2 Observed Condition: Skipping and Insufficient Adhesive Most frequently related to amount of adhesive in pins.

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Pin size too small	Increase pin size
2. Pin shape incorrect	Select different pin shape
3. Pin does not wet	Clean pin and/or change material
4. Pin immersion incorrect	Check pin position and reservoir depth

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
5. Reservoir withdrawal rate incorrect	Check rate of withdrawal
6. Withdrawal from PWB incorrect	Reduce speed of withdrawal
<i>B. Material/Prior-Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Insufficient adhesive on pin	Adjust viscosity and thixotrophy
2. Adhesive drops off during transfer	Increase viscosity

4.1.3.3 Observed Condition: Excessive Adhesive Most frequently related to flow properties of adhesive and variations in temperature of the reservoir.

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Pin size too large	Reduce pin size
2. Too much adhesive on pin	Reduce depth in reservoir
3. Adhesive reservoir/pin plate not coplanar	Level adhesive reservoir
4. Pins have become rough	Replace pins
5. Build up of adhesive on pin	Clean pins
6. Decreased distance between pin and PWB	Correct spacing
<i>B. Material/Prior-Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Viscosity increased	Adjust viscosity
2. Wrong pins used	Replace pins

5.0 SOLDER PASTE APPLICATION

Several solder paste application techniques are used to transfer solder paste to areas being joined. The most commonly used methods include: stencil printing, screen printing, and syringe dispensing. Less common techniques, such as direct pin transfer and wheel transfer, are used for some special applications. With the trend toward use of components having closer and closer lead spacing, error-free application of solder paste is more difficult and the direct relationship between poor quality application and final yield is more apparent.

Poor application can cause five common defects: insufficient solder, excess solder, shorts, opens, and solderballs. Each of these defects can be the result of one or more of the following symptoms: insufficient solder paste deposited, excess solder paste deposited, wet bridging, or misplaced solder paste. Each of these symptoms can be the result of a variety of causes.

5.1 Stencil Printing

5.1.1 Observed Condition: Insufficient Solder Paste Deposited In order for enough solder paste to be deposited in the area to be soldered, the volume of the stencil opening should be approximately equal to the desired amount of wet solder paste.

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Stencil too thin	Increase stencil thickness

<i>General Guideline of Stencil Thickness for Various Applications</i>	
<i>Stencil</i>	<i>Components</i>
8-20 mils	chip components only
8 mils	leaded with >31 mil pitch
6 mils	leaded with 20–25 mil pitch
<6 mils	finer lead spacing

<i>Potential Cause</i>	<i>Corrective Action</i>
2. Stencil opening too small	Increase stencil opening

The width of a stencil opening is usually defined as the smallest dimension in the X-Y plane. If the width of the opening is too small when compared to the thickness of the stencil, it will be difficult for the solder paste to release from the stencil hole. Examine the smallest holes in the stencil after printing. If solder paste is hanging-up in these holes, but not in the larger ones, it is possible that the stencil is too thick or the openings are too narrow.

If it is absolutely necessary to use a thick stencil with narrow openings, then one can attempt to accelerate the release of the solder paste from the stencil by increasing the snap-off distance to 50 to 90 mils. With this method the solder paste has a better chance of pulling away from the stencil, but there will also be a greater chance of print misalignment.

<i>Potential Cause</i>	<i>Corrective Action</i>
3. Stencil defects	Check quality of stencil

In addition to design defects in stencils, various stencil manufacturing defects are also possible, such as incomplete etch, improper image placement, or rough surfaces inside the stencil holes. If too little solder paste is consistently observed on one part of the board, then examine the corresponding section of the stencil for possible defects.

<i>Potential Cause</i>	<i>Corrective Action</i>
4. Squeegee blade too soft	Soft squeegee blades pressure deform and scoop solder paste out of the large stencil holes, particularly when used with high squeegee pressure. Squeegee blades with a durometer hardness less than 80 are considered soft. Vendors usually manufacture blades in 5 to 10 durometer increments.
5. High squeegee travel speed	The squeegee travel speed may be too fast for the solder paste and stencil design used. If the squeegee speed is not slow enough the paste may not roll or flow evenly into the stencil openings. Normal squeegee travel speeds range from 0.5–2.0 in./second. The solder paste vendor should be consulted for the recommended range for a given formulation.
6. Snap-off distance too small	Some solder paste users attempt to print with thicker than recommended stencils having very narrow openings to compensate for common component problems, such as lead non-coplanarity. As a result, there is a greater tendency for the solder paste to adhere to the walls of the stencil hole. One way to compensate for this is to increase the starting distance between the stencil and circuit board and correspondingly increase the squeegee pressure to force the stencil to the circuit board and solder paste through the holes. The solder paste pulls more easily out of the stencil holes, because the stencil starts to lift from the board immediately after the squeegee passes. This technique is not normally recommended, because the incidence of print misalignment and smear is increased.

