

NEW METHODS FOR EVALUATING THE CLEANLINESS BENEATH LOW STANDOFF DEVICES

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ABSTRACT

The steady drum beat of miniaturization is driven by the insatiable demands of consumers for ever smaller, ever more capable, ever more reliable hand held and portable devices. These market moving trends have pushed technology development for the past few decades, and show no signs abatement. The combination of these requirements: smaller size, more capable, and more reliable are creating new demand for effective cleaning technology that heretofore was seen more commonly in military applications.

As cleaning returns to many assembly houses after a “none-too-brief” hiatus, many manufacturing engineers find themselves searching for standards and accepted metrics to enable cleaning process implementation. The purpose of this paper is to discuss the evolution and current state of the art for evaluating cleanliness of electronic devices including process design, process validation, and daily manufacturing floor quality monitoring. A detailed discussion of accepted industry standards, as well as new emerging techniques, is accelerating the evaluation and implementation timeline for hard pressed process design engineers.

BACKGROUND

The first question on every engineers mind after being assigned a cleaning project is “how clean is clean?” The short answer to that question is clean enough to meet your customers’ quality standards. However, there is a longer answer. One that is based on an array of methods, some developed decades ago that have stood the test of time. This paper reviews the dominant methods in use today, and attempts to present cleaning assessment methods that seek to answer the process engineer’s question of “how clean is clean.”

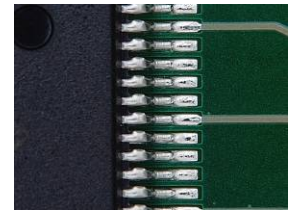
The industry’s views and approach to cleaning has evolved dramatically over the past 20 years. In the 80’s wave solder and thru hole ruled. Everything was cleaned and virtually all of it was cleaned with blends dominated by CFC-113. Early cleaning methods were subjugated by this near universal process. Since then we have progressed through the somewhat short lived semi-aqueous cleaning phase, then the aqueous phase, which was interrupted by the no clean era, and now we find ourselves fully immersed in lead free. Each of these

phases has had an affect on the methods of evaluating cleanliness, as well as what the appropriate cleanliness standard should be. Now we’ll look at these methods of assessing cleanliness and see how they were affected by the changes in the world at large.

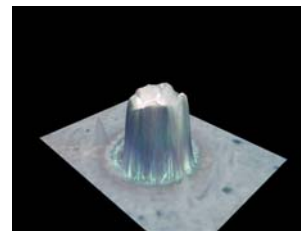
Method 1: Visual



Microscope well suited for production environment



Example of digital high magnification



Example of ultra-high magnification

While typically derided as unimportant, simply looking at the bare board or assembly often can be very informative. The sources of these unwanted residues that can be seen are many: particles from handling (fingerprints), packaging (airborne debris), embedded particles from upstream abrasive processes; flux and wave solder spatter; as well as solder balls from the reflow process.

So, there is plenty to see, but just how should we be looking? As with each of these methods, we need to consider just what task we are focused on.

An NPI shop and design houses should consider a well equipped digital microscope with photo capability that will allow thorough inspection of residues. Unless we’re focused on wafer level packaging, 100X should be plenty, though 400X is often more enlightening but can be much more costly. This same recommendation goes for the cleaning material suppliers. New product development requires careful scrutiny

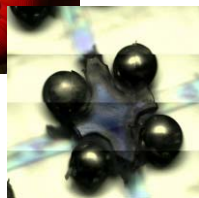
of results throughout the development cycle and product introduction.

If the focus is a quality inspection program then 10-15X is the norm most often without digital camera capability. This allows the inspectors a closer look, but keeps us well away from the noise level. Likewise, these scopes are very economical and within the reach of every assembly operation.

Method 1A: Visual followed by FTIR Analysis



Micro FTIR Device



Laser FTIR Image

The detection of any defect by any means always results in further analysis. While this subsequent evaluation can take many paths it always starts with a visual evaluation. Likewise, this visual evaluation will often identify an area of interest for further evaluation. If the area of interest presents a film or residue of some kind, then another helpful tool is Fourier transform infra-red spectroscopy or FTIR. This technology can be of great benefit for identifying organic residues.

Of particular benefit is an FTIR with laser microscope capability that allows for extremely precise μ FTIR analysis of a very specific location on an assembly. This non-destructive evaluation can be done on both test cards and production assemblies or devices. While the expense of acquiring and maintaining this instrument is quite high, its ease of use and speed are of enormous benefit.

