AUSTIN AMERICAN TECHNOLOGY

A Five-Step Approach to A Successful Cleaning Process

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Using a Five-Step Approach

Defining and implementing a successful cleaning process, no matter what the product – circuit assemblies, components, stencils, or others – involves a five-step process. The technology can range from a simple hand-cleaning system to a sophisticated high-ticket inline cleaning machine with multiple solvent systems, but the step-by-step procedure is the same for all. These steps are also applicable regardless of volume - one item or a thousand.

The first step involves determining our purpose for cleaning– a deceptively simple question. Do we need to remove a potentially corrosive residue or just improve the cosmetic quality of the assembly? To be successful, we must identify what standards we are going to use to judge the effectiveness of that process, so that we know we have accomplished our objective.

The second step involves finding the correct and appropriate solvent system that will remove all residues of concern. Hopefully, we will find a single solvent system that will accomplish the task at hand. The simplest solvent system, of course, is water. Beyond that, we have water/solvent combination systems all the way up to a pure solvent system. In Step Two, our goal is to find a solvent system that works for all residues that must be removed from a particular object or assembly. Hopefully we will be able to settle upon a single solvent system, which is preferable (both in terms of simplicity and cost) to multi-solvent systems.

The third step is to select a cleaning system, a procedure that could be as simple as cleaning with a wipe, or as complicated as using large automated high-volume in-line cleaners, multiple cleaners and advanced chemistries and technology. What are we going to need? What equipment will best employ and be compatible with the chemistry that we have selected as most appropriate for our cleaning application? Note that when ordering equipment make sure that the pump and filter seals are compatible with the solvent system selected in Step Two. There are many types of solvent delivery/cleaning systems ranging from basic manual wipe or brush to complex fully automated wash/rinse/dry with built in process control. The end user has to decide what is best overall. The complexity and volume of the cleaning operation selected should serve as a guide to lead you to a cleaning system that provides an appropriate degree of quality assurance and cost efficiency.

Once we have identified our purpose for cleaning, the appropriate solvent system, and the proper cleaning equipment, we can move onto Step Four. Step Four involves testing and certifying the new cleaning process. In Step Four we test and certify that the cleaning process selected meets the standards that were identified in Step One. For example, if you have identified that surface insulation resistance (SIR) was the key qualification to validate the cleaning process, you'd want to perform some SIR testing at this point to determine if the cleaning process will meet those standards.

The last step in this process is to integrate the process control systems that will alarm operators and /or management if process parameters change causing an out of control process. Systems here should ideally be simple, easy to use, and show a rapid response to change.

Step 1: Determine Why You Are Cleaning, and What Standards Apply

Why do people clean? The primary reason is to ensure the reliability of their products, real or perceived, meets market expectations. Effective cleaning has proven to improve the reliability of products by increasing their mean time to failure. Part of reliability, involves perceived reliability. The customer may view or regard an un-cleaned board as cosmetically unattractive, and therefore unreliable because it does not meet the perceived market expectation of being visually clean to the un-aided eye. Industry standards require circuit assemblies to be visually clean at 1X inspection unless otherwise specified. Generally, cosmetics are the first reliability concern that people have.

The second reliability concern is electrical failure due to corrosion and/or electrical leakage. It's very likely that if you don't reduce ionic residues below a certain level, they will eventually react with moisture from the environment and cause failure of the circuit assembly in the field. This is a real reliability problem experienced may times over!

The next consideration that would favor cleaning is electrical performance. A lot of high clock speed circuit boards, especially those that operate in excess of one gigahertz, are exceptionally vulnerable to contamination; merely the presence of the physical residue itself can cause problems with circuit performance due to RF skin effects and mismatched impedances in data transmission lines. As clock speeds get higher and higher, we see many instances in which even random distribution of flux residue on the board cause serious yield problems at first electrical test.

Another process yield issue related to cleaning is testability. There are many no-clean fluxes out there that are still not easily probe testable. These materials can cover test pads and gum up test points, such that you can end up failing them even though they are perfectly fine. This is due to problems such as gummy residue buildup on the test pins.

Finally, one may want to clean to improve adhesion of encapsulants and underfill used to protect the circuit from environmental and mechanical hazards the product may experience in use, transportation, or storage. A thin film of organic contaminate can prevent proper bonding or sealing of the electrical device and seriously compromise the reliability of the product. This would apply to flip chip underfills, conformal coatings, and component encapsulants.

