Utilizing and Understanding the Various Methodologies for Evaluating Ionic Cleanliness of Printed Wiring Assemblies

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Topics Discussed

- Reasons to Evaluate / Monitor PWA Cleanliness
- Cleanliness Evaluation Techniques Covered in this session:
  - Resistivity of Solvent Extract (ROSE)
  - Ion Chromatography (IC)
  - Surface Insulation Resistance (SIR) Testing
  - Electrochemical Migration (ECM) Testing

Why Evaluate PWA Cleanliness?

Most importantly because YOUR products affect lives!

Additional Reasons to Evaluate Cleanliness

- To baseline residues not directly related to YOUR assembly process.

- To understand the residues left by YOUR assembly operations and how they impact YOUR product.

- To be proactive in capturing residue issues before they become an issue.

Test Methods

- There are numerous methods that can be used to evaluate the cleanliness of your assemblies.

- This talk focuses on four of the most commonly used cleanliness evaluation techniques.

  - 1. Resistivity of Solvent Extract (ROSE)
  - 2. Ion Chromatography (IC)
  - 3. Surface Insulation Resistance (SIR) Testing
  - 4. Electrochemical Migration (ECM) Testing

ROSE Method Background

- Principle of method was developed by R.J. DeNoon and W.T. Hobson of the Naval Avionics Center in the 70's.
  - Why 75 % / 25 % IPA and Water?
  - Conductivity was basis of residue measurement
- Their method became part of MIL-P-28809 (DoD Spec for Acceptability of Military PWA's).
- This ultimately led to adoption of the method by the commercial industry, through MIL-P-28809, MIL-STD-2000, and J-STD-001
- Instruments were later developed (late 70's) to automate the test.

ROSE Testing

- ROSE has become the most prevalent cleanliness evaluation technique for two reasons:
  - Cost
  - Ease of use

- There are two types of analytical approaches used in ROSE testing:
  - Static: refers to to a closed-loop system that re-circulates the 75/25 extraction medium through the conductivity detector without being passed through the anion / cation exchange cartridge. The result is the accumulation of the residues extracted over the test duration.

  - Dynamic approach uses an integration of the residues over time. The extract solution is continually filtered through the anion / cation exchange cartridges and the results are plotted over time.

ROSE Data

- J-STD-001 Limits
  - 1.56 micrograms / cm^2 of NaCl equivalence.
- This has nothing to do with how much sodium or chloride residues are on the assembly.
- This historical value was derived for high solids (>30%), rosin-based fluxes with solvent cleaning using a room temperature extract solution.
- The limit is not really applicable today. Why?

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Applicability of ROSE Data

- All extraction tests are based on solubility of the soil, temperature of solution, and time of extraction
  - Older instruments: room temperature, 10 minutes
  - Newer instruments: elevated (45C), 10 minutes
  - Typically, no one runs it longer because it could mean failure

- Modern fluxes, especially low residues, are not made to be soluble, at least at these conditions

- ROSE Test Limitations per IPC-TR-583
  - Showed that the ionic cleanliness testers (circa 1995) were neither repeatable nor reproducible, and that the "equivalency" factors were meaningless.

Our Experiences with ROSE Data

- Insufficient detail about process residues.
- When you see an increase, you don't have a clue as to what is causing the increase.
- Field failures have occurred despite passing ROSE testing.
  - Broad blade ax vs. surgeon's scalpel
- ROSE data + IC + Other product reliability testing

What Is Ion Chromatography?

- Developed in the 70’s by Dow Chemical Company.

- IC allows for the separation of numerous ionic species by incorporating the following:

  - Mobile phase = eluent (chemical for moving the ions through the column)
  - Pump
  - Solid phase = analytical column
  - Suppressor = filters background noise from eluent
  - Conductivity cell and detector

