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IPC-7526

Stencil and Misprinted Board Cleaning Handbook

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A standard developed by IPC

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Stencil and Misprinted Board Cleaning Handbook

Developed by the Stencil Cleaning Task Group (5-31g) of the Cleaning and Coating Committee (5-30) of IPC

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

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Acknowledgment

Any document involving a complex technology draws material from a vast number of sources. While the principal members of the Stencil Cleaning Task Group (5-31g) of the Cleaning and Coating Committee (5-30) are shown below, it is not possible to include all of those who assisted in the evolution of this standard. To each of them, the members of the IPC extend their gratitude.

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1 INTRODUCTION

1.1 Scope This Handbook addresses the removal of solder paste and uncured/unreacted SMT adhesives from stencils, misprinted printed circuit boards (PCBs) and application tools connected to the soldering paste application processes.

1.2 Purpose The purpose of this handbook is to provide a basic understanding of stencil/misprint cleaning processes. The handbook serves as a guide to users or prospective users of stencil/misprint cleaning technology.

1.3 Overview Cleaning of stencils and misprinted PCBs has taken an increasingly important role in surface mount technology. Fine and ultra-fine pitch lands, together with other advanced packages, place new demands on stencil cleaning. Paste volume is a critical issue for fine, ultra-fine, chip-scale, BGA and flip-chip components. Insufficient solder due to clogging of stencil apertures is a primary cause of defects. This results in poor paste printing and therefore; clean stencils are important in delivering the proper amount of paste. Process engineers estimate that approximately 70% of surface mount technology defects are due to solder paste printing problems.

Cleaning agents must be effective, safe for workers, and safe for the environment. Isopropyl alcohol (IPA), commonly used for cleaning, poses both environmental (VOC) and safety (i.e., fire hazard) concerns. Today, a much wider array of cleaning agents exists for stencil cleaning.

The residue encountered on stencils is generally nonreflowed solder paste. After hours of use, the solder paste may partially dry. This increases the difficulty of cleaning. In addition, there is also a need to remove uncured SMT adhesives used for bottom side mounting of surface mount devices. These issues afford the same cleaning problems for misprinted PCBs.

Section 2 provides a partial listing of documents and references that may need to be considered in the stencil cleaning process.

Appendix A provides definitions for terms used in this handbook.

1.4 Problem Statement Proper stencil cleaning should remove all solder particles and flux vehicle (organics) from stencil apertures without damaging the stencil, bonding adhesives, and elastomer frame. Solder paste residue on a stencil can result in transferring paste from the bottom of the stencil onto the next board printed. The residue can also interfere with good ‘‘gasketing’’ of the stencil to the board being printed. Any of these conditions can cause misprints, solder paste where it should not be, or missing solder paste from where it should be, resulting in shorts, solderballs, or lack of sufficient solder paste when the PCA is reflowed.

1.5 Common Production Problems Printing or dispensing of solder paste is a crucial step in production of SMT PCAs. The stencils used must be clean and free of solder paste residue to avoid misprinting/misapplying solder paste deposits to PCAs. Additionally, the wetness and thixotropic property of the paste being applied, flatness of the PCA, the positioning of the stencil with respect to the PCA lands, the squeegee pressure, stencil aperture opening in relation to the PCA land dimensions, type of stencil technology, etc. can all result in solder paste being left on the stencil.

For the reasons stated above, the bottom of the stencil requires inspection, monitoring and wiping throughout the process. Printers provide various methods to wipe the stencil bottom. For printers that do not provide understencil wiping, manual methods must be employed.

Failure to implement a process that removes residue from stencil apertures contributes to board processing problems. Factors outside the cleaning process may also contribute to process issues. Figures 1-1 through 1-10 identify issues that contribute to stencil printing problems.

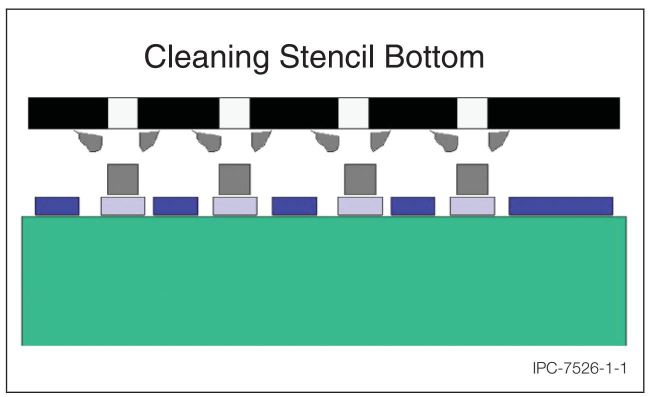

Figure 1-1 Cleaning Stencil Bottom

(Figure 1-1) Failure to underwipe or clean the bottom side of the stencil contributes to inconsistencies in solder paste deposition.

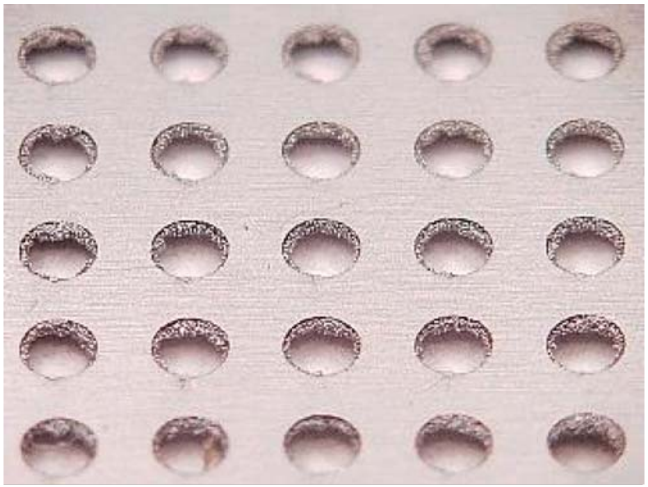

Figure 1-2 Solder Paste Buildup on Walls of Stencil Apertures

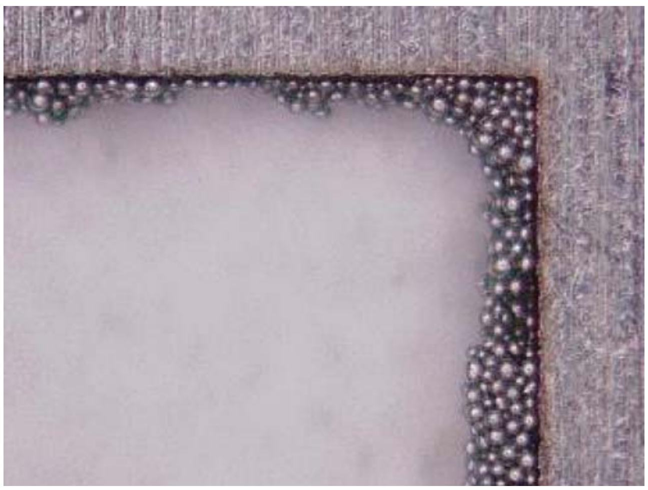

Figure 1-3 Solder Paste Buildup on Walls of Stencil Apertures

(Figures 1-2, 3) Solder balls attach to the walls of the stencil aperture over time. Failure to clean this buildup from the stencil affects the amount of deposited solder paste and could potentially cause open solder joints, bridging, and solder ball formation on the subsequent PCA.

Figure 1-4 Open or Insufficient Solder Joints

(Figure 1-4) When solder paste and/or the flux vehicle is not completely removed from stencil apertures in the cleaning operation the dried residue partially or completely blocks the correct volume of solder paste, resulting in insufficient or open solder connections.

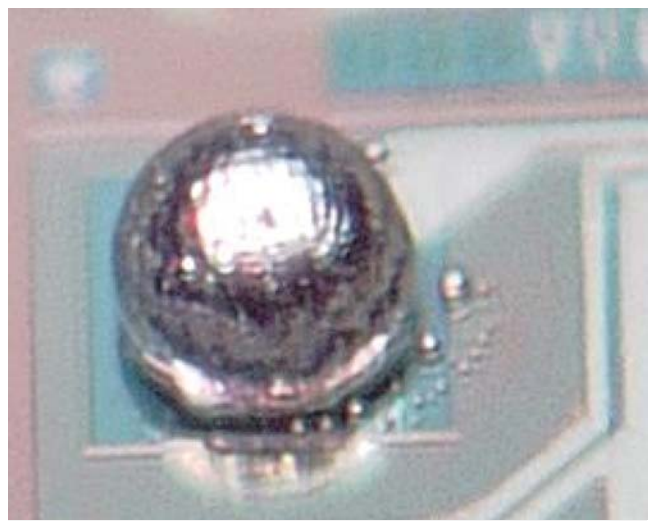

Figure 1-5 Solder Balls Following Solder Reflow

(Figure 1-5) Water or solvent remaining on circuit boards or stencils following cleaning may be mixed with the solder paste resulting in satellite solder ball formation in the solder reflow process. Improper cleaning of solder paste from miprinted boards can leave large quantities of solder balls from the solder paste on and around the lands and in the vias.