In summary, reasons for cleaning are essentially focused around cosmetics, corrosion/electrical leakage, electrical performance, testability/manufacturability and mechanical stability.

The second part of Step One involves the questions, “What standards apply to my cleaning application?” and “What standards am I going to observe or adhere to in order to guarantee that I meet my requirements for manufacturability and reliability?” The answers are going to come from three areas. The first is customer requirements; for example, a customer wants you to build a 10gHz board and will allow no foreign matter visible at 10X optical inspection. The second part of the answer will involve internal standards, such as general company workmanship standards. This may require, for example, every board be free of solder balls. The third part would involve general industry standards, such as the universally recognized IPC standard which has an entire section devoted to inspecting, qualifying, and controlling one’s cleaning process.

Step Two: Identify and Select the Appropriate Cleaning Solvent System

Normally, we're looking for a single solvent system, beginning with the simplest system, water. It is the easiest, most economical, and generally perceived to be the most environmentally friendly system used. However, water can only be used approximately half the time. The other half of the time chemistry based cleaning, either with or without water, is used.

The first decision we need to make is what solvent is going to remove all of our residues. This begins with identifying all residues on the board or part, not merely the most obvious ones. This list will include such things as solder paste type A, type B, type C, essentially all the types that are used; also liquid fluxes, wave solder fluxes, uncured adhesives, and even solder balls. If the IPC standard requires no loose solder balls, and your process has a solder ball problem, it is a cleaning problem, albeit of a different type. Removal will not be strictly a function of solvent action, but will require a certain amount of kinetic energy in the cleaning process. Fingerprints are a type of ionic contamination that obviously result from handling circuit boards. Thus, we have to make sure that our solvent system removes these as well

After identifying all contaminants and residues present on the substrate, it is necessary to find the simplest single solvent system that will remove all of these effectively. It is usually necessary to perform research and testing to properly determine the solvent system. This could range from simple water, to water/solvent mixtures, semi-aqueous, saponifier, etc. to all-solvent and even multiple-solvent systems.

It is best to screen potential cleaning agents by simulating the cleaning process in a laboratory environment, whether it means soaking the product in a beaker of solvent, or using some type of hand spray or immersion technique. The goal here is to discover if a solvent system is effective in removing the offending residues and what parameters (time, temp, physical energy) and methods will be needed to use this solvent system. This is very important because these process conditions will have to be duplicated when we select the method or equipment to implement our cleaning process in actual production.

Step Three: Selecting The Right Cleaning System

The right cleaning system for the job can be as simple as a squirt bottle, brush and a hand wipe pre-soaked with solvent or as complicated as a multi-solvent automatic in-line cleaner. Basically, when selecting a cleaning system, there are really only two choices: hand cleaning or machine cleaning. Under machine cleaning, there are batch and inline cleaning systems; the deciding factor is volume requirement. With very low volume and/or low cleanliness requirements (simple metal parts, boats, etc.), soaking and hand cleaning may suffice. Tougher jobs requiring higher cleaning standards (stencils, boards, assemblies) will require process automation and control to assure and produce a consistent result.

In terms of process cleaning parameters, i.e., the key process parameters affecting cleaning, we must pay attention to and be able to control temperature, time, and physical action. In order to clean properly, you have to have all of these in the right proportions and under control. For example, just as an automobile engine requires fuel, spark, and air to operate - the cleaning process require the abovementioned essentials to operate. When selecting a cleaning machine, you should choose one that will meet volume requirements, provide for control over the key parameters of the cleaning process, as well as offer the correct delivery systems, i.e. spray under immersion, high impingement air spray, ultrasonics, or vapor degreasing.

Obtain the best technology to get the job done at the best price, and optimize the cleaning process – this is where we come to Step Four.

