J-STD-001 Rev G Amendment 1
Process Qualification

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Special Thanks to Doug Pauls, Collins Aerospace
Today’s Discussion

- Overview of the IPC- J-STD-001 Rev G. Addendum 1
- Qualify a Manufacturing Process for J-STD-001
  - Level 1 (Major Change)
  - Level 2 (Minor Change)
  - Process Stability through process control
- How to generate “Objective Evidence” for J-STD-001 or similar and Keep confidence
- Summary and Discussion

Source: Gen3 Systems Ltd.
Since the 1970s, ROSE testing was used to determine “clean enough”

In 2015, the J-STD-001 committee assigned a team to develop the next generation of “cleanliness” requirements

Two Objectives
- Proposed re-write of Section 8 for committee review for Rev G, Amendment 1
- Generate an associated white paper to explain the new section to the masses
  - Need to address: clean and no-clean processes, process validation, and process monitoring
  - What does the “next generation” of ionic residue testing/validation look like?

Made recommendations in June 2017
- IPC-J-STD-001, Rev G, Amendment 1 released 22 Oct 2018
- IPC-WP-019A published to explain the new requirements
- 30 min “Wisdom Wednesday” webinar explaining the new requirements
  - https://www.youtube.com/watch?v=coYbqn4gyuk&feature=youtu.be
New Section 8

- There is a “if it ain’t broke, don’t fix it” option (so don’t panic)

- Qualified Manufacturing Process (QMP)
  - Unless otherwise specified by the User, the Manufacturer shall [N1D2D3] qualify soldering and/or cleaning processes that result in acceptable levels of flux and other residues. Objective evidence shall [N1D2D3] be available for review. See J-STD-001 Appendix C for examples of objective evidence. Rework processes shall [N1D2D3] be included in the process qualification.
  - The use of the 1.56 µg/NaCl equivalence/cm² value for ROSE (Resistivity of Solvent Extract), with no other supporting objective evidence, is not considered an acceptable basis for qualifying a manufacturing process (see IPC-WP-019A).

- Key Concepts
  - ROSE testing for product acceptance (pass-fail) is an obsolete practice for determining acceptably clean
  - ROSE testing for process control is perfectly acceptable, but the numbers have to MEAN something. And those values need to be scientifically/statistically determined.
  - There is no ONE set value that defines the line between acceptably clean and unacceptably dirty
  - There is no ONE method to determine acceptably clean and unacceptably dirty
“How to Qualify a Manufacturing Process for J-STD-001”

WHAT DOES THIS CHANGE MEAN FOR ASSEMBLERS
What does this mean to Assemblers?

- **IIABDFI (if it ain’t broke don’t fix it)**
  - Company A, is a small contract manufacturer which has been manufacturing a product with the same manufacturing materials and processes for their customers for 10 years, always meeting the required 1.56 metric.
  - None of their customers have reported any problems of an electrochemical nature on products.
  - The manufacturer can point to the history of the product as acceptable objective evidence and no additional testing is required or warranted.

- **A QMP should be determined using some form of temperature-humidity-bias sort of testing (such as SIR)**
  - Qualifying a manufacturing process through chemical analysis alone (e.g. ion chromatography) does not tell you the effects of the residue under humid conditions, which is where electrochemical failures occur.
  - Companies that have come up with ionic standards by IC usually had temperature-humidity-bias (THB) testing somewhere in the background.

Courtesy Doug Pauls, Cleaning and Coating Conference, 2018 Personal development course.
What change constitutes a need for Requalification?

**Major/ Level 1**

- **Flux or flux-bearing materials** (e.g. flux, solder paste, paste flux, cored wire solder)
  - Different residues, different activators, different solubilities
- **Cleaning agents** (e.g. solvents, aqueous detergents, topical cleaners)
  - Differences in surface tension, ability to get under low standoff devices
- **Changes in manufacturing suppliers**
  - There may be a reason they are half the price
- **Changes in solder mask type**
  - Changes in porosity, surface energy, etc.
- **Changes in printed board fabrication processes or surface metalization**
  - See IPC-5703
- **Geographic change in manufacturing location**
  - Change in cultures, training, supply chain

**Minor/ Level 2**  
*Intent was to be a lesser effort*

- **Changes in cleaning parameters:**
  - Increase in belt speed (in-line cleaning systems), or decrease in cycle time (batch systems).
  - Decrease in pressures or flow rates.
  - Decrease in wash or rinse temperatures.
  - Any changes in these process parameters that are beyond the recommended process windows for the equipment or chemistry suppliers.
- **Changes in reflow, wave solder, or selective solder recipes**
  - Beyond the recommended process windows established by the equipment, flux, or paste suppliers
- **Changes within a manufacturing location**
  - Moving a line from Plant A to Plant B or Location A to Location B

