

HOW CLEAN IS CLEAN

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INTRODUCTION

For over 40 years, the electronics industry has been seeking ways to determine an answer to the thorny old question: How clean is clean?

Meanwhile, others were plotting ways that they could monitor the quality of their production process with specific regard to the presence of ionics (salts) that conspire to cause circuit failure.

They figured that using a blend of alcohol with de-ionised water would be an ideal medium, measuring its conductivity before and after.

Why Alcohol? Because conventional rosin based fluxes used at that time were soluble in alcohol.

Why water? Because salt dissolves in water.


So, mix 75% propan-2-ol (IPA) with 25% de-ionised water and use a mixed resin filter (a mixture of Cation, Anion and Chelate) to “strip out” ionics as they pass through the medium.

How it is done

Mix Alcohol (IPA) with de-ionised water at a ration of either

- 75% to 25% or
- 50% to 50%

Measure the resistivity or conductivity of the solution

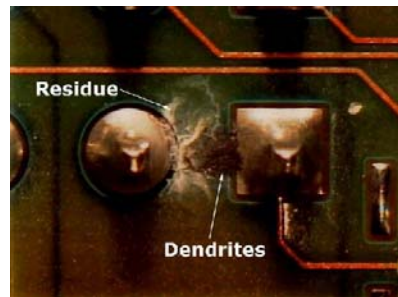


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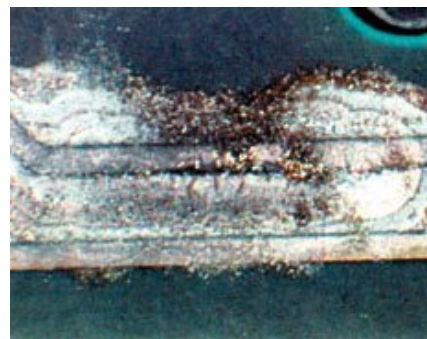
Clean the test tank and its contents to a determined Conductivity level, expressed as micro-Siemens (μS); put the object to be tested into the tank and measure the change to the conductivity. Extrapolate the result as an equivalence of NaCl – plain salt – and you now have a record of the amount of ionics your process leaves on, or puts on, the circuit assembly.

The names employed for this test are: ROSE or SEC:
ROSE = Resistivity of Solvent Extract
SEC = Solvent Extract Conductivity

Those seeking better process control had found an ideal tool – a measurement of ionics that might be present on a selected sample. Then, during the working day, changes in the level detected would be a really good indicator that the process was in or out of control.



Ionics take several forms and from many and various process steps, some are more soluble than others. If they are present on your circuit and are exposed to moisture in the presence of electricity, then an electrolyte is formed, electro-chemical reactions occur, and that results in dendrites – inter-metallics between the cathode and anode that provide a path of lower resistance leading to short circuits and/or circuit failure.



In the 1970's the US DoD considered that this might be a useful test to control cleanliness in production and established a “Pass/Fail” at a level of $3.1\mu\text{g}/\text{cm}^2$ ($20\mu\text{g}/\text{inch}^2$) of NaCl equivalence with “Dynamic” Testing and $1.56\mu\text{g}/\text{cm}^2$ ($10.06\mu\text{g}/\text{inch}^2$) of NaCl for “Static” Testing.

This was not such a good decision for two reasons:

1. Because, by logical extension, it indicated that you could safely leave UP TO that amount of measurable ionics (SALT) on your assembly surfaces.

2. There is no difference between Dynamic and Static, both test methods now require $1.56\mu\text{g}/\text{cm}^2$ NaCl equivalence and the dictum remains: "it's OK to leave that amount of salt on my assembly."

As many have found to their considerable cost, it is not.

TEST TIME

This is important because exposing any circuit assembly to a mixture of alcohol and water for 15 minutes or more significantly increases the risk of other ionics leaching out of the laminate and onto the surface (Swedish Institute for Production Engineering Research - IVF report 1990).

HOT OR NOT?

It has been suggested that the test solution used may be heated to 40°C or more.

No. Apart from the fundamental changes in conductivity, and its effect upon test accuracy, it significantly increases the risk of sub-surface ionic leeching as well as posing an explosion risk. Note that the test solution flash-point is 19°C at ambient temperature.