Step Four: Test and Verify

Now we put together a test vehicle or test coupon that contains all required residues that we'll have to clean, run it through the cleaning process and then test the vehicle to see if it meets the standards that you have identified. There are four basic tests specified by IPC. The first two are intended to be process-checking tests, and the other two are for qualification testing. The first is 1X 100% visual examination of each board, IPC-JSTD-001 D-2.1.2. This test is mandatory even if you don't clean the board because one can still have satellite solder balls or other foreign matter and soil contaminating the circuit board. Even if you're not cleaning, you still have to visually inspect the board so that it meets the visual criteria set down by the IPC standard. The second level of test, not mandatory, applies only if you clean the board, and is basically ionics checking, IPC-JSTD-001 D-2.2.1. This involves the use of an ionics testing meter (water extract resistivity testing) based on a sodium chloride equivalent. It's not a precise test, since it does not positively identify residue you're dealing with, and it won't tell you where the residue came from. It's really just a process indicator. As such, its real value lies in the controlling of the process. By establishing the historical average value and standard deviation achieved with this test, you can measure trends and changes, good or bad, in the cleaning process. There is an absolute limit of ten micrograms per square inch that is listed in the IPC Standards; your process is generally not going to fail to meet this limit unless it is way out of control.

The next two tests are for qualification only. One would never run these tests daily, weekly, or monthly to check one's processing, but rather they are something that you check initially, and periodically go back and re-check and re re-certify on the order of every twelve to eighteen months. These tests are ion chromatography testing and SIR (or surface insulation resistance) testing.

Ion chromatography (IC) testing, IPC-JSTD-001 D-2.2.2, is a very precise, sophisticated, and sensitive test that is similar to ionics or extract testing. However, it is much more sensitive and tells you exactly what kinds of ions are present. IC testing can be used to evaluate specific areas on a board, for example, underneath a BGA, whereas extract testing can give you only the average value for the board. This test requires very sophisticated and expensive equipment, and requires a well trained operator, such as a lab technician or chemist. It is unlikely that you'd be able to perform this test in house.

The last test recommended by IPC is SIR (surface insulation resistance) testing, IPC-JSTD-001 D-2.1.1, and is basically a humidity temperature test. In this test, test coupons using specific comb patterns are tested in a humidity chamber for seven days at a specific temperature and humidity level, depending on the class level of the product. One monitors these coupons electrically during this period of time looking for static corrosion and or electrochemical corrosion on the board. Usually 5 x 10^8 ohms or higher on a comb pattern is an acceptable passing resistivity level value.

In addition to these tests, and meeting IPC requirements, it is also necessary to meet any additional customer requirements that may be required of the cleaning process; thus, one must meet a combination of industry standards and customer requirements in the cleaning process. Remember that it is also necessary to re-certify the process occasionally.

Step Five: Keep The Process In Control

Most people are familiar with SPC techniques and measuring defect rates and yields in order to keep their process under control, to ensure process consistency, and to produce the highest yields possible. The same techniques that are applied to other process steps in the manufacturing of circuit assemblies also apply to cleaning. In this case, we're integrating process control systems into our production line to monitor key process indicators. The items that we select in order to do so vary from time to time, but they basically default to industry standards and customer requirements. Therefore, if we were going to integrate these process control systems, we would look at such things as visual standards and get a yield report where we tracked it within control limits. We would also consider such things as what our reject rate was, day to day, week to week, and month to month. For visual rejects, let's say that for customer A, one out of every 1000 boards fails, and is consistent plus or minus one board on standard deviation. As long as they stay at that level, no problem. If our staff comes in tomorrow and finds that one out of 100 board is being rejected outright, then they realize that they have a problem and immediate action must be taken to correct this yield problem.

Look For The Hidden Costs of Cleaning

Once you have established your cleaning operation, keep in mind that the total cost of cleaning involves a lot more than simply investing in technology, i.e., the cleaning machine or equipment. So many different factors influence the overall cost including equipment cost, equipment/process efficiency, chemical costs, disposal costs, power consumption, floor space occupied, labor cost, maintenance, and more.

Surprisingly enough, the highest cost in the cleaning equation is the cost of operating the cleaning process including labor, chemicals and water. These costs alone usually account for 70% to 80% of the total cost of cleaning. Equipment cost is a relatively low cost compared to the overall cost of operation, particularly the labor of personnel required to operate the cleaner(s). Operating costs, not equipment costs, have always been the most significant elements in the cost-of-cleaning model. Conversion to no-clean assembly processes has driven up the costs of cleaning due to loss of efficiency in converting from in-line to batch processes. So, in the end, keep an eye on cleaning costs, as well as everything else. If your overall cleaning costs in a low to medium volume batch-cleaning environment seem overly expensive or appear to be rising, it makes good sense to look at contract cleaning as an alternative, as the cost may be lower than what you can do in-house.

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