**Requalification Required**

Courtesy Doug Pauls, Cleaning and Coating Conference, 2018 Personal development course
Ensuring Process Stability defined by Rev G. Section 8

PROCESS CONTROL AFTER QUALIFICATION
On Site Test Methods

<table>
<thead>
<tr>
<th>Evaluation Criteria / Method</th>
<th>Visual Inspection</th>
<th>On Site Ionic Contamination Testing</th>
<th>Site Specific Testing</th>
<th>Objective Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual with Microscope</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>ROSE</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Corrosivity Index C3</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Ion Chromatography</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>SIR</td>
<td>No</td>
<td>Limited Today</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Without Objective Evidence, Your “Number” does not mean ANYTHING*
The Manufacturer shall determine an Upper Control Limit (UCL) for ionic residue process testing based on the results of 8.1 (Process Qualification), and have objective evidence available for review.

- At what point do you take action, not accept/reject, but take action?
- Team determined it was unreasonable to require a manufacturer to go hunting for the point their hardware became “bad”
  - Though it may be prudent to do your own studies
- The manufacturer selects the action point

No Lower Control Limits specified

- But you start seeing low values, best to check why
Process Monitoring

- Process Qualification testing is used to establish:
  - Sampling Frequency (statistically based)
  - Control limits (action points) – Upper Control Limits (UCL)
- Actions to take when the UCL is exceeded

**Process Control Set Up**

*Assuming, SIR and IC have shown I have a qualified manufacturing process*

- **ROSE testing on Product A (cleaned) done 3 times per day, Product B (no-clean) is done 1 time per day**

<table>
<thead>
<tr>
<th>Assay</th>
<th>SN</th>
<th>ROSE Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>A</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>A</td>
<td>4</td>
<td>1.7</td>
</tr>
<tr>
<td>A</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>1.42</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td>.20</td>
</tr>
<tr>
<td>Mean+3SD</td>
<td></td>
<td>2.11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assay</th>
<th>SN</th>
<th>ROSE Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>6</td>
<td>2.8</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>2.2</td>
</tr>
<tr>
<td>B</td>
<td>8</td>
<td>2.3</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>3.0</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>2.5</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>2.56</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td>Mean+3SD</td>
<td></td>
<td>3.40</td>
</tr>
</tbody>
</table>

*Courtesy Doug Pauls, Cleaning and Coating Conference, 2018 Personal development course*
Data is uploaded to SPC control charts
I can “choose” an UCL of mean + 3 sigma
As long as the ROSE value, for that tester, remains below that UCL, all is well
If a ROSE value goes above the UCL → triggers notification of cognizant IE/QE
A process investigation ensues as to why
A second assembly, same configuration, is tested
  ▪ If it passes, can continue on, failure #1 was a fluke, but we choose to rewash
  ▪ If it fails, figure out why.
  ▪ Company policy: Product made since the last passing result is quarantined and recleaned.

ROSE is being used for process control, not product acceptance

Number is Process Control Only
Visible Residues

- Assemblies subjected to cleaning processes shall [D1D2D3] be free of visible residues (see 12.1.2.1 Table 3 for magnification requirements) which violate minimum electrical clearance, unless identified as benign through laboratory analysis or equivalent. All other visible residue requirements shall [N1P2D3] be as agreed between Manufacturer and User.
  - Residues which DON’T violate MEC are not a defect.
  - Residues which DO violate MEC are not a defect if you have objective evidence that the residue is not a reliability risk
  - All of this can be over-ridden with AABUS

Visual Inspection is a Valid Process control

Courtesy Doug Pauls, Cleaning and Coating Conference, 2018 Personal development course
When the UCL, established by the Manufacturer (or by as agreed between Manufacturer and User), is exceeded:

- Manufacturer shall [N1D2D3] investigate the cause of the occurrence. (Note: This should be pursued as soon as possible).
- The ionic test shall [N1D2D3] be repeated on a new sample of the same assembly/configuration that failed the first test, or a similar sample cleaned (processed) at approximately the same time (or from the same lot).
- If the second test exhibits in-control test results, no process action is required, but process investigation is recommended.

  ■ Note: It is recommended that the out of control assembly be visually examined at 10X magnification for signs of residues or contamination. Specialized chemical tests, such as local extractions may be used to investigate localized sources of ionic residues.

- If the second test also exceeds the established control limits, the Manufacturer shall [N1D2D3] document the disposition process.

  ■ Note: For assembly processes incorporating cleaning, the entire lot should be evaluated and re-cleaned if necessary and a random sample of this lot and each lot cleaned since performing the last acceptable cleanliness test should be tested.
Questions?

What a relief!