Ion Chromatography

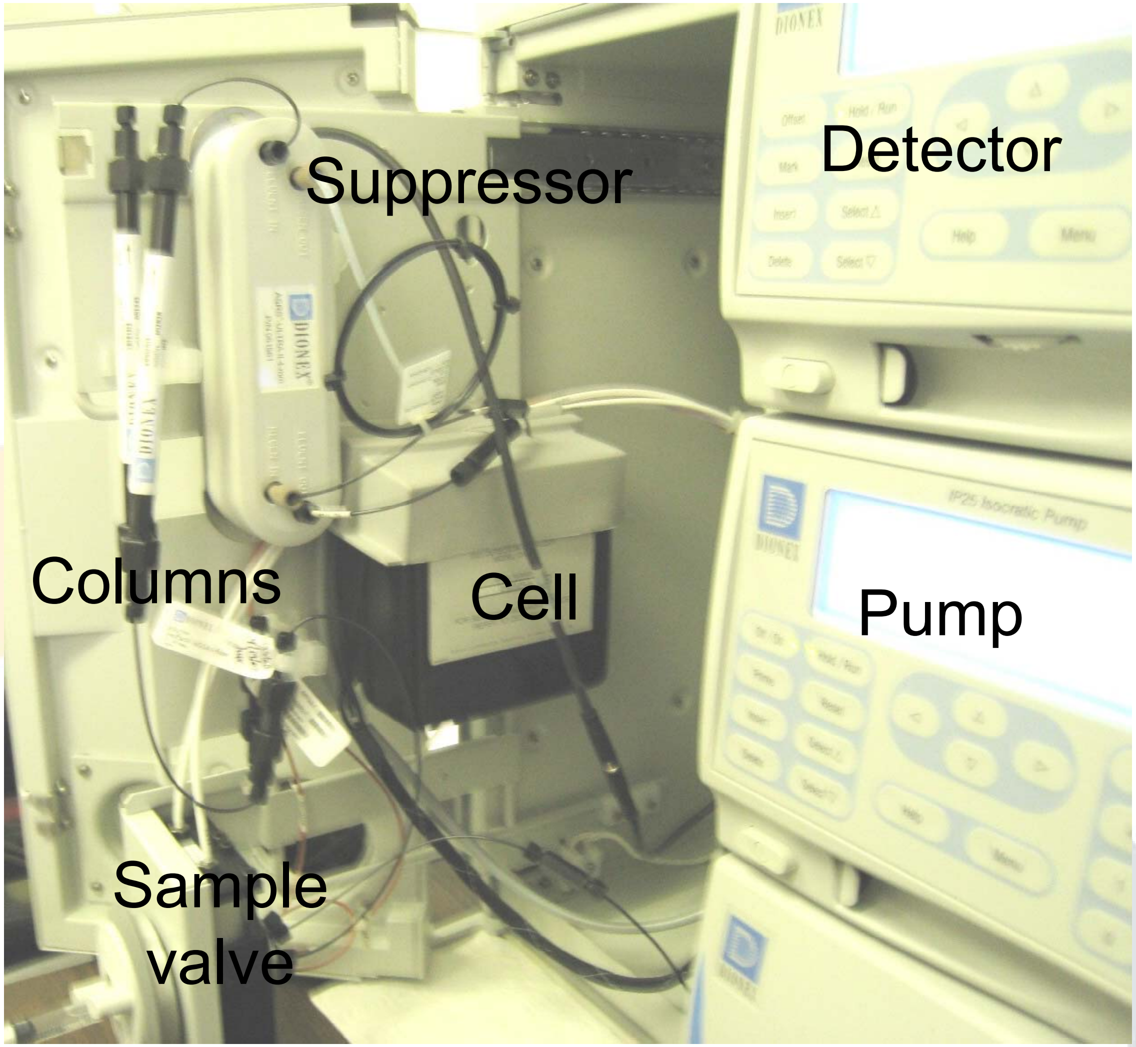

