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An Overview on Global Change in Ionic Cleanliness Requirements

A White Paper Report Developed by IPC

Association Connecting Electronics Industries



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- Contain simple (simplified) language
- Just include spec information
- Focus on end product performance
- Include a feedback system on use and problems for future improvement

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Developed by the J-STD-001 ROSE Working Group of IPC

Users of this publication are encouraged to participate in the development of future revisions.

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Overview

For many years, military (e.g., MIL-STD-2000) and commercial (e.g., IPC-J-STD-001) manufacturing standards have required manufactured circuit card assemblies (CCAs) to meet an ionic cleanliness requirement of 1.56 microgram (μg) of sodium chloride (NaCl) equivalence per square centimeter (cm^2) of extracted surface, using Resistivity of Solvent Extract (ROSE) testing per IPC-TM-650, method 2.3.25.

It is the position of the IPC committees that the value of 1.56 μg NaCl equivalence per square centimeter should be considered as **obsolete** for the following reasons:

- This test methodology was originally developed in the 1970s; it was never intended to be used as a cleanliness test, nor as a test for product acceptability, it was only intended to be used as a process control method.
- The use of the ionic contamination value as a measure of product acceptance was the result of a US Department of Defense desire to implement a pass/fail criteria.
- This ionic contamination value, and those derived from them, were originally developed for high solids (35% solids) rosin fluxes and ozone depleting chemical (ODC) cleaning. The flux chemistries and cleaning solutions used today are completely different from those used when the ROSE limits were established.
- Modern assemblies are simply too complex in terms of residues to have a single "one size fits all" cleanliness criterion.
- There is mounting evidence that as CCA component density increases, so does the sensitivity of the circuit to ionic contamination. Modern circuit assemblies have far greater component densities than found in the 1970s. This also means that residues that had minimal impact on 1970s component technologies can now have a significant impact on component reliability.
- For many assemblies, ROSE testing is no longer a sufficient test regimen to adequately predict acceptable levels of ionic residues. IPC has compiled a list of technical presentations showing the inadequacy of ROSE to predict ionic residues for high performance electronics (see last page of the document).
- It is recognized that ionic residue testing is critical for reliable circuit function and so the ROSE test has continued in use until a more suitable alternative can be identified and implemented.

The IPC Technical Report 583 (IPC-TR-583, 1995) documents a review of the ionic contamination testers on the market at that time. The study reported an apparent lack of repeatability and reproducibility between the different systems available at the time and that the use of "equivalency factors", correlating the results between different kinds of testers, should be considered invalid.

It should also be noted that the TR-583 conclusions refer to the ionic testers of that era (1990s). Many of the more modern configurations of the ionic testers have been shown to be repeatable and reproducible. See Reference [36] as an example of testing modern instruments for repeatability and reproducibility.

The Executive Summary of IPC-TR-583 is included with this document as Appendix A. The full technical report is available from the IPC.

Many of the other references in the Bibliography section can assist the reader in understanding the history of the ROSE test, as well as some of the shortcomings of using ROSE as a measure of product acceptance.

Terminology

Over the years, the industry has developed various terms surrounding this test and the meaning of the established criteria. In many cases, the various terms used have led to a misunderstanding of the test and associated specification.

Ionic Cleanliness:

The greatest fallacy for the ROSE test is that it is often referred to as a "cleanliness test", with the natural assumption that if you pass this test with a value of 1.56 or less, then the assembly is "clean" or "acceptable", and if the test result was more than 1.56, then the assembly was "dirty" and "rejectable". This is often not the case. Any extraction based test, such as ROSE, is based on variables of solvency, time and temperature.

- If a residue is not soluble in isopropanol and/or water, it cannot be detected with ROSE.
- If a residue is not soluble within the extraction time, it cannot be detected with ROSE.
- If a residue is not soluble at the extraction temperature, it cannot be detected by ROSE.
- If a residue does not impact the electrical conductivity of the extract solution, it cannot be detected by ROSE.

Consequently, passing the ROSE test using the 1.56 value, does not guarantee that an assembly is "clean" or "good" or "acceptable".

Ionic Testing for No-Clean Processes

ROSE testing was developed and widely implemented during an era when almost everyone cleaned circuit assemblies. As such, a cleaning process has always been an assumed background to the use of ROSE as a measurement tool. As more of the industry transitioned to low-residue (e.g., no-clean) materials and processes, the question of how to apply ionic contamination testing to a no-clean assembly process has been raised repeatedly, but without a good answer.

In general, ROSE testing for the monitoring of a no-clean assembly process should not be used, for the following reasons:

- The isopropanol will leach out materials (e.g. resin) out of the flux residues, yielding high NaCl-equivalent readings, but which do not have an effect in a given humid end-use environment. The "high" values observed are often viewed as indicators of an unacceptably dirty board, and this is often not the case.
- No-clean flux residues often turn white after exposure to the isopropanol/water mixture of the ROSE test, leading to an assembly which may be functionally acceptable, but cosmetically unacceptable. Consequently, ROSE is considered to be destructive test for no-clean assembly processes.
- No-clean assembly lines are often very high in manufacturing volume. If typical ROSE sample rates of once per shift were applied, it would create unacceptably high non-value-added testing, with an associated high scrap rate of product.