When you find documentation you know you wrote.
THERE ARE MANY ACCEPTABLE PATHS TO A QUALIFIED MANUFACTURING PROCESS!
Level 1 or 2 Modification Focus Points

- Incoming Materials & Factory Considerations
- Product Package and Shipment
- Product Burn In
- Conformal Coating And Curing
- Pre-Coat Baking
- Solder Paste Application & Inspection
- Rework
- Localized Cleaning
- Final Cleaning
- Adhesive Dispense And Cure
- SMD Placement & Inspection
- Rework
- SMD Adhesive Dispense and Cure
- Surface Mount Reflow & Inspection
- Cleaning and Drying
- Through Hole Component Placement
- Hand Soldering
- Wave Solder
- Cleaning and Drying
- Hot Air Reflow BGA Rework Station
- Mechanical Operations
- Electrical Test
- Manual Part Additions
Quality standards (ISO 9000, AS9100, etc.) define what is a major or minor change in a product, and often is influenced by the judgment of the Subject Matter Experts (SMEs).

These standards do NOT define what is a major or minor change in a manufacturing process. This almost always devolves to the judgment of the SME.

IPC Adage: In God we trust, all others bring data.

The SME with the best data wins.

The IPC SMEs (Rhino Team) discussed at length this issue.
Cleaning Change Examples

- Change from Cleaning after each reflow to cleaning after Second reflow only
- Change from 2.5 fpm to 4.5 fpm
- Change from 60C wash temp to 54C
- Change from 14% saponifier concentration to 12%
- Change from a 14 day dump cycle to a 28 day dump cycle
- Change from “clean within 8 hours” to “clean within 3 days”
- Changing localized cleaner from Solvent A to Solvent B

How do you know these changes don’t negatively impact the product?

- Could do SIR mini-studies
- Could run “out of bounds” conditions as part of the qual run
- Could do Ion Chromatography to compare residue sets
VISUAL INSPECTION
THE FIRST STEP
Leaded vs. Leadless Components
Component Removal

• Component shearing
  – Tooling that shears the component in the absence of heat
  – The objective is to inspect for residues present under the bottom termination

• De-Soldering
  – Flux residues can escape from the solder or move

Source: Kester – Kyzen Research
Leakage Currents and/or Dendritic Growth
Ceramic Glass Slides

- Ceramic-glass test boards provide the assembler
  - Run through the reflow and cleaning process
  - Visual – inspect cleaning under leadless components
  - Correlates to production hardware
Optical Inspection Post Cleaning

- Quantitative method
- Cleaning properties of specific flux types in the cleaning agent and cleaning machine process
Visual Evidence

• IPC TM-650 specifies visual inspection
• Glass Slides Provides the assembler with an accurate metric for
  – Dialing in the process
  – Cleaning all visual residues under leadless components
  – Standardize approach allows for process control
IONIC CHROMATOGRAPHY
Ionic Contamination

• Wide number of sources
  – Flux residue is commonly the primary source
    • Inorganic ions
    • Wide variety of Weak Organic Acids

• Creates an electric charge in humid conditions

• Ionic residues on PCB Assemblies
  – Electrically conductive
  – Lead to several failure mechanisms

• Component specific ionic contamination testing provides a better measure of ions present
Bulk IC In a Nut Shell

<table>
<thead>
<tr>
<th>PRO’s</th>
<th>CON’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Accurate &amp; Quantitative</td>
<td>✓ No Pass/Fail - Assembler determines acceptable limits</td>
</tr>
<tr>
<td>✓ Invaluable when doing process troubleshooting</td>
<td>✓ Expensive</td>
</tr>
<tr>
<td>✓ Process optimization work</td>
<td>✓ Long Test Time, usually offsite</td>
</tr>
<tr>
<td>✓ Commonly used for establishing the qualification baseline</td>
<td>✓ Bulk test gives average over entire board, not site specific</td>
</tr>
<tr>
<td></td>
<td>✓ Different flux types take longer extraction times.</td>
</tr>
</tbody>
</table>
# Localized IC In a Nut Shell

<table>
<thead>
<tr>
<th>PRO’s</th>
<th>CON’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>✅ Accurate/Quantitative</td>
<td>✅ No Pass/Fail - Assembler determines acceptable limits</td>
</tr>
<tr>
<td>✅ Quick on the floor test</td>
<td>✅ Component orientation and size limitations</td>
</tr>
<tr>
<td>✅ Site specific testing with C3</td>
<td>- Test cell needs to have complete seal around component for accuracy</td>
</tr>
<tr>
<td></td>
<td>- QFN’s and similar must be removed for accuracy</td>
</tr>
<tr>
<td></td>
<td>✅ Flux needs to be solubilize by steam alone</td>
</tr>
</tbody>
</table>
SURFACE INSULATION RESISTANCE (SIR)
1. Every Flux Impact SIR
2. Cleaning Conditions impact SIR
3. These measurements can be used to develop “objective evidence”