Figure 1-6 Bridging or Poorly Defined Solder Paste Printing

(Figure 1-6) Damage to the stencil patterns during removal of excessive solder paste or in a cleaning process will result in poorly defined joints or bridged parts. Improper rinsing of stencils can leave surface contaminants or residual cleaning fluid on the surface of the stencil. These contaminants promote flux bridging under the stencil during the printing process. The release of the board from the stencil creates a vacuum as the stencil separates from the board, sucking the solder paste beneath the stencil, leaving poorly defined prints or bridges.

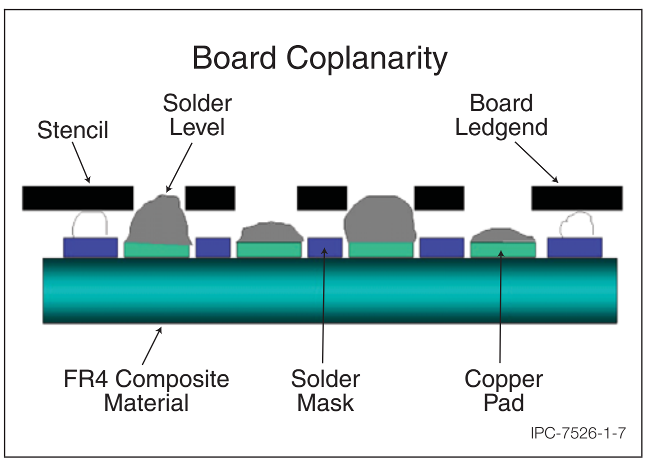

Figure 1-7 Failure to Place the Stencil on a Level Plane

(Figure 1-7) The stencil must sit on a level plane that is flat with well-identified points and lines. The stencil should contact the board at the solder mask height. Variations in hot air solder leveling (HSAL) or excessive legend ink thickness can lead to poor gasketing, which will allow solder paste to flow beyond the aperture opening on the bottom of the stencil resulting in poor print definition.

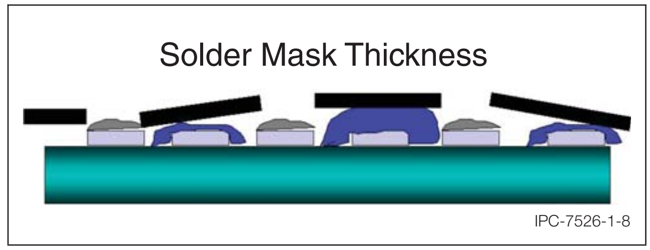

Figure 1-8 Variations in Solder Mask Thickness

(Figure 1-8) Variations in solder mask thickness contribute to inconsistencies in solder paste deposition. This condition is similar to the board coplanarity problem and will lead to poor definition and increase the need for stencil wiping.

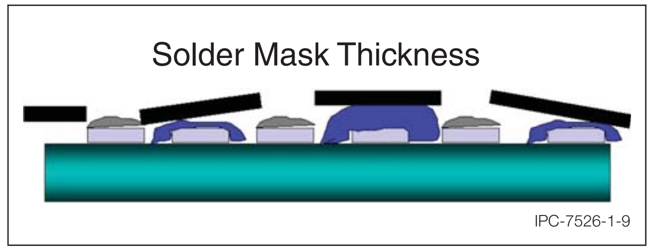

Figure 1-9 Inconsistent Component Land Width

(Figure 1-9) Component land width must be consistent. Variations contribute to inconsistencies in solder paste deposition. If the land is smaller than the aperture, paste will flow beyond the land and if soldermask is not present, the possibility of bridging between the lands will increase.

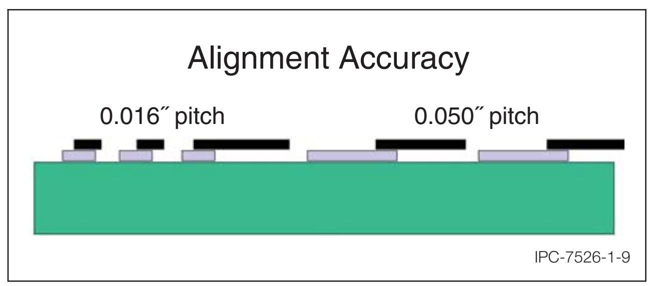

Figure 1-10 Misaligned Stencil

(Figure 1-10) Poor alignment contributes to inconsistencies in solder paste deposition and increases contamination of the stencil bottom. This leads to poor definition on subsequent prints and increased frequency of the stencil bottom cleaning to maintain acceptable print quality.

2 BIBLIOGRAPHY OF DOCUMENTS, SPECIFICATIONS AND REFERENCES

The following documents are provided as possible sources of additional information.

2.1 IPC[1]

IPC-SC-60 Post Solder Solvent Cleaning Handbook

IPC-SA-61 Post Solder Semiaqueous Cleaning Handbook

IPC-AC-62 Post Solder Aqueous Cleaning Handbook

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

IPC-CA-82 General Requirements for Thermally Conductive Adhesives

IPC-A-610 Acceptability of Electronic Assemblies

IPC-3406 Guidelines for Electrically Conductive Surface Mount Adhesives

IPC-3408 General Requirements for Anisotropically Conductive Adhesive Films

IPC-7525 Stencil Design Guidelines

2.2 Joint Industry Standards[2]

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

J-STD-005 Requirements for Soldering Pastes

2.3 American Standards for Testing Materials[3]

2.4 Federal Laws and Standards[4]

CAA Clean Air Act

CWA Clean Water Act

CERCLA Comprehensive Environmental Response, Compensation and Liability Act

RCRA Resource Conservation and Recovery Act

SARA Superfund Amendment and Reauthorization Act

2.5 Department of Defense[5]

MIL-C-85447 Cleaning Compounds, Electrical & Electronic Components

2.6 Occupational Safety and Health Administration[6]

OSHA 29 CFR 1910.106 Flammable and Combustible Liquids

OSHA 29 CFR 1910.134 Respiratory Protection

OSHA 29 CFR 1910.1000 Air Contaminants

2.7 Environmental Protection Agency (EPA)[7]

EPA 40 CRF 63 National Emission Standards for Hazardous Air Pollutants for Source Categories

EPA 40 CFR 82 Protection of Stratospheric Ozone

EPA-453/R-94-081 Guidance Document for the Halogenated Solvent Cleaner NESHAP

EPA 40 CFR 117. Determination of Reportable Quantities for Hazardous Substances

EPA 40 CFR 131.36 Toxic Criteria for those States not Complying with Clean Water Act Section 303(c)(2)(B)

EPA 40 CFR 261 Identification and Listing of Hazardous Waste

EPA 40 CFR 302.4 Designation of Hazardous Substances

EPA 40 CFR 355.30 (b) Emergency Release Notification

EPA 40 CFR 370 Hazardous Chemical Reporting: Community Right To Know

EPA 40 CFR 372 Toxic Chemical Release Reporting: Community Right-to-Know

2.8 Department of Transportation[8]

DOT 33 CFR 153.203 Procedure for the Notice of Discharge

2.9 National Fire Protection Association (NFPA)[9]

NFPA 35 Definitions of Flammable & Combustible Substances

2.9.1 Air Quality Management Standards (AQMD)

3 STENCIL CLEANING PROCESS

3.1 Objectives for the Cleaning Process Stencil cleanliness is an essential issue for delivering the proper amount

1. www.ipc.org
2. www.ipc.org
3. www.astm.org
4. ecfr.gpoaccess.gov
5. www.answers.com/topic/united-states-department-of-defense
6. www.osha.gov/
7. www.osha.gov/
8. www.dot.gov/
9. www.nfpa.org/

of solder paste to the PCA lands. Stencil cleaning must remove all solder particles and flux vehicle from stencil apertures without damaging the stencil, bonding adhesive, or elastomer frame.

The degree of required cleanliness varies with complexity of the board design. Stencils are usually cleaned to a visually clean condition. However, cleaning misprinted circuit assemblies requires the removal of uncured solder paste and ionic contaminants that could interfere with wetting and bonding. For assemblies, a visually clean appearance provides a satisfactory cosmetic condition, but this condition does not necessarily assure product performance. Semiquantitative and qualitative ionic contamination testing provides cleaning verification that may be important for long term field reliability. While cleaning to defined requirements is the primary objective, other objectives must also be set and achieved. The cleaning process must not damage the parts being cleaned and cleaning must be accomplished in a practical and cost effective way. The process employed must be safe to operators and environmentally compatible.

State of the art stencil cleaning processes integrate mechanical and chemical cleaning forces. Cleaning chemistry suppliers often work closely with cleaning equipment manufacturers to provide an integrated process. Stencil cleaning faces the challenge of removing solder paste and SMT adhesive from tiny apertures while not damaging the thin stencil foil. To achieve reproducibility in cleaning, the process requires a mild chemistry integrated with stencil cleaning equipment that provides mechanical scrubbing action and exceptional residue removal. Further, there must be a way to clarify the cleaning chemicals by extracting and isolating the adhesive or solder solids and flux materials.

In summary, the stencil cleaning objectives are the removal of contaminants in the form of nonreflowed solder paste, flux residues, uncured adhesives, and other process residues. Process engineers are seeking robust processes that provide practical, cost effective, safe, and environmentally friendly methods.

