

# Advances in Cleanliness Testing

By Steve Stach, Chief Technical Officer

For the last fifty years, assessment of circuit cleanliness on manufacturing lines has relied heavily on two methods for maintaining daily control. Visual inspection identifies the bulk residues and resistance of solvent extract or “ROSE” testing identifies the ionic residues. These two process control methods remain today as the standard in assessing production cleanliness. But take a closer look and change is happening. Visual inspection by humans is being replaced by automatic inspection systems. They are not quite good enough yet to look under parts, but that day is coming. The current ROSE test, let’s call it the ROSE I test, was developed to assess flux residue under parts and other invisible ionic residues like finger print or plating salts. For many years the electronics industry has been searching for a new “ROSE II” test that could be tuned to the flux type and product requirements, and of course be automatic and free. That day also may be coming.

The original ROSE test method remains essentially unchanged since the mid 1970’s although the nature of soldering has changed considerably. In the 1980’s surface mount technology replaced the traditional wave soldering process. Cleaning changed significantly with the Montreal Protocol banning the use of most halogenated hydrocarbons used to clean circuit cards. This led to the introduction of low activity no-clean fluxes. Following the turn of the century, circuit manufacturing underwent another major soldering change, the introduction of lead free soldering alloys. Higher reflow temperatures required new changes to the fluxes, and that again changed the cleaning requirements.

The ROSE test was developed in the 1960’s as a method to quantify the amount of activated rosin flux residue remaining on a completed circuit assembly. A mixture of isopropyl alcohol and de-ionized water was selected as the extraction solvent to dissolve the rosin based flux. The ROSE method quickly gained acceptance and was incorporated in the US military specification, Mil-P-28809 in 1971. It required a sample board to be pulled from normal production and a daily ROSE test performed. In 1994 the Mil-P-28809 requirement was dropped for US military contracts and the ROSE test was further defined and incorporated into the generally recognized industry standard set forth by the IPC.

A lot has been said about the validity of the current IPC ROSE test. Some say it is no longer valid because most new flux residues are not soluble in the IPA/water extraction solvent. Others have concerns about contaminated board escapes allowed by sample testing versus 100% testing of all product. The key to updating the current test method hinges on two improvements. First, we need to eliminate sampling and test 100% of all product cleaned. This means inserting the ROSE test into the cleaning process. We also need to look at using extraction solvents other than IPA and water mixtures.

To accomplish this, let’s look at what ROSE testing is and how it works. In theory, an extraction solvent, presumably one that dissolves the flux and other ionic residue remaining, is flows across the circuit for some time and dissolves the remaining residue. The amount of residue removed is then determined based upon a drop in the resistance in that solution.

## ROSE Testing in Batch Cleaners

To achieve this in a batch cleaner, the ROSE test is inserted after flux cleaning the final rinse and before drying as shown in figure 1 below.

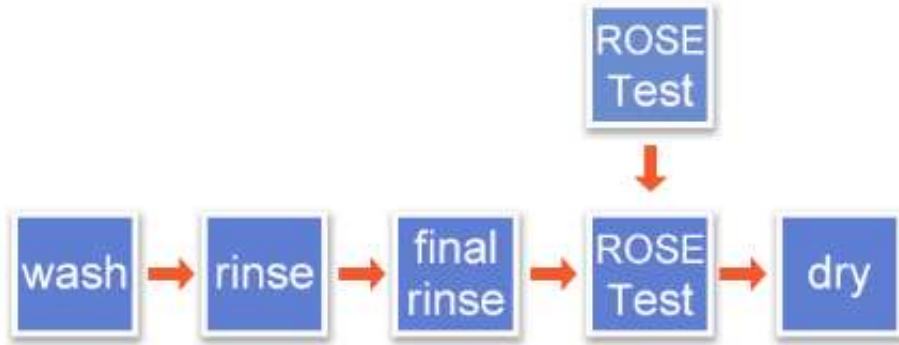


Figure 1: Batch cleaning sequence showing ROSE test insertion

It is customary in batch cleaning process to rinse to a programmed resistivity/conductance level before drying the assemblies. Once that level has been achieved, a ROSE test can automatically be performed by continuing to flow the rinsing fluid over the parts for a few more minutes while monitoring the resistance of that fluid. The final cleanliness level can then be calculated in the same way it is currently.

