Electronics IPC Midwest

Understanding Cleanliness and Methods of Determination

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Overview

- Reasons to Evaluate Cleanliness
- Discuss the following Cleanliness Evaluation Techniques
  - Resistivity of Solvent Extract (ROSE)
  - Ion Chromatography (IC)
  - Surface Insulation Resistance (SIR) & Electrochemical Migration (ECM) Testing
- Discuss Background, Method Applications and Limitations
- Case Studies Applying Techniques
- Conclusions

Reasons to Evaluate Cleanliness

- The reliability of a product cannot be accurately known unless you understand the residues present and their effects
- You need to understand if the residues are coming from your suppliers, from your manufacturing materials or from your manufacturing environment
- This knowledge allows you to be proactive in capturing residue issues before they become a costly issue
- Most importantly – Some products directly affect lives

Understanding Cleanliness Requires

- Engineers acquiring and understanding of materials science
  - Need to understand the chemistry of your products
  - Need to understand where the residues come from in your process
  - Need to understand if those residues are benign or harmful
  - Need to understand the compatibility issues that might exist between different materials – some don't play well together

- Engineers need to be versed in the different techniques currently available to evaluate cleanliness
  - Each analytical method has its advantages and disadvantages

ROSE Testing

- Resistivity of Solvent Extract – developed in the 1970s
- Was originally intended as a process control tool ONLY
- IPC-TM-650, method 2.3.25 (both static and dynamic)
- Current J-STD-001 ROSE criteria is 10.06 microgram per square inch of NaCl equivalents (1.56 µg/cm^2). The present pass-fail criteria is bogus for modern material sets
- Shortcomings of ROSE testing documented in IPC-TR-583
  - A general lack of repeatability and reproducibility in all instruments
  - Instruments are not comparable to each other or not even to other instruments of the same model
  - The equivalency factors are meaningless

