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# SMT Stencil Cleaning: A Decision That Could Impact Production

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Ultrasonics, coupled with an aqueous detergent process that cleans at below 43ºC, may be best suited for fine-pitch SMT screens and stencils. Aqueous detergents clean more effectively than solvents, with little or no environmental impact.

Because of the environmental concerns driving today's technology decisions, the once simple decision of selecting a stencil cleaning process is now clouded with different chemicals, different cleaning machines and various types of solder paste, all with specific environmental, health and safety related issues and regulations.

Now that CFCs are undesirable, many companies that clean PCBs have changed to using saponifiers and hot water to clean RMA flux from post soldered boards. When the PCB cleaners were using CFCs, they cleaned solder paste very effectively. Thus, it seemed only natural to follow the lead of the PCB cleaners when the switch was made to saponifiers and hot water to clean solder paste from SMT screens and stencils. However, a major variable was overlooked: the effect on the stencil. PCB's travel through a 200ºC reflow oven, and are not sensitive to elevated temperatures. The SMT stencil, on the other hand, is manufactured using heat-cured adhesives that bond the metal foil to the screen and the screen to the frame. If a stencil is washed in hot water or dried with hot air, the "heat sensitive" adhesives will tend to breakdown and the stencil will fall apart. However, this is not the main concern with using hot wash water or hot drying air. If the stencil begins to break apart, the problem is obvious and the stencil can be replaced at an added expense. The real problem arises because screens and stencils are made up of different metals. The frame is aluminum, the screen is either stainless steel or polyester, and the metal foil (metal mask) is either stainless steel, brass or nickel. When stencils are washed in hot water or dried in hot air, the different metals will expand and contract at different rates and cause minor distortion to the etched image, stress on the adhesive bond and loss of tensioning. This could lead to mysterious misprints, causing downtime for trouble shooting a problem that could have been prevented if only hot water or hot air had not been used.

## ALTERNATIVE SOLUTIONS

The stencil-cleaning equipment manufacturers soon realized the dilemma and tried to remedy the situation by incorporating other chemistries, such as alcohol and terpenes, for cleaning PCBs. Both cleaners were used at ambient temperatures, just like CFCs. The problem was thought to be resolved. Then along came "no-clean" solder paste and the realization that Isopropyl Alcohol (IPA) and terpenes are very selective as to what type of paste they can clean. Besides, they are both flammable and potentially explosive. Neither is very effective at cleaning most no-clean type fluxes. To complicate things even more, fine-pitch and ultra fine-pitch apertures were becoming a reality.

The SMT assembler has always been faced with the responsibility of first selecting a stencil cleaning machine from one vendor, then selecting a chemistry to address the particular flux and then, hopefully, finding a waste-treatment process to handle the mess that was created. Finally, if the process does not work, the assembler was faced with two or three different vendors, pointing fingers at one another, and nobody taking responsibility to correct the situation. The solution to the assembler's problem seemed to lie in a complete process that could be offered by one vendor: the right cleaning machine, the correct chemistry and the proper waste handling system, all in one. At least if it did not perform to specification, the assembler would know who to blame and that vendor would be responsible for correcting the process.

## WHAT'S IMPORTANT TO YOU

When selecting an SMT screen/stencil-cleaning process, it is critical to prioritize the deciding factors that are most important to the user.

- Can the process effectively clean fine and ultra fine-pitch apertures?
- What flux do I need to clean now and will it be necessary to clean a different flux in the future?
- Can the process support these potential changes?
- Can the process clean dry as well as fresh paste?
- Are there other objects to clean, such as misprints, pallets, adhesives, etc.?
- What is the environmental impact?
- What is the capital investment?
- What is the operating cost?
- Are there any health or safety hazards to consider?
- Does the process have any detrimental effects on the stencil?
- What is the maintenance and potential downtime?
- Are there any special handling or storage requirements for flammable or hazardous chemistries?
- Who will take responsibility for correcting the process if it fails to perform?

## TYPES OF STENCIL CLEANERS

There are only a few stencil-cleaning machines from which to choose. The main ones include those using spray-in-atmosphere technology, spray under immersion or ultrasonic agitation.

The chemistries range from solvents (alcohol, terpenes and hydrocarbons) to saponifiers that require hot-water solutions, to specially formulated detergents that clean in hot-, cold- and/or warm-water solutions.

Waste handling can be complicated. Depending on the cleaning process, the waste handling process can range from hauling the waste away and creating a long-term liability, to the purchase of an expensive filtration/clarification system that may or may not resolve the waste problem.