## ROSE Testing in Inline Cleaners

Incorporating ROSE testing into an inline cleaner requires a slightly different approach because continuous product movement from section to section is not practical to isolate a single assembly in a test chamber for an extended test time. First a board ID system must be added to the cleaner so each assembly being cleaning is identified with the proper circuit area. Incorporating automatic ROSE testing requires a modification of the final rinse plumbing and the addition of a board tracking system in the cleaner. The modifications as shown in figure 2 allow an individual assembly to be tracked as it progresses through the cleaner. Upon arrival in the final rinse the decrease in resistivity can be recorded providing the data to calculate the cleanliness level in sodium chloride equivalent per square centimeter.

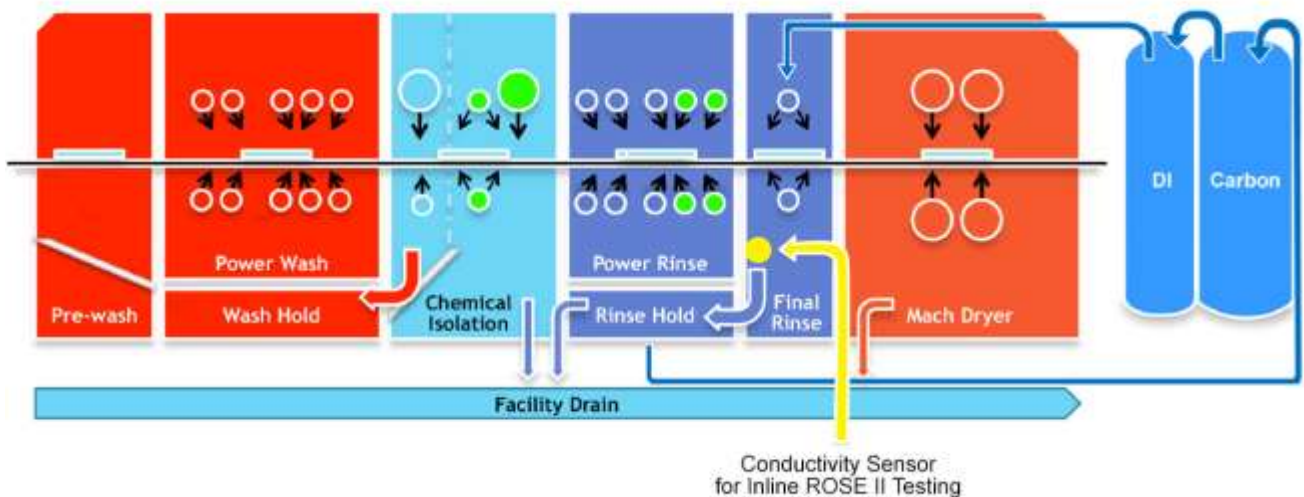


Figure 2: Inline modification allowing automatic ROSE testing.

The unpopulated belt with constant DI flow will produce an equilibrium baseline as shown in graph 1 below. When an assembly enters the final rinse section an increase in conductance of the flowing water is recorded. Software then measures the area under the curve which corresponds to the final cleanliness level.