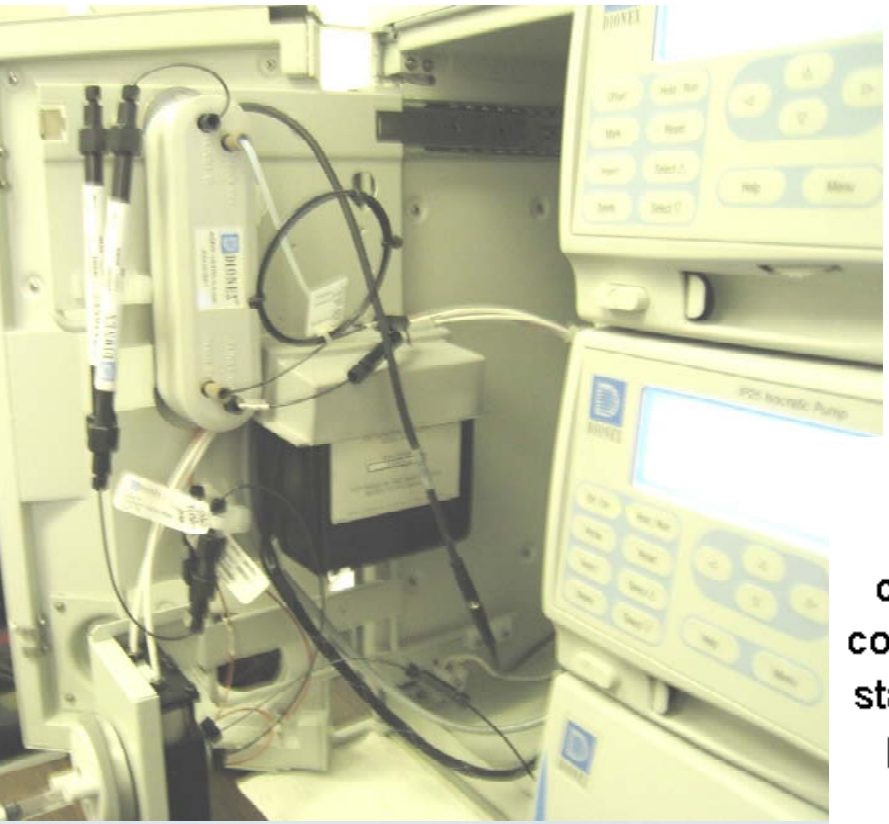
Why ROSE Is Not Applicable Today

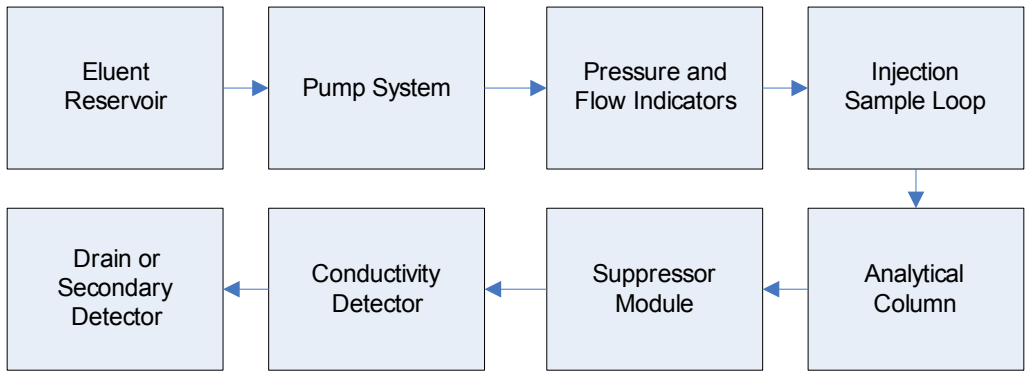
- Pass-fail criteria was based on high solids (35%) RMA flux
  - Very few use this flux technology any more. Most use water soluble or low solids fluxes
  - The solubility of modern fluxes in IPA/water is greatly different than the old RMAs
- Field failures regularly occur with boards/assemblies that have passed this test, often with flying colors
- These instruments are still valid as a process control tool in some instances, but not for product acceptance (though still used as such)

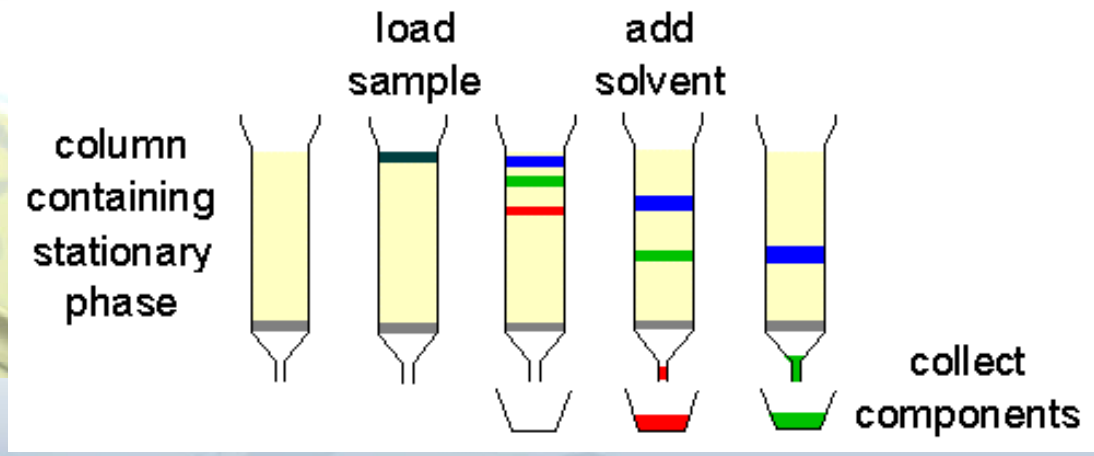
Ion Chromatography (IC)

- Method of choice for determining ionic residues in manufacturing processes
- A good basic text for understanding IC is:
  - Ion Chromatography, 3rd Edition, James Fritz, Douglas Gjerde
- Like most chromatographic methods, this involves taking a mixture of materials, passing them through a column of specially charged and precisely packed resins, which separates the mixture into its fractions for analysis

Ion Chromatography (IC)