3.2 Substrate IPC-7525 *Stencil Design Guidelines* documents the design and fabrication of stencils for printing solder paste and surface-mount adhesive. The fabrication of stencils combines various metal alloys (stainless steel, copper, aluminum, nickel) as well as plastics in their construction. Frames are typically aluminum with the mesh border permanently mounted using an adhesive. The mesh material holding the stencil to the frame is typically polyester fiber. Frames may be tubular or cast aluminum with the border permanently mounted using adhesive.

Cleaning chemistry and temperature, used in the process, may affect stencil compatibility. Cleaning chemistry designs must consider stencil construction materials and address compatibility constraints. Alkaline cleaning agents may chemically react with metals such as aluminum, causing the surface to tarnish or darken over time. Elevated cleaning temperatures, in excess of 110°F, may result in the interaction of the cleaning chemistry with the adhesive bond to the frame, causing the stencil to loosen or break from the frame. Compatibility concerns must be considered when selecting a cleaning chemistry.

3.3 Tools Squeegees, spatulas and solder paste pots are some of the many tools that require cleaning. Similar to compatibility issues discussed for stencils, the cleaning chemistry must be compatible with tools being cleaned.

3.4 Pallets Some assemblers also use their stencil cleaning process for removing flux residue build up on pallets. Pallets passed over a solder wave see many process cycles before cleaning. This requirement calls for a cleaning chemistry that exhibits enhanced effectiveness for removing baked-on flux residues.

4 MISPRINTED CIRCUIT BOARD CLEANING

To reduce problems such as those shown in Figures 1-1 through 1-10, misprinted solder paste or adhesive and related contaminans must be totally removed from the board surface.

4.1 Solder Paste PCBs that are misprinted and rejected by vision inspection systems require cleaning of nonreflowed solder paste or adhesive. Hand wiping is not effective due to solder ball smearing over the surface of the circuit assembly. Tiny solder balls may end up in vias or other small spaces and lead to shorts.

Solder paste and particulate removal is often more difficult than dissolving uncured flux residue. The most reliable removal method for removing solder paste is a process that integrates mechanical and chemical driving forces. Solder balls are held in place by the flux composition. Developing an integrated cleaning process, releases the solder balls and allows removal during the wash and rinse cycles.

Solder balls are collected in the cleaning chamber over time. Most cleaning machines use filtration methods to prevent solder balls from being picked up by the pump and resprayed onto the board. Typically, the equipment-operating manuals provide maintenance procedures to remove uncured paste from the wash holding tank and filters.

Double-sided surface mount assemblies are printed, populated and reflowed on one side; then flipped, printed, populated and reflowed on the other-side. From a cleaning perspective, the scenario that is commonly overlooked is reflowed flux residue on the second-side of the misprinted board. In such a scenario, the cleaning process must be capabile of removing both cured and uncured flux residues.

This issue changes the scope of the cleaning process and cleaning chemistry selection. In manufacturing operations that have this requirement, it may be necessary to develop a new cleaning process that optimizes the static and dynamic cleaning forces.

4.2 Adhesives Cleaning uncured SMT adhesive from stencils and boards can also be accomplished in an automated cleaning process. Many aqueous cleaning chemistries are not designed for removing SMT adhesives. When removal of SMT adhesives is required, selection of a cleaning chemistry will be necessary to meet this challenge.

4.3 PCB Cleaning Process Considerations Misprint Board cleaning requires a number of process considerations. The following list comprises factors for consideration when engineering the process for cleaning misprinted boards.

- When using a spray-in air cleaning system, both sides of the board need to be cleaned simultaneously.
- Spray-in-air systems should be equipped with a filter in the recirculation wash to remove dislodged particles from the cleaning fluid.
- A clean water rinse prevents wash contamination from redepositing on the surface of the board.
- Rinse pressure and duration are important process considerations when removing the cleaning chemistry from under components.
- The drying cycle when cleaning a misprint from the second side of a double-sided populated assembly may need to be lengthened.
- Positioning of the PCB is important when cleaning a misprint board with high impingement air spray. An adjustable board holder that secures the board in place and maintains the correct impingement angle for particle removal facilitates this process.
- Cleaning systems that use ultrasonic technology should have the PCBs oriented with unreflowed solder paste side down to allow gravity to carry the solder paste away.
- A separate ultrasonic DI water rinse may be necessary when cleaning boards.
- Studies by the Electronics Manufacturing Productivity Facility (www.empf.org) suggest an ultrasonic frequency of 40 kHz or higher is effective and should alternate or "sweep" ± 3 kHz.
  - Sweep technology eliminates hot spots or focused ultrasonic energy in the wash bath.
  - The lower the ultrasonic frequency, the more aggressive the scrubbing action (cavitation).
  - The power density is the amount of electrical energy delivered to the bath via the ultrasonic generators. This energy is measured in watts per liter of wash solution. For example, if the wash bath contained 100 liters and the generator is rated at 1000 watts, the power density would be 10 watts/liter. The same studies indicate that the power density should be around 10 watts per liter or less.
- Table 4-1 lists process recommendations when cleaning different types of contaminants from misprinted boards.

Table 4-1 Process Recommendations for Misprinted PCBs with Different Types of Contaminants

Contaminant Source	Nature of Contaminants	Cleaning Process Steps
Adhesive Dispense	Misprinted, Uncured Adhesive	Do not scrape the adhesive - Remove all components carefully if populated and not reflowed Make sure no adhesive residues are present on lands or in the via holes Send the board through the cleaning system with appropriate cleaning chemistry
Adhesive Curing	Populated with components and cured	The board is not cleanable
Paste Printing	Wet or dry misprinted solder paste - no components placed Wet or dry misprinted solder paste - components placed Wet or dry solder paste + uncured adhesive with populated or unpopulated boards	Do not scrape wet solder paste or placed components from the boards. If parts have been placed, pick off carefully. Brush with appropriate cleaning chemistry to dissolve the adhesive and/or solder paste and send the board through the cleaning system Clean and Inspect per IPC J-STD-001
Printing, Placement and Reflow Soldering	Excessive SMT no clean solder paste flux residue >20 solder balls per panel or all over the laminate (>5 mils diameter or 5 solder balls/square inch) <20 Solder balls at a fine pitch SMT component Micro solder balls (<6 solder balls to a side of a land) or >20 solder balls in via holes	Clean in the Aqueous/Semiaqueous Wash System with appropriate Wash Chemistry.

5 CONTAMINANT TYPES AND REMOVAL CHARACTERISTICS

5.1 Polar Residues Materials that form ions when dissolved in water are termed ionizable or polar. For example, when a typical polar residue, ''salt'' (sodium chloride) in a fingerprint deposit, dissolves in water, the sodium chloride molecule dissociates in water into positive sodium ions and negative chloride ions: ($NaCl^{-} = Na^{+} + Cl^{-}$). In its ionized form, sodium chloride will increase the electrical conductivity of water. The more ions formed the higher the electrical conductivity of the water. Ionic residues cause signal changes in electrical circuitry and may initiate electromigration and corrosion. Highly ionic contamination over the board surface may reduce coating adhesion.

As polar residues are soluble in water, they can be removed by a plain water wash. However, polar residues are often embedded in water-insoluble deposits. A good example is a fingerprint residue, where salt and perhaps some water-soluble amino acids are covered by skin oil. As water cannot wet the composite residue and solubilize the oil film, additives must be used to remove the oil film and allow dissolution of the embedded polar materials.

Typical Polar Residues:

- Plating and etching materials
- Chemicals from the substrate or component fabrication process
- Water soluble soldermask constituents
- Deposits from manual handling
- Water soluble solder flux constituents
- Activators from rosin or SA type solder flux

5.2 Nonpolar Water Soluble Residues Organic materials that are water soluble but do not ionize in water are capable of interfering with wetting and bonding of conformal coatings when cleaning misprinted circuit boards. If the nonpolar materials are hygroscopic, formation of surface water films can be expected with a resulting decrease in surface resistivity and, under favorable conditions, electromigration may occur.

Polyglycols are water-soluble but nonionizable. They are widely used in water-soluble flux formulations and in wave oils. The degree of solubility of polyglycols varies with compound type used.

5.3 Nonpolar Water Insoluble Residues Rosin, no-clean resins, and SMT adhesives are common examples of water insoluble residues. The presence of these residues can interfere with wetting, bonding and coating operations, as both wetting of surfaces and bond development will be adversely affected when cleaning misprinted circuit boards.

Typical Nonionic Water Insoluble Residues

- Rosin
- Synthetic resin
- Organic compounds from low residue/no-clean flux formulations
- Plasticizers from core flux
- Greases and oils
- Finger print oils
- Release agents on components
- Insoluble inorganic compounds (oxidation products)
- Rheological additives to solder pastes
- Improperly cleaned flux residue

5.4 Nonreflowed Solder Paste Fluxes used for solder paste comprise resins, activators, solvents, and rheological additives. For special systems, additives such as tackifiers, surfactants, and corrosion inhibitors may also be used. Resins are organic materials compounded with medium and high molecular weight rosin, synthetic materials, and polymers. Activators, being acidic, boost fluxing activity and are easily removed by the cleaning agent. Oxygenated solvents are used to give the solder paste a maneuverable homogeneous fluid form. Rheological additives increase wetting, spreading and tack life of the solder paste. Fluxes are categorized as water-soluble, rosin, no-clean and synthetic. The cleaning chemistry must dissolve the flux composition to allow the solder balls to break up and remove from the stencil aperture.