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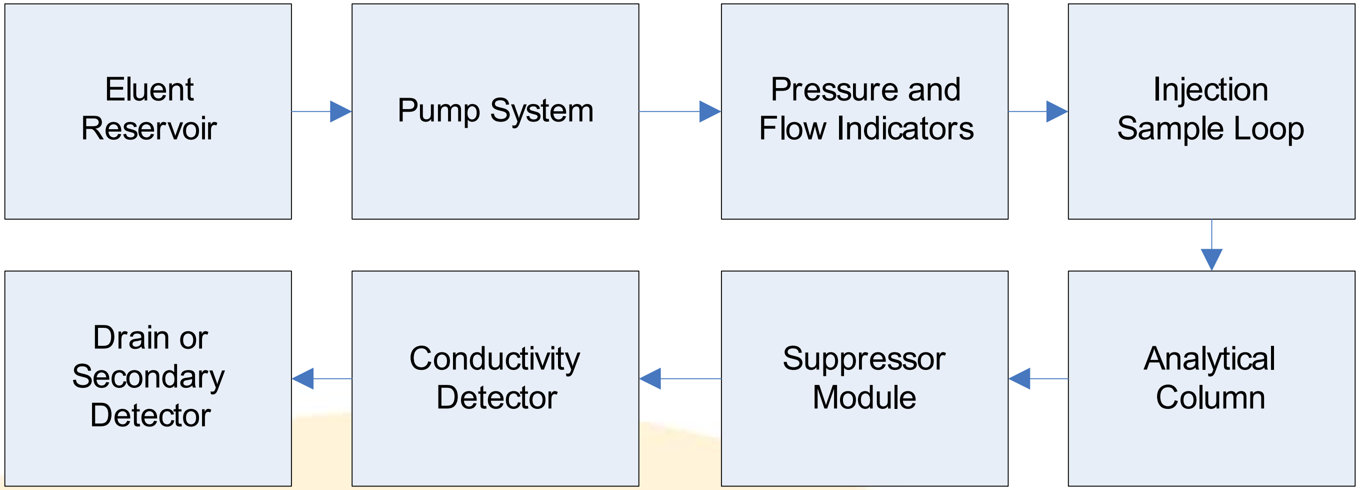