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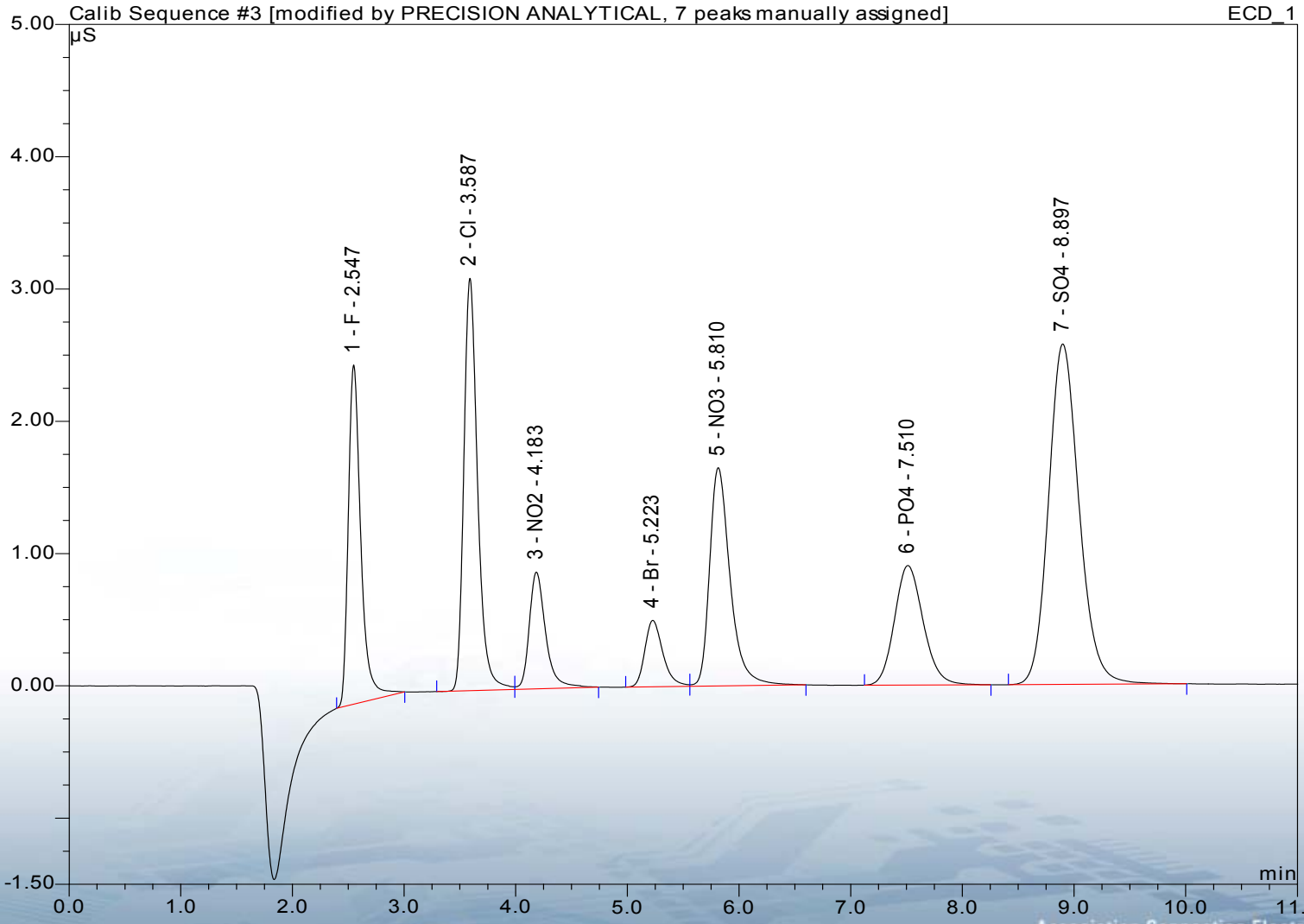
Typical IC Chromatogram



How is IC Different?

- PCB / PCA extraction methodology (more rigorous)
- The IC method (2.3.28) utilizes the same extract solution as ROSE – 75% IPA / 25% DI water
- Typical ions analyzed by IC:
  - Anions: fluoride, chloride, bromide, nitrate, nitrite, phosphate, sulfate, iodide
  - Common organic anions (short list): formate, maleate, succinate, acetate, citrate, adipate, methanesulfonate
  - Cations: lithium, sodium, magnesium, potassium, ammonium, calcium

IC – Cleanliness Criteria

- Pass / Fail Criteria for Bare Boards
  - Bare PWB's – IPC-5704 (Good start)
  - Assemblies – User Defined
- The days of the "one size fits all" cleanliness criteria are gone. That horse has left the barn.
- For assemblies 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.
  - All are in the same ball park

IC – Method Limitations

- 75% IPA / 25% Deionized Water can have a limited ability to dissolve some material residues (i.e. some no clean flux)
- Measurement accuracy of a boards surface area can limit measurement accuracy
- Data interpretation can be hindered due to lack of materials knowledge

The Usual Suspects

- Monovalent ions are most often at the heart of electrochemical (ECM) failures
  - Chloride, bromide, sulfate
- Weak organic acids can also contribute to ECM failures
- Other ions can be used as “process indicators” that help narrow down an investigation
- Cations not often the cause of electrochemical failures but high levels of cations can be indicators of problems
  - Solder mask problems often have a high cation load (ammonium or potassium)
  - Sodium is almost always present
  - Amines can often be used as indicators of residual cleaning solution if the saponifier is amine-based