## SELECT THE CHEMISTRY FIRST

When selecting a cleaning process, the chemistry should be selected first. Most people make the mistake of selecting a cleaning machine first, when actually the most important element in the cleaning process is the cleaning chemistry. If the chemistry does not address the contaminant, the mechanical action of the machine will do little to remove the solder paste. A simple example is washing one's hands. Water and hard scrubbing will do little to clean the hands until soap (chemistry) is used. Only after the proper chemistry is identified, is the method of application of that chemical selected. The TABLE lists some of the advantages and disadvantages of the most common cleaning agents.

IPA and terpenes have been used to replace CFCs. However, IPA and terpenes have numerous concerns of their own. They are both volatile organic compounds (VOCs) and therefore smog producers. VOCs are becoming as regulated in many parts of the world as CFCs because of their air polluting qualities.[1] Many areas have limited the consumption of VOC solvents to 1 pound (0.45 kg) of solvent per day per cleaning sight. Since it is common for IPA- and terpene-using machines to consume more than this limit in just the idle state, they are not allowed in many areas.

In addition to contributing to air pollution, these solvents can be very dangerous. Spraying alcohol or terpenes within a closed chamber can result in a fire and/or explosion in the presence of an ignition spark. Several incidents have already been reported. The naive vendor providing an IPA system may feel it to be completely safe because the electronics is isolated from the atomized solvent. However, an ignition spark can result from the moving metal spray nozzles unexpectedly hitting a metal stencil that has become dislodged from its securing fixture. Metal hitting against metal inside of a chamber containing IPA vapors will obviously lead to an explosion. Caution should also be taken as to where an alcohol cleaner is placed. Surrounding non-related electrical equipment can easily generate an ignition spark. In most cases the manufacturer provides a fire-suppression system in case of such emergencies. Such a system would be useful - if it should survive the explosion! IPA and terpenes are also very selective as to what fluxes can be cleaned. If down stream, the user should decide to change flux types, or if VOCs should become regulated in the area, the user may be faced with the same exact dilemma of seeking a new stencil-cleaning system.

Another chemistry that has been tried is the aqueous saponifier. A saponifier is an alkaline chemistry (usually 13 pH+) that combines with the rosin in the solder paste to form a water-soluble soap. This soap can then be cleaned with water, and use the mechanical action of the cleaning machine to remove lead/tin solder balls. Unfortunately, saponifiers require elevated temperatures in excess of 140ºF (60ºC) in order to react with the rosin [temperatures above 110ºF (43ºC) will most likely damage the stencil]. The alkaline saponifier combines with the fatty oil (rosin) and forms a water-soluble soap. This "soap-forming" process is called saponification. The same process is used to manufacture soap. The saponifier takes the place of the lye and the rosin takes the place of the animal fat. Combine the two at elevated temperatures and you get a water-soluble soap. The resulting soap can then be rinsed away using plain water. The alkaline saponifier is consumed during the cleaning process and requires constant replenishment. The high pH and hot solution of a saponifier can also cause a black oxidation to the aluminum frame of the stencil and can be a hazard to the user.

The waste stream of a saponifier proves complicated. This is because the hazardous ingredients contained within the saponifier combines with the lead from the solder paste, which dissolves in the wash solution. The resulting multiple hazardous wastes will require expensive anion exchange or reverse osmosis filtration and chemical neutralization prior to disposal. The discharge to drain is undesirable in many locations and may require a permit.

Various hydrocarbon-based solvents have been tried with little success. Hydrocarbon solvents are very selective in the flux types they can clean. Also, these solvents do not dry "film free," so they require a water rinse. The waste stream treatment can be very sophisticated, costly and provide a long-term liability when hauled away. If the process requires water rinsing, then one may as well wash with water and eliminate the solvent, if possible. This would at least, limit the types of waste streams generated.

## DETERGENTS WORK BEST

An aqueous process, using a specially formulated detergent, seems to provide an answer. Detergents can be chemically formulated to achieve a multitude of cleaning objectives. Unlike saponifiers that require heat to induce a chemical reaction, detergents can clean in cold water. Detergents are surfactants (wetting agents) designed to "cut through" a particular contaminant (in this case flux) and allow the mechanical action of the cleaning machine to release the soil. Detergents are alkaline by design. Alkalinity may range from 8 to near 14 pH. To be considered non-hazardous, OSHA (Occupational Safety & Health Association) requires the pH of a detergent to be less than 12.5. Detergents designed to remove solder paste are usually between 11 and 12.5 pH and non ionic. They may emulsify the soil and become "loaded" which may require filtration. Or, detergents may not inter-react with the contaminant at all, in which case separation of the waste solder paste is very convenient (done by gravity). The solder paste simply falls to the bottom of the wash tank, where it remains until removed for recycling.