5.5 Reflowed Flux Residue Reflowed flux residues are more difficult to clean than nonreflowed solder paste. Water-soluble flux residue is the easiest residue to clean and is easily removed with most cleaning chemistries used in the stencil cleaning process. Rosin and no-clean reflowed flux residues require engineered cleaning chemistries specifically designed to remove baked-on flux residue. SMT assemblers who have this requirement must select a cleaning chemistry with this application in mind.

5.6 Uncured (Wet) SMT Adhesive SMT adhesives are engineered with polymers, a thermosetting component to adhere surface mount components onto SMT boards. SMT adhesives cure during the reflow process. Stencil printed SMT adhesives must be cleaned from the stencil before the adhesive cures. This requires a cleaning process that dissolves or displaces the adhesive. Since SMT adhesives are insoluble in water; cleaning agents must be engineered with ingredients that couple the adhesive with the water-based cleaning bath. When diluting the cleaning chemistry, the solvent phase will dissolve or disperse SMT adhesive and remove the uncured adhesive from the stencil aperture. The adhesive will separate from the aqueous cleaning solution and float to the surface. Filtration systems are needed to remove the adhesive from the wash bath.

5.7 Insoluble Residues Removal of residues that are insoluble in water and organic solvents, and cannot be solubilized by reactive and nonreactive additives, requires strong mechanical action. Dynamic forces require direct spray impingement, brushing or ultrasonic cavitation effects. Insoluble residue disperses within the wash media. As one portion of the dispersion dissolves, the insoluble portion ‘‘floats’’ on the wash surface and is carried away by the wash action. Ultrasonic agitation is the most effective method to remove this residue type.

Typical insoluble residues are:

- Siliceous material from dust and dirt
- Hydrolyzed or oxidized rosin
- Aged (oxidized) chemical process compounds from board/component fabrication
- Silicone greases/oils
- Glass fiber from the laminate
- Silica and clay type fillers of solder masks (permanent and water soluble masks)

6 STENCIL CLEANING PROCESSES

6.1 Under Stencil Wiping Process Reliable, high-yield paste depositions for fine and ultra-fine pitch devices demand stringent automated control over all sub-processes involving material and equipment. Fine pitch stencils require in-process cleaning to ensure accurate solder paste deposition in height and volume. Under stencil-wipe automated systems provide hands-off programmable cleaning of the stencil’s bottom side, using a cleaning solvent and lint-free paper, to remove paste bleed-out. A vacuum system removes unreleased solder paste from the apertures. The process reduces maintenance by filtering particulate within the paper, while a porous solvent bar wets the paper through osmosis, aiding in loosening tacky flux and reducing residual cleaning solvent. A programmable vacuum system removes solder paste from stencil apertures, eliminating opens on final assembly.

There are several contributing factors in determining when underside stencil cleaning is required and how often. The frequency of the wipe is generally determined by a combination of variables; stencil type, solder paste, PCA/substrate co-planarity, printer set up, and pitch of finest device.

In the event that the screen printer is not equipped with an automated understencil cleaning system, two options are available. First, the stencil printer manufacturer may be able to retrofit existing equipment with an automated understencil cleaning system. Secondly, manufacturing sites can also use a hand wipe process. In general, a pre-saturated, lint free wipe material is used to manually wipe the stencil surfaces. This method is operator dependent, and vacuum removal of particulate from apertures is not possible.

6.2 Manual Stencil Cleaning Manual cleaning of stencils is widely used by process technicians. However, the inherent limitations and hazards associated with manual cleaning usually far outweigh the benefits. Stencil cleaning has been identified as the most hazardous process with the highest potential environmental impact of any process associated with SMT assembly. Heavy metal exposure, noxious, flammable or caustic chemistries and vapors all pose hazards to the operator. Cleaning utensils, uneven manual pressure and general handling contribute to stencil damage. Manual cleaning baths, chemical wipes and human error often lead to poor waste management, whereas a stencil cleaning process will normally safeguard against many or all of these hazards, and provide more consistent and predictable cleaning results.

Manual stencil cleaning is usually accomplished at the expense of stencil aperture cleanliness. When solder paste is wiped from the metal etched foil, it is likely to deposit fugitive solder balls back into the apertures. Effective aperture cleaning using manual techniques is not effective and can lead to additional stencil damage. Compressed air used to ‘‘blow-out’’ the apertures will bend the delicate land mass areas between fine-pitch apertures much the same way as high-pressure water sprays can cause bending. The compressed air can also broadcast the solder paste onto other surfaces or personnel. Solder paste that dries in the apertures will be hard as cement and very difficult to remove. Dry solder paste is a leading cause of aperture blockage and insufficient solder paste deposition leading to production downtime and trouble shooting.

Manual stencil precleaning may be necessary for certain stencil cleaning machines. This step can be performed while the stencil is still on the printer, or immediately before placing the stencil in an automated cleaning machine. Usually, just removing the excess solder paste by use of a blade or spatula is adequate. Caution should be taken not to preclean using a solvent or other chemistry different than that used in the stencil cleaning machine as these chemistries could have adverse reactions. Precleaning chemistries or wipes containing different chemistries may change the chemical composition of the solder paste. This condition may render a more difficult to clean residue or produce unwanted and difficult-to-remove white residues.

If a wiping material is to be used, select a stencil wiping material, which does not leave lint, fibers, or adhesive on the stencil. These contaminants can degrade subsequent print runs. If the application requires a precleaning chemistry, select a solvent that dries relatively slow, nonflammable, low in toxicity to skin contact, dries free of residue, low odor, and exhibits good ability to dissolve the solder paste or SMD adhesive.

6.3 Semimanual Stencil Cleaning A number of designs are available for semiautomatic wiping. Common designs used within industry employ ultrasonic agitation.

Design #1: A large sponge is placed into a prefabed stainless steel tray. Solvent cleaners are added to the tray. The sponge absorbs the solder paste or adhesive dislodged from the stencil during the cleaning process. The cleaning solvent will saturate the sponge such that solvent leaks from the sponge upon touch. The stencil is placed on top of the sponge. Solvent is applied to the top of the stencil. The stencil must remain wet during the cleaning process. An ultrasonic handheld cleaning head is applied to the stencil in a motion similar to ‘‘ironing clothes.’’ Minimal pressure is applied to the cleaning head during the cleaning process.

After cleaning, the stencil is removed from the tray and wiped on the top and bottom of the stencil with a clean, wet SMT wipe to remove any remaining solder balls or adhesive. After wiping, the stencil is examined using a magnifying glass to inspect for solder paste in the apertures, especially fine pitch. A note of caution, ‘‘fugitive’’ solder balls may be pushed back into stencil apertures.

Design #2: Semiautomatic ultrasonic stencil cleaners require the operator to move the stencil or substrate from the wash tank, to the rinse tank while drying the stencil manually. The actual cleaning is accomplished automatically by the chemistry and ultrasonic cavitation.

Handheld sprays or spray nozzles that are usually operated by a foot switch may accomplish rinsing. Drying is accomplished by hand-held low-pressure dry compressed air or by natural ambient drying.

Consistent cleaning is accomplished by programmed wash cycles and is less dependent on the operator interface. Caution should be taken not to allow a stencil to ‘‘soak’’ for long periods because of the potential for moisture absorption to the stencil adhesive, which could weaken the bond interface to the frame.

6.4 Single Chamber Equipment Most stencil cleaners operate with a single chamber utilized for both washing and rinsing operations. Although segregated wash and rinse tanks are utilized, single chambers have a tendency to create extensive chemical drag-out (wash solution entering the rinse tank). This is an issue when the process chamber is large and when common plumbing between the wash and rinse is utilized. When a single process chamber is used, the customer should expect increased drag-out due to the surface area of the chamber. This increased drag out makes close looping the stencil cleaner economically difficult.

6.5 Ultrasonic Agitation Ultrasonic Agitation is created by the generation of high frequency sound waves (above 20 kHz) vibrating through a liquid cleaning medium. This action, known as cavitation, consists of the formation and instantaneous collapse of millions of microscopic vapor pockets, or bubbles in the liquid. These vapor pockets occur throughout the liquid even in recesses and tight tolerance areas such as fine-pitch apertures and substrate vias. 40 kHz is most commonly used for stencil cleaning. Lower frequencies create higher mechanical agitation, which could potentially damage the stencil or misprinted PCA. While higher frequencies could technically clean solder paste from stencils, the cycle time would normally need to increase to compensate for the more gentle agitation. The use of higher frequencies is generally more costly and, because the adhesives used to construct stencils are hygroscopic, longer exposure to moisture could weaken the adhesive bond. ‘‘Sweep’’ or ‘‘Multiple’’ frequency technology is standard throughout the industry and is used to distribute the ultrasonic energy evenly to eliminate ‘‘hot spots’’ in the cleaning bath.