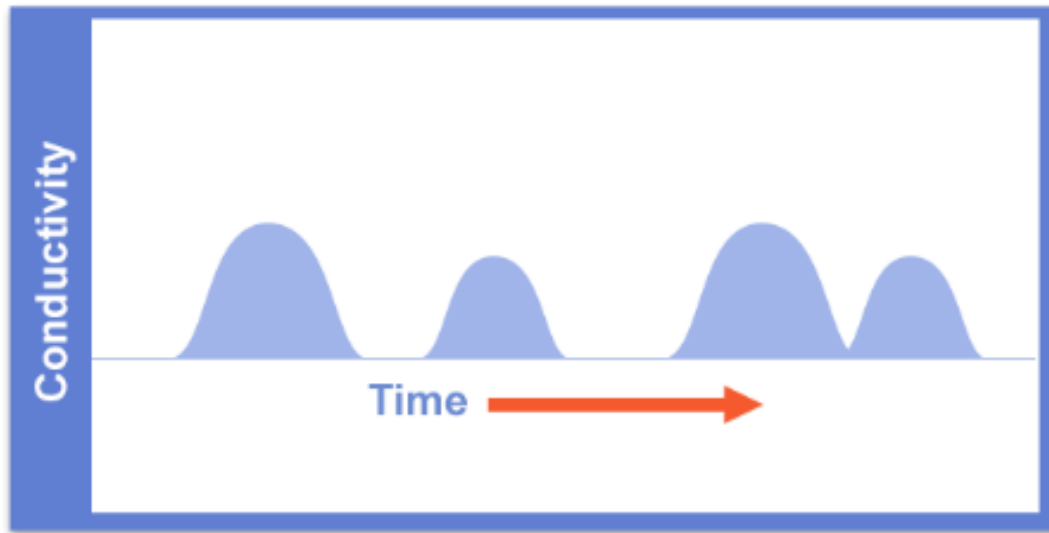


Figure 3: Inline ROSE data

### **Currently Allowable ROSE Extraction Solvents**

The current IPC and Military Spec strictly require the extraction solvent to be a mixture of isopropyl alcohol and water. A ratio of 75% IPA and 25% water plus or minus 5% is most common although some latitude is allowed in this ratio depending on the individual test procedure. Incorporating these flammable extraction solvents into modern cleaning systems requires special design and is impractical. A better approach is to use the purified rinsing agent, generally DI water to perform the ROSE test. As mentioned above this requires a relatively minor plumbing modification for most cleaners and new software.

### **Free Ions versus Inactivated Ions**

The original ROSE test protocol defined in Mil-P-28809 in 1971 was intended to detect residual ionic residue after cleaning trapped in a rosin based flux on a single assembly days or weeks after the cleaning process. That meant that the residues were dried and in a solid salt form on the board's surface and most likely locked in a hardened matrix of rosin flux residue. These flux activators remained potentially active if water was in the operating environment.

In the 1990's a whole new class of fluxes was adopted by a majority of electronic manufacturers. Today we have several flux types which in most applications are safe to leave behind on the board's surface because the flux activators have either locked in a hardened crystalline matrix or evaporated in the soldering process.

### **New ROSE II Theory**

ROSE II protocol focuses on measuring 100% of the product in the cleaning process by inserting the cleanliness test between the final rinses and drying the assembly. The ionic residues remaining after cleaning and rinsing are still free ions in solution. These ions are typically flux activators or amines used in the flux cleaning agents. They are hidden and held by capillary forces in the small gaps under components and in blind holes and cavities in connectors. In a ROSE II contamination control protocol one wants to leave these deactivated residues intact and avoid problems with partially cleaned white residue often found after cleaning some no-clean fluxes with IPA/water. With ROSE II theory we want to quantify the final amount of free or dissolved ions that would remain on the circuit's surface when the rinsing solution is dried.

## New Ion Extraction Solvents

The greatest technical problem with the current ROSE test is the inability to change the extraction solvent. IPA/water is not a good choice for an extraction solvent because so many manufactures today are cleaning no-clean fluxes. It is also and health and safety concern due to it's flammable. Performing a ROSE test with the current 75/25 IPA/water mixture on an assembly soldered with no-clean fluxes can lead to serious cosmetic "white residue" problems unnecessarily. Ideally we want an extraction solvent designed to detect free ions and not to affect adversely any un-cleaned residue remaining.

Water is a much better extraction solvent for "free ions" on the circuit boards. The water's high polarity makes it a better extraction solvent than the IPA/water mixtures. In addition water is approximately four times more sensitive to change in conductance ion concentration than the current extraction solution. This relationship is shown in figure 4.