Because there is not a chemical reaction, the chemistry consumption is much less with detergents than with saponifiers. The liquid hazardous waste stream created by non-hazardous detergents and hazardous lead/tin solder paste can be easily eliminated by routine evaporation equipment. The non-hazardous liquid is evaporates to atmosphere as distilled water and the hazardous lead is left behind as a solid for recycling. The resulting dehydrated detergent has a high BTU content and can be easily incinerated as a solid waste. Or, if the user has an in-house filtration system to handle lead-laden liquid waste generated from a batch or in-line PCB cleaner, the liquid waste from the detergent-based stencil cleaner most likely can be handled within the same filtration equipment. In either case, the waste stream offers virtually no problems.

## SELECTING THE MACHINE

Once the appropriate chemistry is identified, the method of applying or delivering that chemistry to the contaminated stencil can be selected.

There are basically three different types of machines from which to chose: 1) Spray in atmosphere, 2) spray under immersion and 3) ultrasonic.

The selection process should answer the following questions: Can the agitation effectively deliver the chemistry to all of the surfaces to be cleaned inside the apertures and etched-back areas of a fine-pitch stencil? Also, will the agitation adversely affect the integrity of the stencil?

When stencil apertures were 50 mil pitch and larger, the traditional solvent vapor degreaser was effective. The solvent vapors dissolved the RMA flux and the hand-held solvent-spray wand could effectively spray through the relatively large aperture openings to remove the solder balls. However, now that stencil apertures are 20 mil pitch and smaller, it is extremely difficult to "spray" through to tiny holes (See Figure). If the machine cannot deliver the chemistry to the surface to be cleaned, the chemistry will not be able to contribute to the cleaning process. Moreover, the impingement action required to remove the solder balls will be absent. The result will be a fine-pitch stencil with fugitive solder balls contaminating a large percentage of the apertures. This adversely effects the quality of the next stencil print. Attempting to clean a fine-pitch SMT stencil with spray technology is like trying to clean a keyhole with a fire hose. You cannot effectively deliver the cleaning solution through the contaminated apertures.

## SPRAYS CAN DAMAGE A STENCIL

If a spray system is used to clean fine- and ultra fine-pitch apertures and there is limited success, supplemental measures are usually incorporated. The pressure of the wash solution can be increased and/or a small bristle brush could be used to abrade the residual material left in the apertures. However, in either case the opportunity for damaging the stencil increases significantly. The land mass between the aperture openings in a stencil can be from 0.001" - 0.006" in width and from 0.040" - 0.70" in length for ultra fine-pitch or 0.007" - 0.010" in width and from 0.040" - 0.090" in length for fine-pitch printing. When these dimensions are coupled with a stencil thickness of 0.001" - 0.003" for ultra fine-pitch applications and 0.004" - 0.006" for fine pitch applications, the care, storage and damage factor to the stencil becomes a critical part of the manufacturing process.

The fine-pitch (0.016" - 0.020") stencils can withstand the light pressures of current stencil cleaners. However, any type of wash/rinse pressure increase will bend the land-mass between the apertures. This will render the stencil useless because of the lack of coplanarity and the gasketing feature required during the printing process. The use of stencil cleaners in the printing environments using high-pressure sprays as mentioned could introduce process downtime for any or all of the following reasons:

- Under side stencil cleaning due to stencil "bleeding" caused by bent or damaged land bridges

- Possible premature stencil wear caused by printer blade abrading damaged land bridges protruding above stencil surface

- Actual aperture land bridge breakage ruining the utility of the stencil

- Increase solder paste bridging due to lack of intimate board contact during the printing process