An ultrasonic cleaning system consists of four fundamental components: Generator, Transducer, Cleaning Chemistry and Tank. Performance and reliability of the system depends upon the design and construction of the transducers and generators. The number of transducers and generator size is predicated on the tank size, and efficiency of the cleaning chemistry used. Process effectiveness of the cleaning is dependent on the cleaning chemistry. The use of ultrasonics without the proper cleaning chemistry is equivalent to cleaning rosin flux with water only. The tank should be stainless steel and not plastic. Plastic will absorb the sound waves and reduce efficiency. The size of the tank is dictated by the size of the stencil, loading and unloading ergonomics and determines a large portion of the waste-water generated - the remainder being determined by the rinse cycle.

Cavitation is produced by the alternating patterns of compression and rarefaction generated by the rapidly expanding and contracting transducers during sound wave transmission. As the liquid is stretched beyond its tensile strength during rareification, these bubbles grow from microscopic nuclei and then upon compression, they implode violently. This phenomenon occurs at the rate proportional to the ultrasonic frequency generated. Individually, these minute vapor pockets release only an extremely small amount of energy. However, their cumulative effect can be intense resulting is a very effective mechanical scrubbing action which literally ‘‘pulls’’ the contaminant away from the substrate after the chemistry loosens it.

6.6 Automated Ultrasonic Stencil Cleaning Automatic stencil cleaners either transport the stencil or misprinted substrate automatically from wash tank to rinse tank, or transport the wash and rinse solutions into and out of a single process tank. Usually PLC controlled; the operator need only load the substrate into the carrier mechanism and press a start button. Ultrasonic wash, rinse, and drying can be included in the automated program. While not necessarily more effective, an automated system can be more consistent than a semiautomatic system because of reduced user interface.

Automation itself may be more effective due to the consistent nature of automation. Semiautomated stencil cleaners rely on an operator's selective judgments to determine the degree of rinsing required to effectively displace the wash solution and remove residual solderpaste or adhesive residues from the stencil. Additionally, the operator must determine how long to subject the stencil to a drying process. Automation allows all stencils to be subjected to specified cycle parameters, therefore providing results that are more consistent.

The wash tank features multiple side-mounted ultrasonic transducers for thorough paste/adhesive removal. Depending on the chemistry used, automatic wash-solution filtration may be required and can be achieved via a built-in filtration pump. Particle waste is captured in a solder paste tray for fast and easy removal. Some ultrasonic stencil cleaners use just a solder paste trap while others utilize only a pump-driven filtration system.

Rinse tank predrained filtration systems are needed to automatically filter rinse water prior to treatment and discharge. A summary of rinse water treatment: (1) filtered for reuse, (2) potentially drain disposed, (3) evaporated to atmosphere in standard wastewater evaporation equipment.

Certain cleaning agent characteristics can simplify the cleaning operation. A ''no rinse'' chemistry eliminates the need for a rinse cycle/chamber. Some cleaning chemistries displace the residue with the soil while not dissolving in the wash bath. Light residues that float can be removed from the ultrasonic chamber surface via an overflowing cascade stream. Heavy residues that sink can be collected via a trough shaped floor and entrained into a drainage stream. These streams are continuously cleared of the residue content by filtration or routine maintenance and the residue free cleaning media is returned to the cleaning chamber. A no-rinse process should be qualified to assure that chemical agents remaining on the stencil cause no effect on future printing or on stencil life (delamination of the elastomer frame) before use in production.

6.7 Rotating Wand/Fixed Nozzle Spray-In-Air Cleaning These systems consist of a rotating spray wand, which creates zones of constantly changing force for improved cleaning performance. The systems are fully automatic and do not require transferring the stencil between wash, rinse, and dry. The systems are PLC control with a wide range of options.

The systems are designed to use a wide range of engineered cleaning fluids. Aqueous, semiaqueous and solvent technologies can be selected to remove nonreflowed solder paste, uncured adhesive, and reflowed flux residues from stencils and pallets. Solvent systems require flame suppression systems (or intrinsically safe design). Managing rinse water and soil load are critical process items that need to be configured to meet the overall-cleaning requirement.

6.8 Automated Ultrasonic Sponge Stencil Cleaning The stencil is fixtured into a cleaning cabinet. A stainless steel tray that holds a sponge is placed over the stencil apertures. The sponge is wetted with IPA (isopropyl alcohol) or other compatible solvent. Ultrasonic transducers vibrate the uncured paste or adhesive into the sponge material. The waste from the process is accumulated into the sponge. The sponges are dual hazardous waste due to heavy metal and solvent content. Fugitive solder balls are commonly redeposited onto the stencil surface and require wiping. Wiping the stencil surface caused solder balls to be redeposited into the stencil apertures.

6.9 Multifunctional Batch System for Stencils, Boards, and Maintenance Cleaning Given the proper chemistry(s), many stencil cleaner styles provide multifunctionality for cleaning stencils, misprints and production circuit assemblies. In the age of no clean, many assemblers have eliminated the cleaning process. Multifunctional system designs provide a footprint for stencil cleaning, defluxing of populated circuit cards, and cleaning of maintenance items such as pallets. Many spray or ultrasonic systems have process variables that are PLC controlled with programmable process settings. These systems are usually designed for aqueous engineered cleaning fluids. Filtration and water management options need to be configured to meet the process requirement.

7 CLEANING CHEMISTRY OPTIONS

7.1 Cleaning Chemistry Selection Removal of solder paste deposits requires a cleaning chemistry that wets, dissolves, saponifies, or displaces the flux vehicle. Cleaning process development hinges on the cleaning chemistry. Wetting occurs by reducing surface and interfacial tension by using low surface tension materials that allow the cleaner to penetrate and undercut the soil-substrate bond. Dissolution of the flux vehicle allows the metallic spheres to separate and drop from the aperture. Saponification is the reaction of free alkalinity that reduces the flux resin while forming a water-soluble soap. Displacement occurs by bombarding the contaminant with mechanical force that facilitates the removal of soil from the tiny apertures. The cleaning equipment greatly facilitates the cleaning process and impacts reproducibility. Process variables influencing cleanliness include cleaning chemistry, concentration, bath temperature, cleaning time, and mechanical action imparted by the equipment used.

7.2 Chemistry Choices and the Cleaning Process Stencil cleaning products fall into three broad categories:

1. DI-water only, 2. Aqueous with additives, and 3. Organic solvents. No one product or classes of products are likely to satisfy all cleaning requirements. The cleaning agent must be matched to the soil, the substrate, the cleaning requirements, drying requirements, and other performance and environmental constraints. Inorganic soils are often referred to as hydrophilic; they dissolve effectively in water. Organic-based soils, often referred to as hydrophobic, tend to dissolve more effectively in organic solvents.

Table 7-1 is a guide for choosing the right cleaning chemistry for stencil and/or misprint cleaning applications.

7.3 Solvent Cleaning A hydrocarbon solvent represents an organic compound containing the elements carbon and hydrogen. These compounds are primarily from petroleum's, coal tar and plant sources. The principle types of organic solvents include alcohols, aliphatic petroleum's, aromatic hydrocarbons, oxygenated and halogenated solvents, esters and terpenes. A general rule of solvent cleaning is ''like dissolves like,'' which means that usually nonpolar contaminants are best removed by nonpolar solvents, while polar or ionic contaminants are best removed by polar solvents.

7.4 Aqueous Cleaning Aqueous cleaning refers to those processes in which a substrate is first washed with a water based cleaning agent, generally followed by a water rinse (DI or facility water). Water based cleaning agents can be defined as a combination of water and an additive, usually organic. These agents are generally combined with some form of mechanical agitation, such as spray in air, spray under immersion or ultrasonic that promotes the removal of the contamination such as solder paste and SMT adhesives.

When cleaning stencils and misprinted electronic assemblies, the objective is remove contaminates such as solder paste, flux residue (one side misprinted the other reflowed or wave soldered) from the surface of stencil or electronic assembly. Once the wash step is completed, the parts are rinsed with water, either DI or facility water, to remove the cleaning agent and contamination. The parts are then dried, through either heated air or ambient air in the case of stencils. The quality of the rinse water needed in a cleaning application depends on the substrate; for example, facilities water can be sufficient for stencils but is usually not sufficient for electronic assemblies.