STATIC V DYNAMIC WHAT'S THE DIFFERENCE?

IPC-TM-650 2.3.25 & 2.3.25.1 permit the use of either Static or Dynamic test methods.

Whilst both methods should yield the same result, good test methods should have only 1 variable being the item under test. The Dynamic Test method, by its very nature, has an additional variable in that it behaves more like a cleaner with the test solution passing the conductivity probe, the filter and back into the tank. In this way the test solution is being continuously cleaned during the test.

The Static Test, by contrast, re-circulates the test solution via the conductivity sensor but bypasses the ionic exchange filter thereby removing this important variable.

SATURATION – IS THIS A PROBLEM?

Some talk about a "Saturation" problem with Static testing. Given that:

- The Test System may commonly be calibrated up to $30\mu\text{g}/\text{cm}^2$ of NaCl equivalence
- The pass/fail level is $1.56\mu\text{g}/\text{cm}^2$ of NaCl equivalence

If your process was producing boards that had a contamination that was going to send the solution into saturation it would be well above $30\mu\text{g}/\text{cm}^2$ – You should be more concerned about stopping your production process than worrying about the solution saturation!

TEST TANK SIZE – IS IT IMPORTANT?

When selecting a Test System, it is important to use the smallest possible tank size for the circuit under test. As outlined in IPC-TM-650 2.3.25.1:

6.10 There is some concern regarding ROSE tester cell size. Testing a 2 cm x 2 cm [0.79 in x 0.79 in] board in a 20,000 mL cell causes such a severe dilution as to cause the signal to be lost in the noise. A recommended cell size is 5000 mL or less. Smaller cell volumes will allow for a more measurable result. If a smaller cell, or running with a smaller test volume, are not an option, then the number of bare boards can be increased, all extracted separately, and the extract solutions all tested at once.

In a further attempt to destroy any arguments regarding that most heinous subject: The "Equivalency Factor". There is no such thing!

If the test system is working correctly, during calibration you put a quantified amount of NaCl solution into the test tank and the system should be capable of recording the amount – precisely. If it doesn't, then there is something fundamentally wrong with the machine.

From IPC-TR-583 An In-Depth Look At Ionic Cleanliness Testing:

Once the test method and the pass/fail criteria were established, equipment manufacturers began designing and building systems to do this type of testing. Due to efficiency, or perhaps the slightly different measuring process, it was noted that the new equipment would typically give higher results than that of the beaker/funnel technique. In 1978, a second study was performed at NAWC⁴ to establish "equivalency factors" for some of the new equipment which would be incorporated into various military standards, such as MIL-P-28809 and WS-6536. The theory behind the "equivalency factors" was that the same PWA that measured $10.06\mu\text{g}/\text{in}^2$ using the beaker/funnel test would have measured $14.00\mu\text{g}/\text{in}^2$ in a static system, and $20.00\mu\text{g}/\text{in}^2$ in a dynamic system under the conditions of the study. As the years progressed, more advances were made to the equipment such as the incorporation of solvent heaters, microprocessors, and sprays. As the efficiency of the systems increased, it became increasingly apparent that the equivalency factors established for the 1978 equipment did not apply to current equipment. In addition, equipment introduced to the market after the study are not mentioned, even in the revised standards, and erroneously not considered as accepted test equipment by potential users.

Good cleanliness test systems need to be:

- Accurate
- Reliable
- Repeatable
- Simple to use
- Easy to maintain

They also need to:

- Reduce test time to a minimum
- Take account of
 - temperature,
 - circuit volume
 - atmospheric absorption of iogenic gasses
- Avoid polarisation effects between electrodes

If you are making a purchasing decision on a system keep in mind:

- Does it use "curvefitting" algorithms that reduce test time
- Use a pure gold sensor to improve accuracy and reduce maintenance

- Measure at accuracies of better than 0.005 μ S

You should ignore any

- suggestions of using heated test solution
- suggestion that there is a difference between
- Dynamic and Static Testing – there's isn't any suggestions of saturation effects – it is irrelevant as the level of contamination to achieve that condition would be so great.