Legacy boards:
B-52, Foresite Umpire, PCB-SIR

Image provided by Industry Expert Doug Pauls
Cleaning Effects
SIR Testing

- Only method that directly measures the impact of Ionic contamination has on electrical performance of a PCB

**SIR (Surface Insulation Resistance)**

**Possible parameters:**
- Climate: 40°C/93% r. h.
- Test duration: 168 h
- Voltage: 5 V DC
- Sampling rate: 16 min
Even for Rework Processes

- B-52 board
- Remove and replace components outlined in red
- Topically clean and rinse with approved solvents for rework
- SIR test
- Compare standard process with no rework to the same patterns with rework.
  - Do you see a difference in SIR (relative comparison)?
  - Are the SIR levels suitably high (absolute comparison)?
  - Do you see any corrosion or metal migration?
Based on the IPC-B-24 Test Board

- Breakaway coupon on the left for IC Testing
- Several SIR test patterns on the board
- Used for process investigations, process qualifications, and process monitoring
Newly available SIR B-52 Legacy 3 Test Board

- **Component Specs:**
  - QUADRANT 1 – Contains QTY 4 of P/N QFN48T.5-F-ISO (48-Leads, Body 7x7mm, Pitch 0.5mm)
  - QUADRANT 2 – Contains QTY 1 of P/N FBGA 244 (244-Leads WG, Body 19x19mm, Pitch 1mm)
  - QUADRANT 3 – Contains QTY 1 of P/N QFP80 (80-Leads, Body 14x14mm, Pitch 0.65mm)
  - QUADRANT 4 – Contains QTY of P/N QFP160 (160-Leads, Body 28x28mm, Pitch 0.65)

- **SIR Routing**
  - QUADRANT 1 – EDGE PIN 1 = ODD PADS | EDGE PIN 2 = EVEN PADS + GND LUG
  - QUADRANT 2 – EDGE PIN 3 = ODD ROW PADS + GND LUG | EDGE PIN 4 = EVEN ROW PADS
  - QUADRANT 3 – EDGE PIN 5 = EVEN PADS | EDGE PIN 6 = ODD PADS | EDGE PIN 7 = UPPER COMB BUS | EDGE PIN 8 = LOWER COMB BUS
  - QUADRANT 4 – EDGE PIN 5 = EVEN PADS | EDGE PIN 6 = ODD PADS | EDGE PIN 7 = LEFT COMB BUS | EDGE PIN 8 = RIGHT COMB BUS

Economical Tool can validate qualification in production conditions

Images provided by MAGNALYTIX
Component Focused SIR Test Cards

• Known problematic components with breakaway IC coupons enable assembler to:
  – Directly correlate SIR values with IC values
  – Optimize
  – Investigate
  – Process Monitor
  • System built for the manufacturing floor
  • Provides process indications within 24 hours
1. Acknowledges the limitations of the ROSE test, stating **Objective Evidence is required** to ensure reliability from qualification to production monitoring.

2. The ROSE can be used as a Process Monitoring Tool when supporting evidence is available to validate **YOUR** number.

3. New Process Control Tools are being introduced that can provide process optimization and monitoring to meet tomorrow’s challenges.
Questions?

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IPC and SMTA Resources

- **SMTA Chapter somewhere near you**
- **IPC**
  - J-STD-001 Committee
  - Ionic Contamination Ion Chromatography Task Group 5-32a
    - Revision of the ROSE methods, ion chromatography methods
  - SIR TG – 5-32b
    - Revision of IPC-9202/9203 (in revision), SIR Handbook (in revision)
  - Bare Board Cleanliness 5-32c
    - IPC-5704 – validation and work to get into IPC-6012.
  - Cleaning Compatibility TG 5-31j
    - IPC-9505: Test method for determining compatibility of cleaning processes.
- **IPC/SMTA Cleaning and Coating Conference 2020**
Bibliography / Resources

- **IPC Reference Materials**
  - IPC-WP-019A: An Overview on Global Change in Ionic Cleanliness Requirements
  - IPC-CH-65B: Cleaning Handbook
  - IPC-HDBK-830: Coating Handbook
  - IPC-HDBK-840: Solder Mask Handbook
  - IPC-HDBK-850: Potting and Encapsulation Handbook
  - Proceedings from the SMTA IPC Cleaning and Coating Conferences (2008 onward)

- **Industry References**
  - Doug Pauls, SMTA IPC Cleaning and Coating Conference PD Course, 2018
  - Mike Konrad, Aqueous Technologies: 2016 Cleaning in Review (Webinar)
  - Ion Chromatography Overview and Applications, Doug Pauls, Rockwell Collins, SMART Webinar 2015.
  - Kyzen and Zestron webinars
  - DfR Solutions webinars