Table 7-1 Cleaning Chemistry Selection Guide

Process	Nonreflowed Solder Paste/Flux	Uncured Adhesive
Manual Stencil Cleaning	Solvent Wipe	Solvent Wipe
	Aqueous Wipe	Aqueous/Solvent Wipe
Stencil Printer Understencil Wipe	Solvent Wipe	Solvent Wipe
	Aqueous Wipe	Aqueous/Solvent Wipe
Aqueous/DI-Water Rinse		
Spray Under Immersion	Aqueous	Aqueous/Solvent Mix Aqueous Surfactant
	Aqueous Surfactant	
	Aqueous/Solvent Mix	
Ultrasonic Agitation	Aqueous	Aqueous/Solvent Mix Aqueous Surfactant
	Aqueous Surfactant	
	Aqueous/Solvent Mix	
Spray in Air	Aqueous	Aqueous/Solvent Mix
	Aqueous Surfactant	
	Aqueous/Solvent Mix	
Aqueous/No Rinse		
Spray Under Immersion	Aqueous Surfactant	Aqueous/Solvent Mix
	Aqueous/Solvent Mix	
Ultrasonic Agitation	Aqueous Surfactant	Aqueous/Solvent Mix
	Aqueous/Solvent Mix	
Spray In Air	Aqueous Surfactant	Aqueous/Solvent Mix
	Aqueous/Solvent Emulsion	
Solvent Cleaning		
Spray Under Immersion	Solvent	Solvent
Ultrasonic	Solvent	Solvent
Spray in Air	Solvent	Solvent

There is a broad array of aqueous cleaning agents. Each uses inorganic and/or organic mixtures. Most are a combination of low vapor pressure solvents, surfactants or saponifiers, and if required, inhibitors. They are designed to remove polar and nonpolar contamination.

The physical properties do however vary in a number of ways, the most important being, pH and vapor pressure. Saponifier/surfactant mixtures usually have a pH around 11 to 13. Certain new formulations have a neutral pH. The advantage of a pH below 12.5 is user safety and material compatibility, especially in connection with the stencil. The advantage of higher pH is the improved effectiveness for removing flux residues. The other significant differences for readers to consider are the volatile organic content of cleaning agent. An inorganic containing cleaning agent has a low volatile organic content and may therefore qualify for Clean Air Solvent Certification from districts such as South Coast Air Quality Management District. However, some inorganic formulations may not be not sufficient for adhesive removal, and even in some cases solder paste and flux residue removal. Furthermore, some inorganic formulations may leave behind white inorganic residues after the cleaning stage, which may not be as easily removed as an organic based cleaning agent.

Another issue to consider is bath life. Saponifier formulations have a limited bath life since the components are used up in the cleaning process. Formulations that are more modern have a different contamination removal mechanism and allow the contamination to be largely filtered out.

7.5 Semiaqueous This group of cleaners includes blends or hybrids with water and organic solvents. Aliphatic, oxygenated, ester or terpene solvents are blended with surfactants, builders, stabilizers and inhibitors. Sometimes they contain water and sometimes they are applied as received without water, but then are water rinsed. These emulsion cleaners are used in manual, immersion or coarse spray applications to saponify, solubilize, emulsify or disperse soils including grease, oils, wax, adhesives, flux and misprint solder pastes where water can be tolerated.

Semiaqueous cleaning refers to a process whereby the substrate is washed in a solvent followed by a rinse with water. The solvents used in these cleaning agents possess a variety of characteristics. Many semiaqueous cleaning agents are formulated to clean a wide range of soils, including solder pastes and SMD adhesives. They are either soluble in water or insoluble in water, and all commercially available semiaqueous cleaning agents are formulated so that they can be rinsed with water. The cleaning media, along with agitation, will remove the soils from the stencil surface, and the rinse with water will remove any polar or ionic soils, as well as residual solvent and undissolved soils that remain on the surface. Waste management can be complicated because of the creation of both solvent and aqueous waste streams.

8 CLEANING PROCESS CONSIDERATIONS

Physics centered on Test identify the chemical aspects of cleaning; the purely physical mechanisms also play a role. Generally, the higher the thermal and mechanical energy applied, the better the cleaning will become. When cleaning stencils, thermal energy can affect the adhesive bond that holds the stencil to the frame.

8.1 Common Rules that Center on Aqueous Cleaning

8.1.1 Temperature Cleaning effectiveness and speed improve as temperature increases.

- Temperature generally above 110°F (to be consistent with clause 3.2) may delaminate adhesive holding stencil to frame.
- Temperature is typically proportional to cleaning time.
- Reflowed flux resin softens at 140 - 176°F, but can be cleaned with cleaning agents at ambient up to 120°F.
- A rise in temperature typically reduces the cleaning time.

8.1.2 Energy Higher mechanical action (cavitation or impingement) improves cleaning.

- Represents one of the greatest variations amongst cleaning chemistries as some require heat and some do not. If the chemistry will clean without heat, additional heating options may not be required on the cleaning machine which may lower the equipment cost and save energy.
- High spray pressure, low ultrasonic frequencies and high ultrasonic power densities could cause stencil and/or misprinted PCA damage.
- There needs to be a balance to address compatibility constraints.

8.1.3 Solvency/Concentration Higher cleaning agent concentrations may improve cleaning. However, high concentrations may decrease ultrasonic cavitation and reduce the overall scrubbing action.

- Cleaning fluid should be selected first based on soil compatibility.
- Poor solvency for the soil cannot be overcome by using mechanical force.
- Machine should be integrated with the cleaning fluid.

8.1.4 Time Exposure time to the cleaning agent is critical.

- Most elastic of the four variables.
- Increase in temperature, energy, and solvency allows a decrease in time.

- Decrease in temperature, energy, and solvency creates a need for more time.
- Additional cleaning time may cause moisture absorption to the stencil adhesive, which could weaken the adhesive bond interface to the frame and metal etched foil.

8.1.5 Cleanliness Final rinse cleanliness is critical to part cleanliness.

8.1.5.1 Water Quality and the Cleaning Process Whenever water is used during the cleaning process, whether for diluting the chemistry or as rinsewater, DI-water should be considered to ensure optimal cleanliness.

8.1.5.2 Rinses in the Cleaning Process Although rinsing is not always needed, it can be an important step in the aqueous or semiaqueous cleaning process. Often deionized or softened water is used, especially in a final rinse stage to minimize spotting.

Rinsing can be accomplished in many ways. Water spray or mist can be incorporated directly over a wash tank. This minimizes product carryover and replaces volume lost due to evaporation, but may dilute the chemistry concentration in the tank.

Other types of rinses may include spray-in-air or agitation, dipping or overflow rinses accomplished in immersion tanks. Immersion rinses are more prone to contamination from carryover; therefore, it is not unusual for more than one rinse stage to be used. In precision cleaning applications, deionized or reverse osmosis (RO) water is used in the final rinse where water quality is rigidly maintained through continuous monitoring of conductivity and/or refractive index.

8.2 Drying Essentially, there are three common types, natural, mechanical and evaporative, but many machines use a combination of them. A third, but less frequently used, drying method is with use of organic solvents via displacement or adsorption modes.

When off the printer, stencils are normally cleaned for inventory and can therefore be allowed to dry naturally. This conserves energy and frees the stencil cleaner for additional wash cycles.

There are two ways commonly used for mechanical drying, centrifugal and high velocity air (air knife). Mechanical drying, if it is possible, offers the following advantages:

- Low energy requirements
- Rapid and effective
- Removes any residual contaminants in the rinse media

Possible disadvantages of mechanical drying include:

- Heated air used for drying can damage the stencil adhesive in the same manner as heated wash solutions.
- Heated air can cause irregular expansion and contraction of the stainless steel etched foil, causing distortion of the etched image.

9 EQUIPMENT ACCESSORIES

9.1 Equipment Accessories In general, stencil-cleaning machines include a series of accessories or options that will enhance the performance and proper operation of the equipment. These accessories are classified according to different categories depending on the end use and function:

9.2 Process Control Accessories Depending on the level of automation and sophistication of the cleaning equipment, these accessories provide the necessary controls to achieve proper operation of the cleaning equipment. In many cases, these accessories include a series of measuring devices and sensors that are electrically connected to a central PLC (programmable logic controller) or to a microprocessor. Functions can be programmed to execute (or abort) different steps according to the feedback received from the measuring devices. Typically, the measuring elements include:

- Temperature sensors.
- Pressure sensors for both air and fluids.
- Resistively/conductivity monitors for tracking ionic contamination and water quality.
- Refractometers to measure the refractive index of aqueous solutions to determine the volumetric concentration.
- Timers can be either incorporated within PLC software or installed as separate devices. Timers provide control of the different cycle steps such as wash, idle (drag), rinse, and dry times.

9.3 Operation Accessories These devices ensure proper and efficient equipment operations. Proper rating and specification of these must take place in order to guarantee a safe and effective equipment operation. In general, operation accessories can be classified as follows (in no particular order):

9.3.1 Pumps The pumping mechanism is critical to maintain the desired flow rates, impingement pressures, and efficient filtration. Pumps are used for wash and rinse fluid delivery, fluid transfer (i.e., drain), metering proper concentrations, etc. In general, the performance of the cleaning operations is directly related to the impingement pressure delivered by the wash pump onto stencil and PCA surfaces.

9.3.2 Heaters The heating elements, placed inside the wash reservoir, heat the fluid to the desired temperature. The power rating of the heaters should take into account factors such as the fluid volume, operating temperatures, heat exchange losses during operation, start-up time, etc.

Ideally, the heater operation should be automatically control based on the temperature measurement of a thermocouple. Additionally, an over temperature protection shutoff mechanism should be incorporated. In addition, some cleaners have air heaters designed to dry stencil and PCA surfaces. The same precautions/recommendations also apply to the air heating devices.