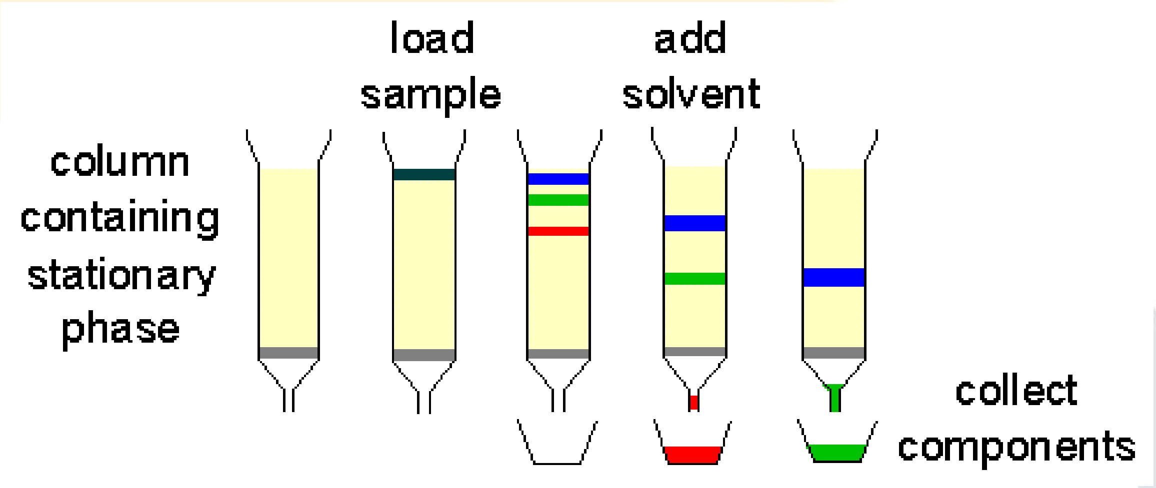
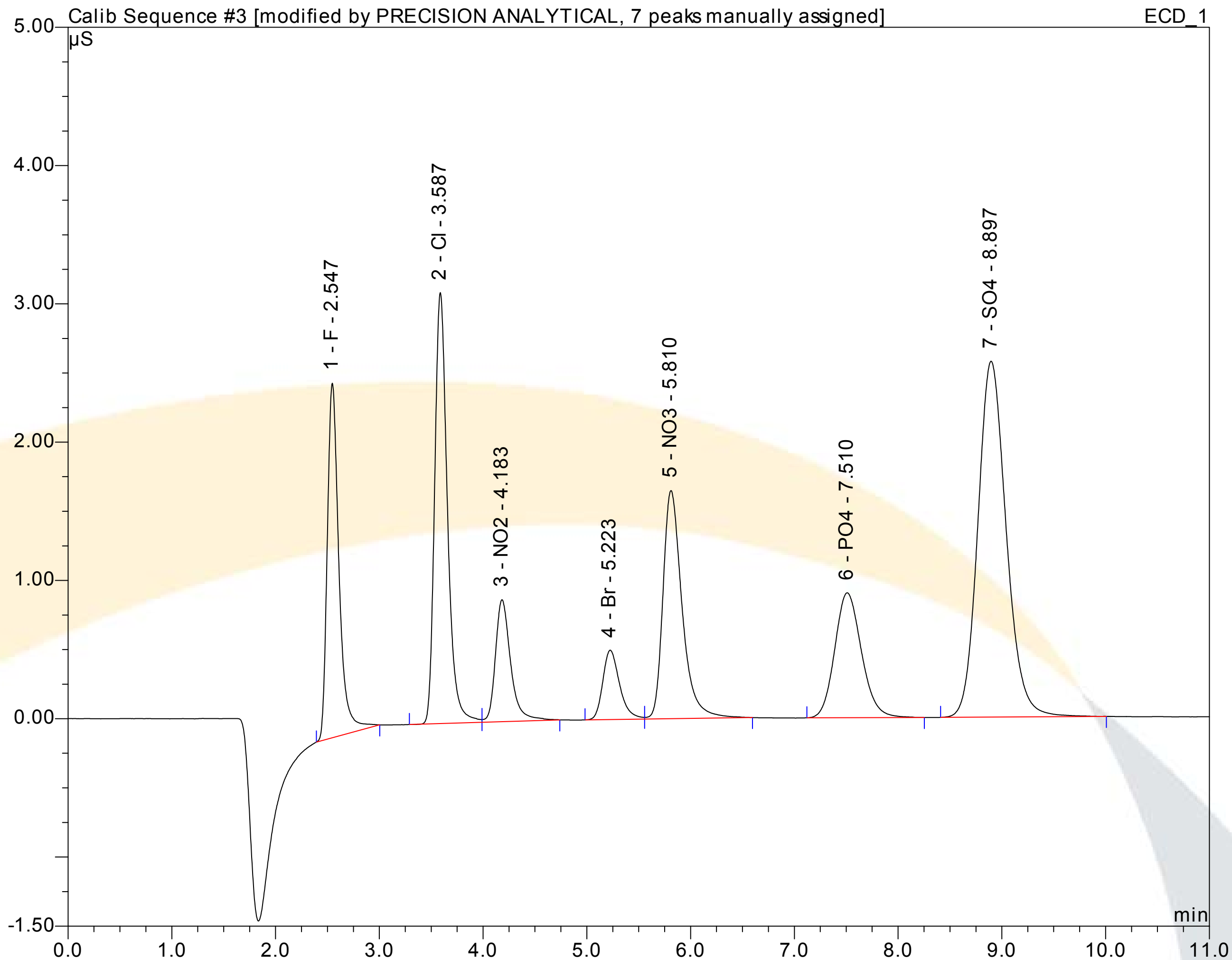
Illustration