- Possible increase of insufficients caused by hardened solder paste in the apertures which was not removed from the previous wash which then causes a change in the printing aspect ratio, thus releasing bad paste release generating the insufficients. As the industry migrates toward micro miniaturization, especially for device manufacturing (i.e. Flip Chip, Micro BGA's and other direct chip attach components), the usage of thinner, 0.001" - 0.003" stencils will increase. The care, cleaning and handling of these stencils becomes even more of a critical factor as part of the printing process one defines on the manufacturing floor. Picture land bridges between apertures which will be 0.001" - 0.003" width, 0.040" - 0.070" length and only 0.001" - 0.003" thick. This is not science fiction. Stencils with these dimensions have been supplied for the last two years. It will not take much wash/rinse pressure to damage these bridges, causing the types of manufacturing process problems previously mentioned. The only way to avoid these problems is to use an ultrasonic based stencil cleaning system. The ultrasonics clean uniformly and without exerting the trauma that high pressure sprays can cause. The microscopic cleaning action of ultrasonics is also more effective in cleaning the tight tolerance areas of fine and ultra fine-pitch apertures.

## ULTRASONICS CLEAN BETTER THAN SPRAYS

Ultrasonics clean so well that the colored emulsion used to coat the screen portion of the stencil can be eliminated. The primary purpose of the emulsion is to fill in the tiny holes of the screen's mesh because if solder paste were to contaminate the screen, it would be very difficult to clean it out if using a spray-type stencil cleaner. An ultrasonic stencil cleaner can clean the screen mesh just as well as the fine-pitch apertures.

Many stencil manufacturers no longer apply the emulsion coating if it is known that the customer will be using a good ultrasonic stencil cleaner. Eliminating the need for screen-emulsion coatings, help reduce the cost of providing an SMT stencil.

| ALCOHOL (IPA) | |
|---|---|
| **<u>PROS</u>** | **<u>CONS</u>** |
| Readily available | VOC (volatile organic compound) |
| Cleans at room temperature | Flammable (can be explosive) |
| Non ozone depleting | Contributes to air pollution |
| Does not oxidize/corrode stencil | Need to haul hazardous waste |
| Minimal liquid waste disposal (due to evaporation) | Need to use full strength |
| Dries fast | Cleans limited types of solder paste |
| Can close-loop | Cannot be used with ultrasonics |
| | Cannot clean most SMD adhesives |
| | Cannot clean flux buildup on tooling |
| | Emits solvent vapors into work area |
| | Becoming highly regulated by AQMD |
| | Requires explosion proof equipment |
| | Requires special storage |

| TERPENES | |
|---|---|
| **<u>PROS</u>** | **<u>CONS</u>** |
| Readily Available | VOC |
| Non ozone depleting | Flammable/Explosive |
| Does not oxidize stencil | Contributes to air pollution |
| Can close-loop | Need to haul hazardous waste |
| | Need to use full strength |
| | Requires a water rinse |
| | Cleans limited types of solder paste |
| | Cannot be used with ultrasonics |
| | Cannot clean most adhesives |
| | Cannot clean flux buildup on tooling |
| | Emits solvent vapors into work space |
| | Becoming highly regulated by AQMD |
| | Requires explosion proof equipment |
| | Requires special storage |
| | Strong odor |

| SAPONIFIERS | |
|---|---|
| **PROS** | **CONS** |
| Readily available | Requires elevated temperatures |
| Non flammable | Cleans limited types of solder pastes |
| Non ozone depleting | Contains hazardous ingredients |
| Low VOC | Caustic pH levels |
| Dilute with water | Some contain VOCs |
| Can use with ultrasonics | Complicated & expensive waste treatment |
| Can clean flux from tooling | Consumed during cleaning process |
| | Does not clean most adhesives |
| | Strong odor |
| | Concentrate requires special storage |
| | Requires large quantities of rinse water |
| | Steam can contaminate SMT assembly area |
| | Dries slower than VOC solvents |
| | High chemical consumption |

| DETERGENTS | |
|---|---|
| **PROS** | **CONS** |
| Readily available | Dry slower than VOC solvents |
| Non ozone depleting | |
| No VOC's | |
| Can clean at low temperatures | |
| Cleans broad spectrum of solder pastes | |
| Can clean SMD adhesives | |
| Can clean flux from tooling | |
| Dilute with water | |
| Rinses with small amounts of water | |
| Contains no hazardous ingredients | |
| Can use with ultrasonics | |
| No steam or water vapor contamination | |
| Liquid waste can be evaporated or filtered | |
| Will not oxidize/corrode stencil | |
| Normal storage | |
| Low chemical consumption | |
| Mild to pleasant odor | |

## OTHER USES OF AN SMT STENCIL CLEANER

Obvious applications include cleaning misprinted substrates, squeegee blades and other tooling of virgin solder paste. If a company has decided to utilize a "no-clean" solder paste flux, all other cleaning equipment from the factory floor has probably already been eliminated. In-line or batch PCB cleaners are no longer required because the low residue left behind on the board does not require cleaning. However, tooling that repeatedly travel through the reflow oven accumulates flux residue, which may need periodical cleaning. A good aqueous detergent, designed to clean fresh and even dried solder paste, should also be able to remove polymerized flux residue from pallets and other tooling. Alcohol and terpenes do not perform well at cleaning flux buildup from wave solder pallets and other tooling.