9.3.3 Filters Filters provide two main functions in spray cleaning applications. First, an adequate filtering system can reduce solder balls redeposition onto PCA and stencil surfaces. Secondly, proper filtration can reduce clogging inside the fluid delivery pipes and pumps of spray-in-air-systems. The filter particle size ranges from 10 μm down to 1 μm depending on the specific application. For drain systems in which the rinse water is transferred out of the cleaning equipment, the minimum filter rating is 5 μm in order to effectively prevent passing of solder balls.

Filters may not be necessary for many ultrasonic stencil cleaners as the wash solution is not recirculated and the heavy solder balls are separated naturally by gravity and fall to the bottom of the wash tank. However, filters for waste management may need to be considered.

9.3.4 Dryers The drying cycle is often the least important step of the overall cleaning process as most stencils are cleaned for inventory and can be left to dry naturally. Many cleaning systems have a water rinse step followed by optional drying. Generally, drying is accomplished by passing compressed air or Nitrogen through an in-line heater and delivered through strategically located air knifes or fixed nozzles, or nozzles attached to the circulating spray wand. Drying is also accomplished by using a fan to pass ambient or heated air over the stencil. Adequate drying may be essential in the case of PCAs. In many cases, the drying cycle is the limiting step in the total cycle time and can be eliminated to improve throughput.

9.3.5 Ion Exchange and Carbon Media The quality of rinse water in terms of resistivity and organic content is crucial particularly for PCA cleaning/rinsing applications. Ionic contamination on PCA surfaces has the potential for highly detrimental effects. Ion exchange resins absorb anions and cations dissolved in rinse water. Carbon media absorbs residual organic substances present in the rinse fluid. The effectiveness of the carbon and ion exchange resins is dependent on different factors such as flow rate, volume, and loading levels. Resistivity/conductivity sensors generally control the operation of the carbon and ions exchange media. See clause on cleaning misprinted PCAs.

9.3.6 Evaporators Evaporators are generally stand-alone systems plumbed into the cleaning equipment through appropriate chemically resistant pipes. The main function of the evaporators is to eliminate the waste rinse water and aqueous wash solutions by evaporation. The successful implementation of an evaporator requires additional facilities connections such as venting and electric (or gas) power. Evaporators are useful in cases where drains are not available or when the wastewater contamination levels are highly restrictive or when the user wishes to eliminate liquid hazardous waste disposal and drain discharge.

While considered an accessory, the wastewater evaporator is usually a separate machine for reducing large volumes of wastewater down to manageable amounts for disposal. Preferred construction is stainless steel in order to prevent rust. Since small systems are usually adequate and gas is not always available, electrically fired systems are more common. Gas fired systems are available and are considered more efficient for large volumes of water.

Evaporators can be either thermal or atmospheric. Thermal units utilize gas or electric heat sources to vaporize (boil) the wastewater. Atmospheric units generate a vacuum to vaporize the wastewater. Thermal systems are more common and generally less costly. If located indoors, a water-tight exhaust duct will be required. Ducting and venting should always be installed and balanced by an HVAC (Heating, Venting and Air Conditioning) professional. Other exhaust systems in the area may be in competition with the evaporator exhaust resulting in inadequate airflow.

When selecting evaporation as the method of wastewater management, the cleaning chemistry must be evaluated for compatibility. When using an appropriate chemistry, the wastewater will be eliminated by sending the nonhazardous water vapor to atmosphere leaving the hazardous solids within the system for disposal. Dissolved lead that would otherwise require expensive ion exchange or reverse osmosis filtration simply precipitates out of the process as a lead salt. Chemistries containing hazardous ingredients, glycol ethers, VOCs, etc., most likely will not be allowed to evaporate to atmosphere. Always check with your local regulating authorities for chemistry compatibility and possible permit requirements.

9.3.7 Exhaust/Venting Systems These are required in cases where solvents are used. The minimum cfm (cubic feet per minute) requirements depend on the specific application. In some cases, exhaust systems are used when heating aqueous cleaning fluids.

9.3.8 Cooling Coils This is a requirement in cases where low flash point fluids such as 2-Propanol (IPA) is used in the cleaning process. In addition, cooling coils are sometimes implemented for rapid heat exchange when fast cooling of the wash or rinse reservoirs are required.

9.3.9 Fixture/Basket Accessories Fixtures and baskets are generally required for safe and effective holding of PCAs, pallets, small stencils, and tools such as squeegees. In the case of PCAs, the board design must allow for holding the substrates in place while preventing physical damage and spray "shadowing." In addition, the design must allow for easy loading and unloading of the PCAs onto the board holder.

9.4 Compatibility Constraints with Cleaning Solutions Care needs to be taken in the selection of cleaning equipment and chemistries. The very narrow solid areas between apertures on fine pitch parts could be damaged due to excessive pressure settings for the wash solution. Additionally, if bristle brushes are used to abrade the residual material in apertures the same situation could occur.

Excessive heat in the equipment could cause minor distortion to the stencil resulting in misprints—due to the different rates of expansion of the stainless steel foil, polyester border, and aluminum frame. The epoxy bond could also come under stress due to heat.

Depending on the cleaning chemistries chosen, there could be a failure in the fiducials on the stencils. Fiducial fillers that are not compatible with cleaning chemistries or temperature settings on equipment could release leaving no method for alignment of the stencil to the boards.

10 ENVIRONMENTAL

Assemblers must consider the effect of the cleaning agent on air emission, wastewater discharge, and solid waste generation. Special authorization or permits for air, wastewater and special handling of solid waste are very often the rule in those nations that have no precise legal definition of permitted discharges. The following are most often a concern:

Air

- VOCs (volatile organic compounds)
- Ozone depleting substances
- Global warming substances
- Odors

Wastewater

- Heavy metal cations (notably lead, tin and copper)
- Anions (notably phosphates, nitrites and sulfates)
- Complexing/chelating agents (notably EDTA salts and ammonium/amine compounds
- PH (acid or base condition)
- COD/BOD
- Toxicity to aqueous life before and after biodegradation
- Other (temperature, solid matter, suspended matter, surface tension modifiers, etc.)

Solid Waste

- Heavy metal cations (notably lead, tin and copper)
- All leachable toxic materials up to 100 years in authorized discharge conditions
- Used solvent

10.1 Air Emissions Air emissions are a concern for some chemical-cleaning agents used for stencil cleaning operations. Generally, there are two types of air emissions from such a cleaning process; (1) VOCs and (2) water vapor. VOCs are generated from cleaning with organic solvents and aqueous cleaners that contain organic solvents. In certain nations and regions, VOCs are highly regulated because their vapors react with nitrogen oxides (photochemically) producing smog. The water vapor from an evaporator that is used to concentrate the chemicals from a wash tank may require an air emission discharge permit. In any case, it is important to consult with the regulatory agencies before a cleaning process is installed. Depending on the particular chemical(s) emitted, the amount of the chemical(s) emitted and the amount of other chemical emissions from that facility, the emissions may or may not be regulated by the State (other regional permitting authority under the Clean Air Act). An air emissions permit may be needed if the emissions thresholds for a given chemical or a group of chemicals at that facility is exceeded. The worldwide trend is toward increasing the stringency of VOC regulations. However, the definition of what constitutes a VOC varies much from one country or region to another.

Odors in the workspace and/or odors exhausted to the outdoors are often a primary concern to maintaining a good working environment.

10.2 Wastewater The discharge of any wastewater stream, both by total flow and by chemical make-up must conform to national, regional and local regulations in all nations. These may vary from lax to very strict limits with little flexible conditions. Many nations, particularly in Europe, have draconian legal requirements dictated on a national scale, covering many aspects of wastewater quality. Others have less comprehensive regulations, covering only the more important considerations. Local authorities may offer derogations to national legislation where their local treatment plant is able to handle the otherwise out-of-tolerance waste. Derogations are frequently accorded to small users, particularly if it may be shown that the cost of treating a small quantity of slightly polluting waste would be out of all proportion to the damage that could be caused. It must be noted that because an installation is approved in one place, it may not be elsewhere. In all cases, it is wise to discuss an installation with the local authorities before putting it into service, as a polluting fait accompli is never looked at with a kindly eye.

In the USA, the discharge of the wastewater stream, both by total flow and by chemical make-up will very likely require a permit form the local public owned treatment works (POTW) under the Clean Water Act (CWA). In addition, such a permit may also require co-current approval (and in rare cases, regional EPA approval). It is important that any new or additional wastewater flow from a post solder cleaning process step be reviewed with local POTW officials before commencing the discharge of wastewater. Such a review may result in the POTW waiving the need for a permit, or in reducing the monitoring requirements of a required permit. Superfund regulations place liability on all drain uses if contaminated sewer sites cannot be linked to the generator. If using the drain for filtered wastewater discharge, the user could be held liable for a neighbor's problem and be required to share in the clean-up costs.

Even though there is no universal US EPA rule for electronics part cleaning, any state can have its own regulations for these processes. Throughout the USA, these vary greatly from one regulatory agency to another, from minimal to very strict. Regulatory personnel's interpretation and knowledge of this process will determine the difficulty that one will have with discharging the wastewater. Some local communities may decide to prohibit a discharge of industrial wastewater. Other communities will follow the state's requirements and will rely on the state to monitor the wastewater for them.