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
  - Looking for electrolytic corrosion, unacceptable leakage currents under humid conditions, and electrochemical migration (dendrites)
- Electrochemical failures need five factors to be present
  - electrical potential, sufficient concentration of ionic residue(s), humidity, temperature and time

SIR & ECM Testing – Failure Driving Forces

Consider the following equation:

Potential + Residue + Moisture + Temperature + Time = FAILURE

Consider that each factor is necessary and influences the outcome

SIR and ECM Tests - Continued

- 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 / 90% RH with an applied bias of 5 VDC, 4-7 days
  - Industry data suggests it is 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
- Test board selection
  - There are several test boards to choose from depending on what you wish to analyze.
  - IMHO, the boards should be made with your preferred materials and surface finishes
  - If you have several materials and finishes, then choose the one that represents the worse case scenario.

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

SIR / ECM Test Considerations

- Always process test boards as you would a normal production unit
- Utilize your test lab professional(s)
- Check your samples for solder shorts before sending them, rework as you normally would in production

Case Study #1 – Component Cleanliness

- Goal: To validate the cleaning process used to remove flux from re-tinned leads on dual in-line (DIP's) packages per GEIA-STD-006, "Requirements for Solder Dip to Replace the Finish on Electronic Piece Parts"

- Test Requirements per GEIA-STD-006:
  - Test a minimum of 1.0 square inch of surface area using IPC-TM-650, method 2.3.25 (ROSE Method) of cleaned parts
  - Result must be below 10.06 micrograms of NaCl equivalents per square inch

- Two package dimensions tested: 8 Pin and 16 pin

Case Study #1 - Continued

- Notes:
  - This was the first time the client attempted to validate their cleaning process to GEIA-STD-006
  - Parts were made in 1986
  - Process cleaning used tap water at ambient temperature

- Our Recommendation
  - Send sufficient cleaned parts to have a minimum of 5 sq.inches for ROSE
  - Add IC testing to validate ROSE result
  - Send additional samples for IC testing to baseline
    - As-received from their client
    - Prior to wash
    - After wash

ROSE Test Results

- 20 parts per package dimension were sent for test
- All parts for the ROSE test had been cleaned post re-tin

Sample Number	Sample Description	Surfce Area (in2)	Result NaCl eq
Sample 1	8 pin DIP (20 pcs)	7.80	13.55
Sample 2	16 pin DIP (20 pcs)	14.40	5.81

Ion Chromatography Results - Anions

- Individual parts were evaluated per each package dimension and condition

Sample Description	Fluoride F	Chloride Cl	Bromide Br	Nitrite NO2	Nitrate NO3	Phosphate PO4	Sulfate SO4	Organic Acids
8 pin DIP (untouched)	ND	0.21	ND	ND	0.53	ND	0.02	7.23
8 pin DIP (uncleaned)	ND	1689.80	ND	ND	ND	ND	ND	188.59
8 pin DIP (cleaned)	ND	9.97	ND	ND	0.67	ND	ND	3.34
16 pin DIP (untouched)	ND	2.54	ND	ND	ND	ND	ND	0.55
16 pin DIP (uncleaned)	ND	910.72	ND	ND	ND	ND	ND	99.34
16 pin DIP (cleaned)	ND	14.54	ND	ND	1.25	ND	0.68	1.96

- Values reported as micrograms / square inch

Ion Chromatography Results - Cations

Sample Description	Lithium Li	Sodium Na	Ammonium NH4	Potassium K	Magnesium Mg	Calcium Ca
8 pin DIP (untouched)	ND	ND	ND	ND	3.34	0.09
8 pin DIP (uncleaned)	ND	ND	179.64	21.09	3.40	0.20
8 pin DIP (cleaned)	ND	ND	8.70	0.79	3.39	0.28
16 pin DIP (untouched)	ND	ND	ND	0.73	3.05	0.17
16 pin DIP (uncleaned)	ND	ND	146.55	16.36	4.44	0.18
16 pin DIP (cleaned)	ND	ND	4.67	0.83	1.87	0.23

Values reported as micrograms per square inch

Case Study #1 Conclusions

- Per GEIA requirements
  - 8 pin DIP failed to meet 10.06 limit for ROSE test
  - 16 pin DIP passed 10.06 limit for ROSE test
- IC results showed:
  - High levels of chloride and ammonium on both parts
    - Flux used was classified as an ORH1 (Alpha Organo 3355-11)
      - IC results of flux confirmed chloride, organic acids and urea (ammonium) were from the flux
  - IC results of cleaned parts showed that the flux residue was not completely removed by tap water cleaning from either part.