Method 2: Checking for Ionic Residues



Typical ionic residue test device

Water soluble and ionic residues can easily be detected and measured. The industry standard test as detailed in IPC TM-650 employs a 2-propanol (IPA)/water blend. Known as the ionic contamination tester, there are several automated systems available to the industry each of which has performed well many years. The ratio of IPA/water varies by the instrument and method selected and reports results in $\mu\text{g}/\text{in}^2$ or $\mu\text{g}/\text{cm}^2$.

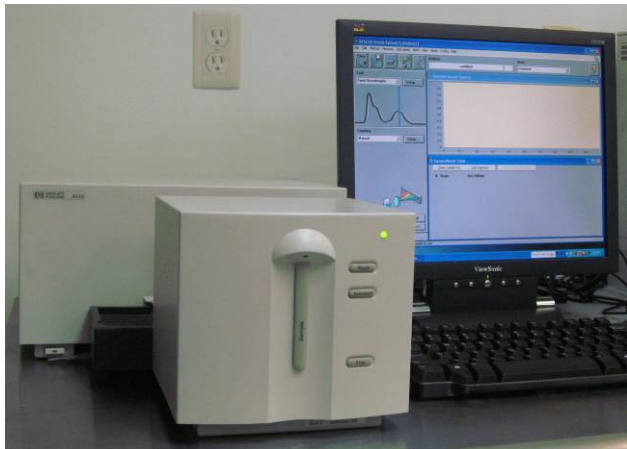
This method is widely accepted as an operation measurement of cleanliness. The test method takes minutes not hours which is required for production method of any kind. Likewise it requires limited sample preparation and the automated equipment allows for delegation to production personnel.

There are several potential problem areas to address. First, the results are reported per unit of surface area. It is important to remember that components and devices have surface area of their own and therefore simple measuring the PCB will not suffice for an accurate measurement. Secondly, the prevalent solvent of choice for this method is IPA due to its wide availability and low cost. However, though IPA is quite effective at absorbing ionic materials, it may not alert the user to residues not soluble in IPA that contain potentially problematic ionic residues that could cause trouble during the assembly's lifetime.

The ionic contamination test also gives us a bit of a window on how the requirements and expectation of what a clean assembly looks like have evolved over the years. Reviewing the IPC Aqueous Post Solder Cleaning handbook (IPC-AC-62A) dated January 1996 one finds a statement that identifies $1.59\mu\text{g}/\text{cm}^2$ ($10\mu\text{g}/\text{in}^2$) sodium chloride as the acceptable limit for military assemblies. At that time, the military was a strong influencer on general industry standards, and that $10\mu\text{g}/\text{in}^2$ was the defacto standard for cleanliness for assemblies cleaned in CFC 113 and the newer, non ozone depleting materials introduced to replace it. Today, most assemblies achieve readings between 0 and $1\mu\text{g}/\text{in}^2$ and modern, very dense military assemblies generally achieve readings well below $10\mu\text{g}/\text{in}^2$. This is a clear indication that new technology has improved performance and the industry has

responded by raising expectations and acceptable levels as well.

Method 3: Residual Rosin



Ultra-violet Spectrophotometry System

This method was used extensively during the transition period from CFC 113 to modern alternatives back in the 1990s. It involves a solvent extraction step which is then evaluated using High Performance Liquid Chromatography (HPLC) and Ultra-violet Spectrophotometry. This is not a method for the production environment due to the equipment required alone. Only the best laboratories in the industry have this equipment in place limiting its availability even for NPI work. Additionally, as the general trend in solder paste and flux technology is toward lower and lower levels of rosin in the popular no clean formulation, the importance of precisely measuring residual rosin comes in to question.

Method 4: Surface Insulation Resistance (SIR)



Atmospheric Control Chamber Element of an SIR System

One test that has continued to provide valuable data is SIR, though even this test is often misunderstood. SIR is normally evaluated using a test substrate with an interleaved comb pattern. The method exposes the test

pattern to cycling, controlled conditions of temperature and humidity as required by IPC –TM-650, Test Method 2.6.3. While some OEMs will simply incorporate such a pattern into a proprietary test board, it is common practice today to employ an industry standard test card commonly referred to as the umpire board (B-24, B-25 or B-36).