In the past, many nations and regions (states) allowed combining of domestic sewage with industrial wastewater including heavy metals as long as the final wastewater complied with the regulations. However, today many of these cleaning operations are now considered as a point source discharge. With increasing frequency, regulatory personnel are taking samples of wastewater from the wash tank drain and the rinse water drain of the cleaning equipment.

In most European countries and many Asian ones, it is a legal requirement that the discharge be measured directly from the machine or the individual wastewater treatment plant and that dilution of the wastewater stream either from within the machine or without it, is expressively forbidden. In other words, if the discharge from the machine does not conform to the regulations, the water must be purified in such a way that it does.

One of the more difficult aspects of wastewater treatment is that of heavy metal cations. Taking the three most important ones for electronics cleaning, the known regulations at the time of this writing may vary from place to place as follows:

In some nations, the permitted concentration is expressed in peak milligrams-per-liter, in other, parts-per-million. For the sake of simplicity, the two units were considered here as equivalent. Very few regulations in the world permit integrating/averaging to determine the limit.

In the calculation of this average, those nations with unlimited permitted total in cation concentration were ignored: this figure is therefore an average of those nations with a finite limit.

It is evident that removing heavy metals from wastewater does not destroy these metals. At the best, they are transported into another form, such as concentrate from membrane treatment or regenerated two bed ion exchangers, as residues from mixed bed ion exchangers or as a solid precipitate after hydroxide or ferrite treatment. All these waste materials are at least as dangerous as the original cations in the wastewater. They are only displaced. It is a bounden duty to ensure they are disposed of in as environmentally friendly manner as possible, no matter the chosen way.

10.3 Solid Waste The disposal of spent or waste-cleaning chemicals is regulated in most countries as hazardous waste. Spent cleaning chemistries, filter cartridges, activated carbon or others must be analyzed and characterized by someone knowledgeable in hazardous waste generation, storage and shipment regulations. In the USA, the federal TCLP (Toxic Characteristic Leachate Procedure) test is the minimum that must be performed. Applicability of the hazardous waste rules subject a facility to extensive regulations on personnel training, storage and handling requirements and record keeping. Even if hazardous waste rules are not applicable, local or state rules on solid waste may apply. Some states offer technical assistance to aid in this determination. Documentation of test results and records must be kept to assure the regulatory agency of compliance with today's "cradle to grave" requirement. Complete records of the amount of regulated wastes generated, transported, and disposed are required.

In addition to analogue regulations, there are very severe rules in Europe simply for the transport of hazardous waste and, for that matter, any toxic material. Furthermore, most regions operate licensed liquid and solid chemical disposal sites, which are specially constructed to protect the air, surface and ground waters (especially phreatic sites) and the surrounding soil. Every load of waste must be clearly labeled as to the nature of the contents. Generally, it is a wise precaution to make sure that a site can accept a given waste before despatching it. Combustible waste is usually incinerated in special kilns. In particular, special licenses are required to transport waste across a national frontier, according to the Basel Convention.

APPENDIX A
Terms and Definitions

Absorbed Contaminant: A contaminant attracted to the surface of a material that is held captive in the form of a gas, vapor or condensate.

Adhesive: A substance such as glue or cement used to fasten objects together. In surface mounting, an epoxy adhesive is used to adhere SMDs to the substrate.

Adhesive Printing: Stencil printing no longer is limited to the deposition of solder paste. Stencils may be used to deposit adhesives on mixed-technology PCA designs in which the bottom of the board features parts attached with adhesives for wave soldering.

Aliphatic Solvent: ''Straight chain'' solvents, derived from petroleum, of low solvent power.

Alkaline Cleaner: An aqueous engineered composition that contains alkaline salts. These materials are in a pH range of 7-14.

Ambient: The surrounding environment coming into contact with the system or component in question. Typically refers to room temperature processing.

Aperture (Stencil): Openings in the stencil through which solder paste or adhesive is deposited onto the circuit board.

Aqueous Flux: Water-soluble organic flux.

Aspect Ratio: Aperture width to depth ratio. If the wall area exceeds the land area, the surface tension of the solder paste will be such that more of the paste will adhere to the wall, risking a clogging condition.

Azeotropic Cleaning Mixture: A liquid mixture of two or more solvents that behave like a single solvent. The vapor pressure by partial evaporation of the liquid has the same composition as the liquid cleaning chemistry.

Bare Board: An unassembled (unpopulated) printed circuit board.

Base Solderability: The ease with which a metal or metal alloy can be wetted by molten solder under minimum realistic conditions.

Batch Cleaning Process: The cleaning of multiple parts or ''batches of parts'' as a group where process cycle times are controlled.

BOD: Biological oxygen demand.

Bridging, Electrical: The unintentional formation of a conductive path between conductors.

B-Side: The bottom side of a printed circuit assembly.

COD: Chemical oxygen demand.

Cold Hand Cleaning: Manual cleaning using a presaturated wipe or brush that contains a cleaning chemistry that readily evaporates.

Corrosion: The attack of cleaning chemistry, fluxes, and flux residues on base metals.

Degradation: A decrease in the performance characteristics or service life of the cleaning chemistry.

Dewetting: A condition that results when molten solder coats a surface and then recedes to leave irregularly shaped mounds of solder that are separated by areas that are covered with a thin film of solder and with the basis metal not exposed.

Double-Sided Printed Board: A printed board with a conductive pattern on both of its sides.

Emulsion Cleaning: An aqueous cleaning mixture that holds immiscible soils, such as adhesive, in suspension.

Feature: The general term that is applied to a physical portion of a part, such as a surface, hole or slot.

Fine-Pitch Technology: A surface mount assembly technology with component terminations on less than 0.625mm (0.025-inch) centers.

Flux: A chemically and physically active compound that, when heated, promotes the wetting of a base metal surface by molten solder by removing minor surface oxidation and other surface films and by protecting the surfaces from reoxidation during a soldering process.

Flux Activity: The degree or efficiency with which a flux promotes wetting of a surface with molten solder.

Flux Residue: A flux-related contaminant that is present on or near the surface of a solder connection.

Hydrophilic: Water loving or having a strong affinity for water.

Hydrophobic: Water hating or having a strong aversion to water.

Hydroscopic: Water loving or having a strong affinity to water.

In-line Cleaning: Parts are processed continuously on a conveyor with process cycle time being controlled by the conveyor speed.

Ionic Cleanliness: The degree of surface cleanliness as measured by the number of ions or weight of ionic matter per unit square of surface.

Manual Cleaning: A cleaning step where parts are processed manually with process cycle time controlled by operator.

Paste Flux: A flux formulated in the form of a paste for joining area array components.

Pitch: Center-to-Center distance between two adjacent conductors or lands.

Polyglycol: Any of several condensation polymers of ethylene glycol.

Residue: Any visual or measurable form of process-related contamination.

Rework: The act of reprocessing noncomplying articles, through the use of original or alternate equivalent processing, in a manner that assures compliance of the article with applicable drawings or specifications.

Saponifier: An alkaline chemical designed to react with organic fatty acids, such as rosin to form a water-soluble soap.

Screen-Printing: The transferring of an image to a surface by forcing a suitable media through an imaged-screen mesh.

Screen and Stencil Cleaning: The process of removing unused solder paste/flux from application tools to maintain them in an acceptable condition for reuse.

Semiaqueous Cleaning: Organic solvent blends are used for washing or dissolving the contaminant followed by water rinsing.

Solderability: The ability of a metal to be wetted by molten solder, a function of the termination finish at the time of soldering. Total soldering ability is a function of matching the design, process, components and substrate to facilitate the formation of a robust solder joint.

Solder Ball: A small sphere of solder adhering to a laminate, resist, or conductor surface.

Solder Paste: Finely divided particles of solder, with additives to promote wetting and to control viscosity, tackiness, slumping, drying rate, etc, that are suspended in a cream flux.

Solder Paste Considerations: Solder paste properties such as particle size and shape, flux type, viscosity and slump characteristics have a major impact on the printing process. Excessive solder paste can result in solder balls or bridging.

Solder Printing: The deposition of solder paste by reproducing a pattern on the printed circuit board.

Solvent Cleaning: The removal of organic and inorganic soils using a blend of polar and nonpolar organic solvents.

Squeegee: Both polyurethane and metal squeegees are used to force solder paste through the apertures of a stencil and onto the circuit board.

Squeegee Side/Board Side: Refers to the two sides of the stencil when mounted in the frame. The squeegee side is the side on which the squeegee travels to print the pattern; the board side comes in contact with the substrate to transfer the solder paste.

Stencil Border: Consists of a polyester fabric stretched on the frame to hold the metal stencil and to permit uniform contact with the board under squeegee pressure for a controlled snap-off.

Stencil Frame: Typically made of aluminum, which is cast or extruded. The cleaning agent must be compatible with the alloy of construction.

Surfactant: An aqueous organic or inorganic wetting agent designed to wet the surface of the product and displace the contaminant.

Ultrasonic Cleaning: Immersion cleaning that is done by passing high-frequency solund waves through a cleaning medium to casue cavitation (microagitation).

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