<i>Potential Cause</i>	<i>Corrective Action</i>
7. Improper squeegee pressure	If squeegee pressure is too light, solder paste may not be effectively forced to the bottom of the stencil hole and will not transfer to the pad. If the pressure is too strong it is possible that the squeegee blade will deform and scoop solder paste out of the larger stencil openings. To properly adjust the squeegee, first decrease pressure until a thin layer of solder paste is left on the stencil after making a pass. Pressure should then be increased slowly until all of the paste is cleaned off the stencil after each pass.
B. Material/Prior-Process Related	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Too little tackiness	The solder paste may not be tacky enough for the given print parameters. In order for solder paste to roll in front of the squeegee blade, instead of slide, it must have sufficient tackiness to adhere to the stencil material. A solder paste which does not roll has difficulty filling all of the holes. Solder paste tackiness is most easily controlled by the vendor when developing the formulation, but may also be enhanced by increasing the flux percent or by raising the solder paste temperature.
2. Too much tackiness	It is also possible for a solder paste to be too tacky for a given application. If the solder paste is so tacky that it hangs up in the stencil holes without fully transferring to the pads, then it is too tacky.
3. Large or irregular solder particles	Particles which are too large or irregular may have difficulty being forced into small stencil openings. If there is any doubt about the solder powder particle size or shape, it can be examined by spreading out a small quantity of solder paste under a 10X to 100X microscope.

B. Material/Prior-Process Related	
<i>Potential Cause</i>	<i>Corrective Action</i>
4. Viscosity too high	The solder paste viscosity may be too high for the print parameter being used. It is difficult to force very viscous solder paste into narrow stencil holes unless the other paste characteristics are properly balanced. In order to maintain consistency, it is best for the solder paste vendor to make any permanent viscosity changes; however, as a temporary step, it may be lowered by increasing the solder paste temperature, adding thinner to increase the flux percent, stirring vigorously or increasing the squeegee speed.
5. Viscosity too low	Low viscosity solder pastes can be scooped out of large stencil holes, leaving a thinner deposit than on other pads. This normally happens when low viscosity solder paste is used in combination with soft squeegee blades and high squeegee pressure. Although the solder paste vendor can increase the solder paste viscosity, the best way to handle this problem is by using a harder squeegee blade.
6. Low percent metal	The percentage of metal in the solder paste may be lower than required to give a proper sized solder joint. Even though the stencil opening may be properly designed for printing, solder pastes having too low a percentage of metal may not give a sufficiently large joint after reflow. Solder paste vendors report the amount of metal in solder paste as a weight percent. Because of the large difference between the solder and flux, approximately 7:1, a small change in metal weight percent has a larger effect on the metal volume percent. Consult the solder paste vendor if it appears that too little solder is in the joint area, even though the recommended amount of solder paste is being deposited.

<i>B. Material/Prior-Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
7. Bubbles in solder paste	Bubbles may surface in the solder paste as it rolls in front of the squeegee, either as the result of air entrapment or as an inherent characteristic of the flux thickening system. Bubbles can prevent the correct quantity of solder paste from being deposited in the stencil holes by displacing solder paste. The solder paste vendor should be consulted if bubbles continue to be observed after several squeegee passes.
8. Low solder paste temperature	Solder paste used at lower than normal operating temperatures will have a higher than published viscosity. The lower viscosity may cause the solder paste to slide on the stencil and not be pushed through the holes. Consult the solder paste vendor for alternatives if the solder paste or environment cannot be warmed up.
9. High solder paste temperature	As temperature increases, the viscosity of solder paste will decrease. Lower viscosity solder paste has a tendency to be scavenged from the pads by soft squeegee blades.
10. Not enough solder paste on stencil	If too little solder paste is used, it is difficult to get proper roll in front of the squeegee and some holes may be skipped. A round bead of solder paste, approximately 1/2 inch to 1 inch in diameter, is normally recommended.

5.1.2 Observed Condition: Excess Solder Paste Deposited Excess solder after reflow or solder shorts caused by excess solder paste deposits and wet bridging.

Although it is very difficult to create excessively heavy fillets by any means other than depositing too much solder paste, there are many reasons for the creation of solder shorts or bridges: improper reflow profile, excessive component placement pressure, component movement, improper solder paste, or incorrect solder paste application.

There are many signs of incorrectly applied solder paste, including: large deposits, wet bridges, smeared print, or misplaced print.

<i>A. Equipment/Process Related</i>	
<i>Potential Cause</i>	<i>Corrective Action</i>
1. Damaged stencil	One very frequent cause of wet bridging is damage to the stencil. In order for solder paste to print cleanly, intimate contact between the stencil and circuit board must be maintained as the squeegee passes the opening. Frequently, the fragile stencil area between adjacent holes can be bent slightly. The bent area allows solder paste to pass underneath the stencil and form a wet bridge. If one consistently observes poor quality print in one area of the board, then one should look for damage in the corresponding area of the stencil.
2. Stencil defects	If the stencil is not properly imaged or etched, inconsistency will exist from opening to opening. Improper imaging or etching can cause some holes to be larger than others and stencil areas between holes may become very narrow. If this happens, one can expect a higher occurrence of wet bridges.
3. Inadequate stencil frame size	Because stencils are anchored within finite frames, the center of the stencil is capable of greater displacement from the frame plane than the stencil edges. When using small snap-off distances, the ability of the squeegee to press down on the stencil will not be affected. Inconsistent print thickness and wet bridging is possible when using large snap-off distances. If consistent wet bridges or smeared prints are found at the edges of the stencil near the frame, but not near the center, then consider decreasing the snap-off distance or using a larger frame size.