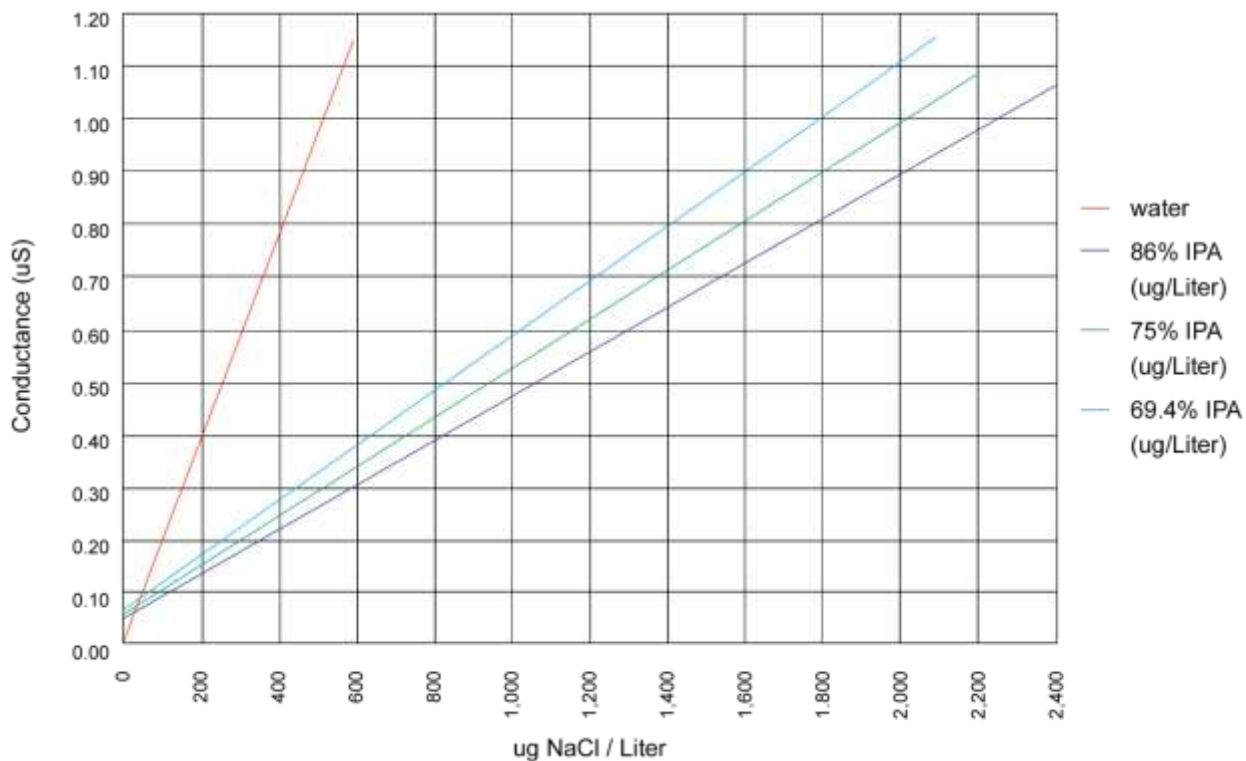


Figure 4: Response of Water and IPA/water mixtures to NaCl

Any solvent which gives a predictable change in conductance with change in ionic concentration would now be a candidate as a viable extraction solvent. The sensitivity of a given solvent's bulk electrical conductance with increasing ionic concentration should be linear over the concentration range. Most ions give a linear response when concentrations are less 10% by weight as shown in figure 5 following.