Due to the use of industry standard test cards rather than production parts, SIR testing is truly a process validation method compared to industry norms rather than a quality control method. As such this testing is conducted under a wide range of scenarios:

1. Supplier NPI Validation: Materials suppliers, such as cleaning materials and solder materials will often conduct SIR testing employing industry standard test cards of their newest materials to demonstrate compliance with industry norms.
2. User NPI Validation: Users will often conduct SIR testing to validate a new process. These OEM evaluations often employ a proprietary test card designed to represent the OEMs specific design environment.
3. EMS Provider NPI Validation: EMS is often required by their customers to conduct SIR testing to validate a new process. These EMS provider evaluations generally employ an industry standard test card to provide data with the broadest application for the EMS provider and their customer.

These test cards are then run through the 7 day (168 hours) temperature, humidity and bias cycling regime. Many OEMs and suppliers have their own SIR testing equipment, though third party laboratories are often used for capacity and independence reasons.

Method 5: Ion Chromatography (IC)



Typical Ion Chromatography System

This is one of the newer methods for cleanliness evaluation and was pioneered by Delphi Electronics (then Delco) in the early 1990s. This method is based on the principle that a specific list of corrosive and insulative ionic residues can be removed by a specific fluid media, and subsequent analysis of that fluid media can separate, identify and quantify the levels of those specific ions of interest. As we are searching for specific ions, it is important to understand that substrate handling and sample preparation are of even more critical importance for this method than any other. Once again, the expense of the equipment and the skills required to conduct the testing make this method inappropriate for nearly all production environments and even some testing facilities. Organizations with this expertise are far less common than or any other cleanliness evaluation method.

Like SIR, IC testing is intended for both NPI and detailed process change evaluations. The process fingerprint developed with IC analysis provides solid data for process validation and can be a critical element in identifying the root cause during failure analysis. Due to the time requirements and queue time at testing laboratories, IC testing is not a real time evaluation tool similar to SIR testing.

IC testing was developed to test for specific ions of interest. The industry standard method, IPC -TM-650, Method 2.3.28 identifies the ions of interest. The list includes Cl, NO₂, Br, NO₃, WOA, Na⁺, K⁺, NH₄⁺, Ca⁺, and Mg⁺. Test results are reported in micrograms of the individual ion of interest residue per square inch of extracted surface (µg/in²), unless otherwise noted. One should not confuse this measure with micrograms of sodium chloride equivalent per square inch, which is the common measure for most ionic cleanliness test instruments.

Method 6: Low Standoff Device Cleaning Evaluation Method

In recent years, as more and more low standoff devices are employed in wide ranging applications, there has been a need for new test methods particularly in the NPI and process validation areas.







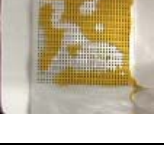
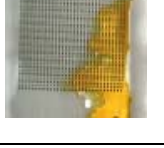

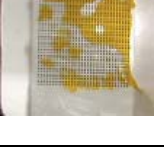





A process validation technique has been developed to evaluate the performance of specific cleaning materials, under various process conditions and to capture that performance on video for evaluation and comparison.

This method begins with glass slides. This is hardly a new technique, and was originally pioneered by Hollis Automation back in the late 1980s and early 1990s as a way to evaluate their innovations in machine design. However, the challenges of cleaning have changed much since then. This new method used a BGA type array of spheres under a large glass die. The die stand off can be adjusted to best match the process being validated. This

method also allows for the specific flux materials in use to be evaluated, providing a strong basis for correlation with the eventual assembly process.

The novel part of this new method is employing video technology to capture the actual cleaning process being used. This approach has significant benefits for each member of the value chain.

1. For the Cleaning technologist, it supplies previously unavailable data to evaluate the affect different product designs have not only on the cleaning end result but how the materials clean and at what rate.
2. For the Solder technologists, it also provides previously unavailable data sets. Contrasting known cleaning materials versus an array of flux technologies can and has provided valuable insights for use in future product development.
3. For the end user, it provides the data to refine and optimize their cleaning process to assure cleaning results under the die will meet the needs of their design and their customer's expectations.

Dynamic Energy	Approach A	Approach B	Approach C
Before Cleaning			
15 minutes			
30 minutes			
45 minutes			
60 minutes			

As table 1 shows, this technique allows the user to map results under the die on a time line. The ability to correlate this data with other controlled variables, such as, raw materials, soils and their raw materials, cleaning process design or process parameters is a truly enabling advancement for all the technologists involved.

Of course, these glass slides can be subject to some of the other test methods described in this paper to correlate these visual results with residue evaluation for non-visual residues for a comprehensive evaluation approach.

CONCLUSIONS

There are many methods available to evaluate cleanliness. The key is matching the recognized test method with the objective being sought, and bringing the right technology partners into the process for their abilities not only to conduct the testing but to evaluate the results and provide the analysis that will empower the decision makers to achieve their objective.