Chromatogram



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How is IC Different?

- The IC method utilizes the same extract solution as ROSE – 75% IPA / 25% DI water.

- Assembly extraction methodology (more rigorous)

- Typical ions analyzed by IC:
  - Anions: fluoride, chloride, bromide, nitrate, nitrite, phosphate, sulfate
  - Common organic anions: formate, maleate, succinate, acetate, citrate, adipate, methanesulfonate
  - Cations: lithium, sodium, magnesium, potassium, ammonium, calcium

IC - Data

- Ion Chromatography not as widely used as ROSE
  - More capital intensive (though costs are coming down)
  - Takes longer than ROSE to run
  - Requires a more skilled person to run the IC
  - Requires a more skilled person to interpret the IC
  - Higher cost on a per sample basis
- So why implement ion chromatography?
  - The investment pays for itself
  - Selectivity and Sensitivity
  - Gives exceptional insights into the manufacturing process for process troubleshooting and process optimization
  - White paper on setting up ion chromatography

IC – Pass Fail Levels

- Pass / Fail Criteria
  - Assemblies – User Defined
  - Bare PWB's – Delphi Electronics Specification Adoption

- The days of the "one size fits all" cleanliness criteria are gone. That horse has left the barn.

- Cleanliness needs to be viewed as a sliding scale of risk, not a go/no-go value.

- Several test labs have recommended ion-specific levels to be used as cleanliness breakpoints until more focused product-specific tests can establish better values.

Recommended Starting Points

Condition	Chloride Cl	Bromide Br	Nitrate NO3	Phosphate PO4	Sulfate SO4	Organic Acids
Bare Board (Non-HASL)	< 1.0	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	PI
Bare Board (HASL)	< 2.0	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	PI
No Clean Assembly						
Surface Mount Only	< 2.5	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	5 - 20.0
Mixed Technology	< 2.5	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	20 - 50.0
Through Hole Only	< 2.5	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	50 - 100
Post-Assembly Cleaning						
Surface Mount Only	< 4 - 5.0	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	5 - 20.0
Mixed Technology	< 4 - 5.0	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	20 - 50.0
Through Hole Only	< 4 - 5.0	< 12.0	< 3 - 5.0	PI	< 3 - 5.0	50 - 100

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Performance Testing

- Residue specific information itself is not enough and does not always predict reliability. It only gives you a snapshot of the residues present.

- You have to correlate the amount and kind of residue to some measure of electrical performance or estimate of field service reliability

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SIR and ECM Testing

- SIR / ECM testing are techniques that give insight on the propensity of a material system for electrochemical failure mechanisms.
  - Electrolytic corrosion, electrochemical migration, electrical leakage
- Five elements must be in place to initiate and sustain such failures:
  - moisture, an electrical potential, a sufficient level of ionic residue, temperature and time

SIR and ECM Tests

- All are a form of accelerated aging, trying to determine in a short period of time what will happen in field service
- A wide range of SIR/ECM test methods
- The more modern SIR tests are based on the work of Dr. Chris Hunt, NPL, UK
  - 40C / 93% RH with an applied bias of 5 VDC, 4-7 days
  - More stringent that the historic 85 C / 85 %RH with 50 and 100 VDC applied biases.
  - The argument (substantiated) is that the new environment preserves the residues rather than evaporates them, as occurred with the traditional 85 / 85 environment.
  - Still it is up to the user to define for their product which environment will be best for helping them to discriminate between "good" and "bad" product.

Critical Points for SIR/ECM

- Always, Always, Always include “control” samples whenever performing SIR or ECM testing.

- It is a good idea to have the test boards made by your board supplier.
- *Note: Typically SIR tests are done of boards designed for this type of testing. An example is Doug’s IPC-B-52 test board. Functional assemblies are not good candidates for this testing as live components will affect resistance readings*.

Critical Points

- Always process test boards as you would a normal production unit.

- Use your test lab professional.

- Check your samples for solder shorts before sending them, rework as you normally would in production.

SIR/ECM Data

- The data indicates how your assembly process and materials ***may*** affect electrical performance under humid conditions.
- Using more frequent monitoring, you can examine the stability of the system and more easily catch the growth of dendrites
- Visual conditions of the boards and test patterns after testing can give clues as to the corrosivity of the residues
- SIR and ECM will not tell you if you have a “good” or “bad” process, but can give an indication of the risk of electrochemical failures.

Conclusions

- ROSE testing was meant as a process control tool.
- Periodically verify ROSE results with a more accurate method.
- IC is a good cleanliness tool and provides insight into YOUR process residues.
- SIR/ECM testing can give insights into whether observed residue levels are at elevated risk for electrochemical failures.

Conclusions

- To truly have high reliability on an electronic assembly, you **MUST** know what kinds of residues are on the products you ship.
- When changing, troubleshooting, or optimizing a manufacturing process, you have to have a good understanding of the sources of residues and how they impact field reliability.
- If you think testing is expensive, imagine the cost of ignorance.

Questions