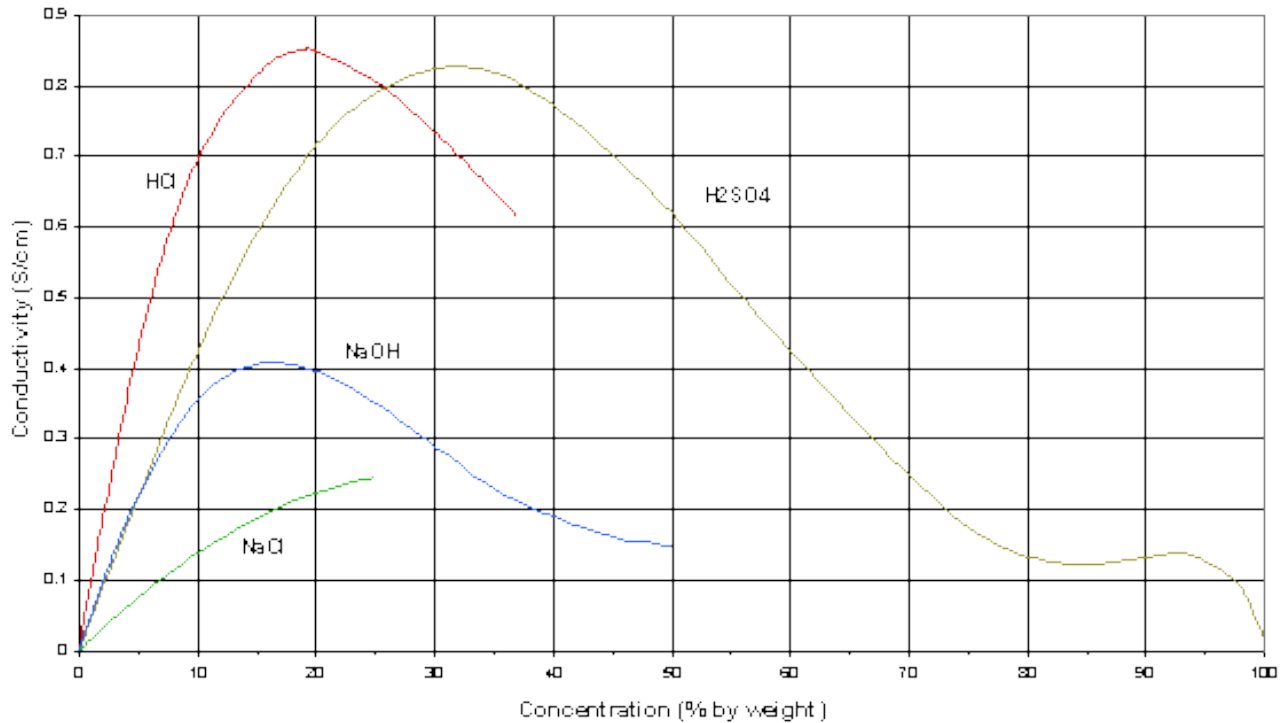


Figure 5: Graph of Conductivity vs Concentration showing linear range below 10% Concentration  
 \*source:Langes Handbook of Chemistry

The rate of change in conductance with ionic concentration is defined to be the solvent sensitivity value (SSV). This can be determined by measuring the slopes of the data plotted in figure 4. Once this value is established for any given extraction solvent or solvent blend the following equation shown in figure 6 can be used to determine the total ionic content removed in testing.

$$\text{Total Ionic Contamination} = \text{Test volume} \times \Delta \text{ Conductance} \times \text{SSV}$$

Where

Test volume = volume of the extraction solvent used

$\Delta$  Conductance = the change in conductance in the extraction solvent start to finish

SSV = Solvent sensitivity value  $\Delta$  Conductance/ $\mu\text{g NaCl}$

Figure 6: Equation for calculating total  $\mu\text{g NaCl}$  eq. extracted

### New Ionic Contamination Limits for ROSE II

There will be a need to adjust the ROSE II process integrated test limits to correlate with established ROSE I limits of  $1.56 \mu\text{g NaCl eq./cm}^2$  because for inherent differences in the two testing methods. The first difference that should be noted is that all boards are tested in ROSE II protocol. When an assembly is tested by a solvent extraction method like the ROSE test the ions measured were removed from that board leaving the board cleaner than it was before the test. When we report the ionic cleanliness for a board or a batch of boards, we need to report it as less than, not equal to the value calculated amount of contamination. This may seem like a small difference but depending on whether the dryer strips or

evaporated the rinse solution, it could be much less when measured with ROSE I methods. These off-sets are easily determined by comparing ROSE I results with ROSE II results.

## **Conclusions**

ROSE II testing protocols allow manufacturers to take the next big step in controlling the ionic cleanliness of circuit assemblies. Incorporating automatic ROSE testing into the cleaning process requires minor cleaner hardware modification, a board tracking system, and software to interpret and record the cleaning results. ROSE II protocol expands the extraction solvent choices to any solvent that responds predictably including water and other organic solvents and blends thereof.

Adding automatic ROSE testing to the cleaning cycle makes sense from several points of view. First it costs extra to purchase a cleaner equipped with integrated ROSE testing. It's a programmable feature that can be turned on or off in the software. ROSE II data is immediately available to be acted upon versus periodic sampling used in ROSE I protocols which leaves gaps of exposure where ionic levels could exceed control limits. Finally a better controlled cleaning system will produce a product that has lower over-all ionic levels insuring high production yields and better product reliability. The savings to manufacturers and consumers of their products will be substantial.

## **Recommendations**

Circuit manufactures should adopt the new ROSE II protocol in addition to the ROSE I sampling plan to achieve the advantages of 100% cleanliness testing of product.

Circuit Assemblers, Equipment Suppliers and Industry Organizations should work to correlate, implement, and agree to new standards for ROSE II testing for the mutual benefit of the industry and its customers. Rose I protocols should be used to establish and validate ROSE II limits.

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