Case Study #1 Recommendations

- Suggested client switch from tap water cleaning to DI water cleaning (2 – 10 Megohm-cm)
- Suggested using a heat wash and rinse
  - 140 to 150 F
- If heated DI wash was still not effective, recommended adding saponifier
- Results of the next round of testing are pending.

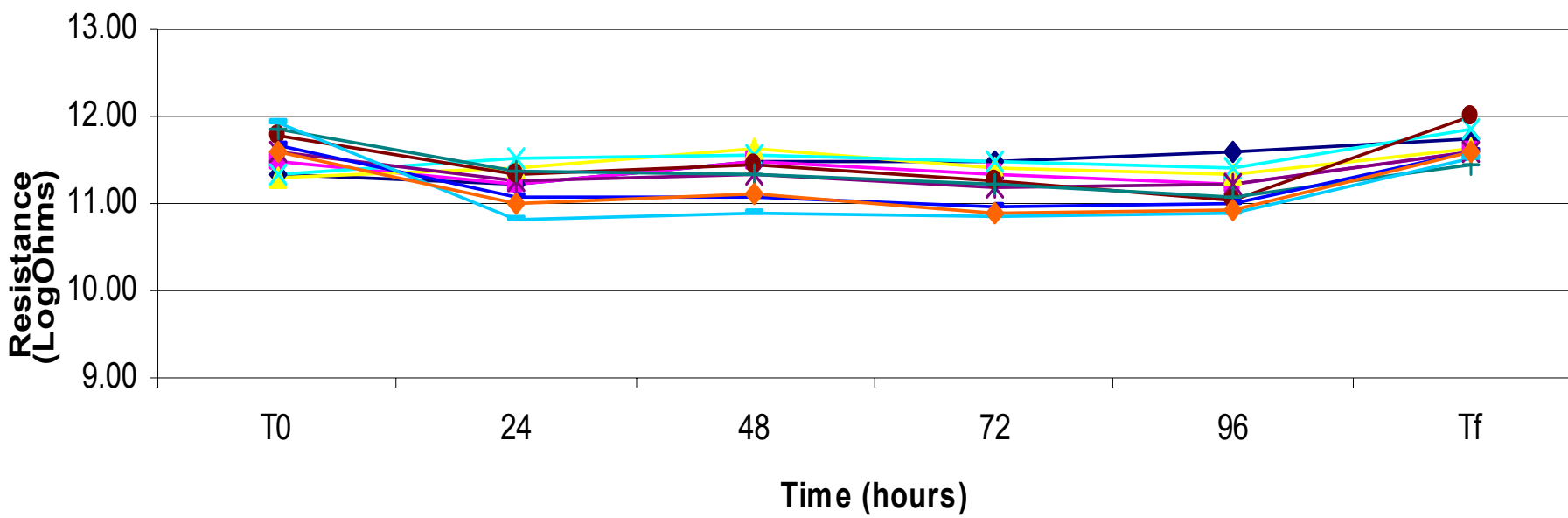
Case Study #2 - SIR of Flex Cable

- Client desired to utilize SIR testing to evaluate polyimide flex cables to screen for any issues in the flex
- SIR test would be used to corroborate functional testing
- Flex cable used for a low impedance hi-rel application
- Test conditions were as follows:
  - 40C / 93% Relative Humidity
  - 3 DC volt bias
  - Test duration – 96 hours