BUT IS THIS THE ONLY WAY TO ANSWER THE ORIGINAL QUESTION – HOW CLEAN IS CLEAN?

Well, no it isn't. It is surely the quickest and simplest check that your production process is under control but it is important to recognise that these "Cleanliness Testers" are NOT cleanliness testers; they are IONIC CONTAMINATION TESTERS. They do NOT inform about the presence of non-ionic contaminants of which there are many.

NON-IONIC CONTAMINANTS?

Yes. An enormous variety of surfactant additives in various process chemistries:

- Solder resist
- Solder flux, wire, paste
- Adhesives
- Cleaning chemistries

They are mostly used as wetting, levelling or de-wetting agents that can contribute to failure by adverse electro-chemical reactions especially if the manufacturing process does not include cleaning.

SO WHAT ARE THE ALTERNATIVES ANSWER THE QUESTION?

It is not the intention of the author to now examine in detail each of the alternative test method's, rather it is to simply highlight these alternatives to better appreciate why ROSE testing is such a preferred technique.

ION CHROMATOGRAPHY (IC)

IC is based on the use of specialised column packing for separation of ions that is able to separate, identify, and quantitate ions in a sample matrix allowing the separation of ions and polar molecules based on their charge.

Advantages:

- Highly accurate – it can identify exactly what kind contaminants on the boards, and help to trace back the root cause of problem of each production process
- Can be used as a quality control tool, eg. for goods inwards inspection on a sampling basis (ie solder mask cure)
- Excellent species differentiation
Can be employed for localised contamination

Limitations:

- Requires highly skilled operators

- Expensive to run
- Time to run test \square 15 minutes
- Ion Chromatography will tell you exactly what is on the surface under test, it will NOT tell you whether the end product will be reliable.

FTIR - FOURIER TRANSFORM INFRARED SPECTROSCOPY

This is a measurement technique whereby spectra are collected based on measurements of the temporal coherence of a radiative source, using time- domain measurements of the electromagnetic radiation or other type of radiation. It involves collecting infrared spectra, but instead of recording the amount of energy absorbed when the frequency of the infra-red light is varied, the IR light is guided through an interferometer. After passing through the sample, the measured signal is the interferogram.

Advantages:

- Highly accurate – it can identify exactly what polymers may be on the boards

Limitations:

- Requires scientifically trained operators
- Expensive to run
- Generally run off-site at independent laboratories
Like IC, it will tell you exactly what it has found (polymer contaminant) but it will NOT tell you whether the end product will be reliable with it's presence.

SIR TESTING = SURFACE INSULATION RESISTANCE

This principal involves an inter-digitated test pattern to which is applied an electrical bias. It is then measuring the degradation or changes to surface insulation resistance.

Advantages:

- Determines the effects of both ionic & non-ionic contamination
- Demonstrates the electro-chemical compatibility between ALL process materials
- Can be used to monitor material trends
- A quantitative not a qualitative test method
- Works in conjunction with ROSE / SEC
- Predicts whether your end product will be electro-chemically reliable

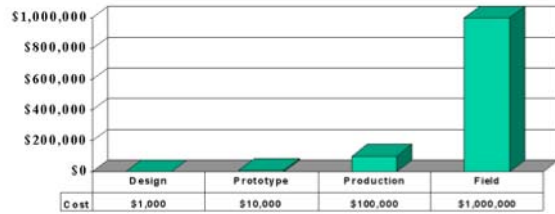
Limitations:

- It requires skilled operators
- Requires dedicated equipment
- Is carried out on dedicated test coupons that are representative of the end product
- Takes a long time - not less than 72 hours
- Expensive
- It will tell you if the end product will be reliable, but it won't tell you what's there causing a failure.
Then IC or FTIR are required

In summary and by my recommendation:

- 1 Decide on your preferred process material mix and run SIR qualification tests
 - a. Use the IPC B52 Test Coupon/Vehicle that includes ROSE and IC snap-off coupons
- 2 Analyse any failures using IC or FTIR
- 3 Use ROSE / SEC tests to maintain process control
- 4 Use SIR to monitor material quality by trend analysis

Cost of repairing mistakes increases roughly by an order of magnitude at each stage



Courtesy of Harvard Business School ("Business Week" Magazine)