## A SOLDER BALL NIGHTMARE

Avoid attempting to use a stencil cleaner as a "final clean" for assembled PCBs. When using a stencil cleaner that relies on high-pressure sprays to do the cleaning, one can experience what could amount to a "solder ball nightmare!"

When cleaning SMT screens and stencils, the contaminant is millions of solder balls within the paste flux. During final cleaning post-soldered PCBs, the contaminate is primarily flux residue with just a few fugitive solder balls. A traditional spray-style stencil cleaner relies on a series of filters to strain out the contaminates as the cleaning solution recirculates for reuse. Even if the filtration system is 99.9% efficient, assembled boards could potentially be bombarded with hundreds or thousands of solder balls left in the system after cleaning virgin solder paste from a screen or stencil. For similar reasons, a stencil cleaner using sprays should not be used for cleaning misprinted solder paste from double sided boards. The sprays will broadcast the solder balls throughout the wash chamber, allowing them to become lodged under and around the components located on the reflowed side.

Cleaning populated boards in an ultrasonic stencil cleaner poses a completely different concern. While there has been some concern over the years about cleaning populated boards with ultrasonics, this is not the case with today's ultrasonic systems.[2,3] The United States military has acknowledged the benefits of cleaning high density SMT assemblies with ultrasonics over spray technology. [4,5,6]

There are a few concerns about cleaning populated assemblies in an ultrasonic stencil cleaner. Because ultrasonics is so efficient in driving the cleaning solution under and around components, it now may require an ultrasonic rinse to remove the wash solution. Ultrasonic stencil cleaners rinse the smooth geometry of a stencil and therefore only incorporate spray rinses. Ultrasonic rinses would add too much cost to the manufacture of the machine and render it non-competitive in the marketplace. Some users of ultrasonic stencil cleaners do occasionally clean assembled boards in their stencil cleaner and use a separate ultrasonic tank filled with deionized water as a final ultrasonic rinse. If the detergent is a non-ionic surfactant, rinsing becomes less of an issue and standard spray rinsing my be adequate. The concern about solder ball contamination with an ultrasonic stencil cleaner does not arise. The solder balls fall safely from the board to the bottom of the tank where they remain because the wash solution of an ultrasonic system does not normally require recirculation. Only enough ultrasonic power necessary to achieve proper cleaning should be used. High-powered ultrasonics above 40 watts per gallon should be avoided. [2,5]

## THE IDEAL COMBINATION

It has been estimated that 51-72% of all solder defects are a result of the screen-printing operation.[7] Thus having a clean and accurate stencil is a major concern. An SMT stencil that has maintained good structural integrity and has zero contamination within the apertures will produce a better and more consistent print, which reduces incidence of misprints and downtime.

Alcohol and terpene solutions are not recommended to clean SMT screens and stencils because of the high risk of fire and/or explosion, their selective cleaning characteristics and VOC concerns. Saponifiers are not recommended because they require elevated temperatures to activate and will damage the heat-sensitive stencil. Also, the resulting waste stream is particularly cumbersome. Ultrasonics, coupled with an aqueous detergent solution that cleans at low temperatures (below 110ºF or 43ºC), would be considered to be the ideal process combination for cleaning fine-pitch SMT screens and stencils.

Detergents are wetting agents that can be formulated to attack specific contaminants given specific cleaning parameters such as low temperature and type of cleaning agitation. Ultrasonics is the best possible cleaning agitation to deliver the cleaning solution, and to "scrub" the fine- and ultra fine-pitch apertures. It causes the least possible trauma to the etched image.

The resulting liquid waste can be easily filtered in an existing filtration system designed to handle lead contaminated water or safely eliminated by standard evaporation equipment. The non-hazardous liquid component safely goes to atmosphere as distilled water vapor and the hazardous lead solid is left behind to be recycled as a dross or melted down in a wave solder pot. The dehydrated detergent has a high BTU value and can be conveniently incinerated as a solid waste.

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