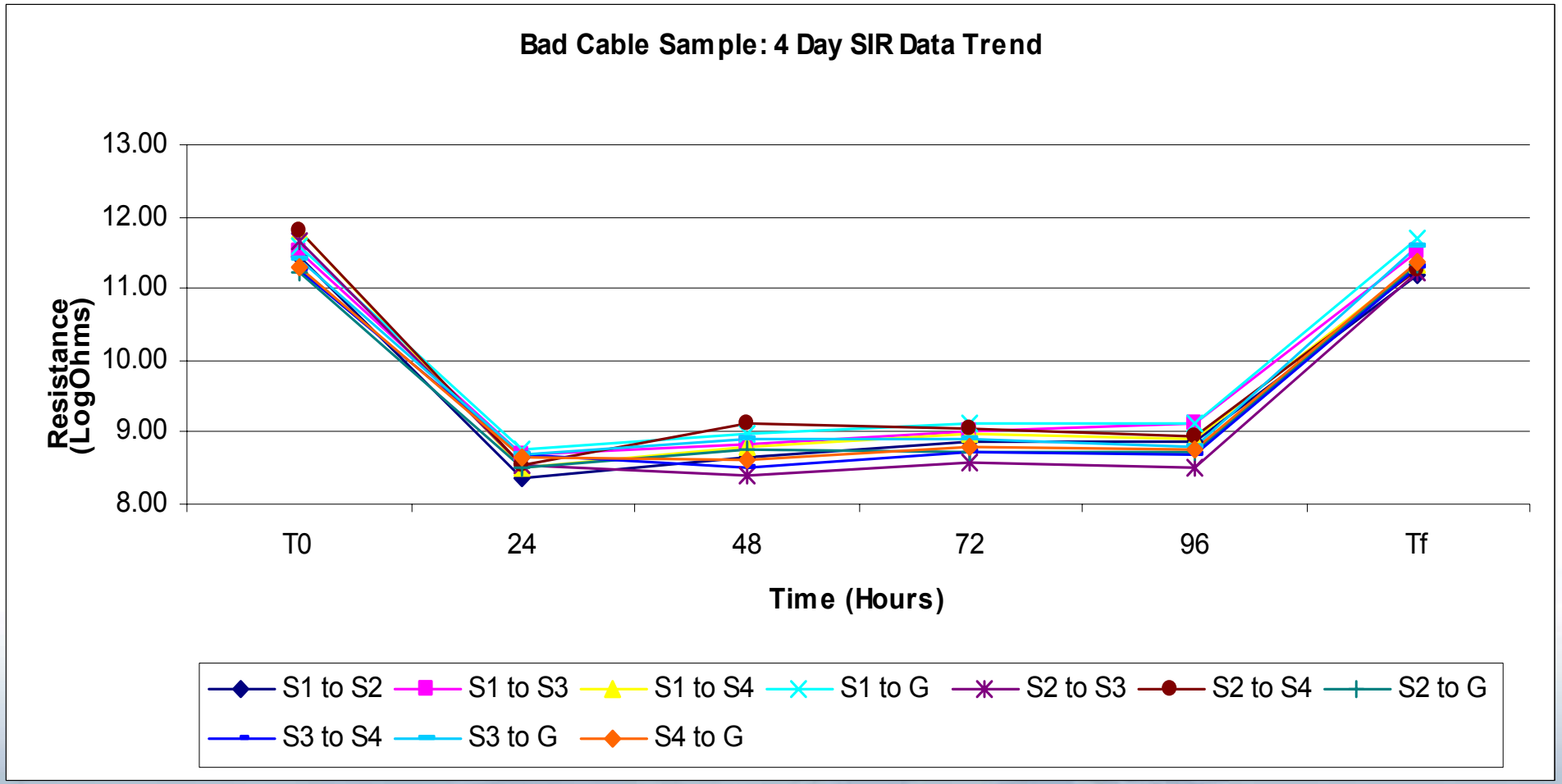
Case Study #2 - Continued

- Pass limit:
  - Measurement paths (10 paths total per flex) must maintain at or above 1000 megohms of resistance (9.0 LogOhms) for duration of test.

Case Study #2 – Results (Good Unit)



Case Study #2 – Results (Bad Unit)



Case Study #2 - Conclusions

- Thirty flex cables were evaluated in this study
  - Only one unit failed the test, but no assignable cause
  - Subsequent functional testing confirmed the failed unit was "bad"

- Client performing additional tests to determine if residual plating salts were present
  - Results not conclusive

Conclusions

- In today's manufacturing world, it is of growing importance that engineers understand all materials related to their products and any compatibility issues that could exist
  - To truly have product reliability on an electronic assembly, you **MUST** know what kinds of residues are on the products you ship

- It is also important that engineers understand the various methods used for evaluating cleanliness
  - It is likely that no single method will answer all questions

Conclusions - Continued

- ROSE testing is a very common method for evaluating cleanliness. However, limitations in the extraction process, the lack of selectivity and sensitivity may mean it does not assess cleanliness accurately for some products. As such, it should only be employed as a process control tool. It should never be used for validation or qualification purposes

- IC is more residue specific and sensitive, but limitations in the extraction protocol and surface area measurements can have limit the accuracy of the results

- SIR / ECM testing is good for evaluating residue interactions, but it is not designed to validate functional product

Questions?