J-STD-001 Requirements

After publication of J-STD-001, Revision F, July 2014, the leadership of the J-STD-001 committee formed a working group of subject matter experts (SMEs) (shown below) to determine what the "next-generation" ionic contamination requirements "should" be for future revisions of the standard. The following individuals were involved in this effort:

Name	Company	Category
Doug Pauls, Chair	Rockwell Collins	Aerospace OEM
Dan Foster (J-STD-001 Task Group Chair)	Missile Defense Agency	Class 3 user
Kathy Johnston (J-STD-001 Task Group Chair)	Raytheon Missile Systems	Aerospace OEM
David Lober	Kyzen Corporation	Cleaning Chemical Supplier
Eric Camden	Foresite	Test Lab / Ionic SME
Erik Bjerke, Joe Kane	BAE Systems	Aerospace OEM
Graham Naisbitt, Mark Routley, Dr. Chris Hunt	Gen3 Systems Ltd.	Cleanliness Tester Mfr, IEC leader
James Saunders	Raytheon	Aerospace OEM
Jason Keeping	Celestica	Class 2/3 EMS
Rick Kraszewski, Josh Huetner	Plexus	Class 2/3 EMS
Dr. Udo Welzel, Dr. Lothar Henneken	Robert Bosch GmbH	Automotive OEM
Michael Sosnowski	Dell Computers	Consumer Electronics OEM
Joe Rousseau	Precision Analytical Labs	Test Lab / Ionic SME
Dr. Karen Tellefsen, Jason Fullerton	Alpha Metals	Flux Supplier
Teresa Rowe, Linda Stepanich	IPC	IPC Staff Liaison

These individuals and companies were chosen to give a good cross-section of manufacturing materials and process experience, and those with experience determining the impact of residues on the functional performance of electronic hardware in the end use environment.

A word on "Objective Evidence": This term is used often in J-STD-001, but many do not understand what the term means. Consequently, Appendix C of J-STD-001F was written by IPC leaders to give guidance on this important topic. A general concept in J-STD-001, and similar IPC standards, is that you must manufacture according to the standard. If you wish to manufacture differently than the standard, then you need to have documented evidence that the alternative methods produce acceptable product.

A Walk Through J-STD-001G Section 8

IPC has found it beneficial in the past to generate explanatory text surrounding a standard or specification, especially if it marks a dramatic change, to give the reader the context by which manufacturing requirements should be viewed. Throughout the following section, the proposed text for J-STD-001, Section 8, is shown in indented *red italics*.

General Things to Keep In Mind

- IPC classifies requirements according to the Class 1/2/3 nomenclatures. In the experience of the working team, Class 1 products seldom, if ever, have ionic contamination requirements or require J-STD-001 compliance, so Class 1 requirements are generally listed as N1 through the following sections.

8.1 Qualified Manufacturing Process *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-019).

The core concept for materials compatibility and residue acceptability is that of the qualified manufacturing process (QMP). In a QMP, the manufacturing materials and processes used to produce electronic hardware have been benchmarked and validated against electrical performance in hot/humid conditions in some manner. The art of characterizing what chemical residues exist on a manufactured assembly, and how to assess the impact of those residues on electrical performance, is neither a trivial nor easy exercise. Residues that may have no impact on one assembly may have significant impacts on other assemblies. That is why it is difficult, if not impossible, to direct a user to a single test or a single requirement for acceptability from a residue/cleanliness standpoint. This paper, IPC-WP-019, was written as an overall guide to assist the reader in this area.

ROSE testing can be performed at almost any point in the manufacturing process, such as after automated assembly and cleaning, but prior to secondary processes, such as rework, attachment of heat sinks, adhesive bonding operations, etc. In such a case, the ROSE data would not include the residue affects attributable to these secondary operations, which can have a major impact. Rework, which includes touch up soldering (where flux is added), is often an area where ionic residues cause assembly failure. For that reason, rework processes and their residues are required to be part of the qualification process.

It may reasonably be asked about how to handle rework and repair operations that occur AFTER the conformal coating is applied and cured. An example would be replacement of a defective component after product burn-in testing. A classic case would be stripping off the coating, removal of the defective component, soldering the replacement component in place, locally cleaning the flux residue, and then recoating. How would one verify that the rework site has an acceptable residue condition prior to re-coating? Reference 30 shows various techniques in which residues in a localized area may be characterized.

A thorough process qualification effort would incorporate rework operations prior to conformal coating, as well as incorporate characterization of rework on conformally coated boards.

The second paragraph directs the user on how to view historical ROSE data for product. There have been many published accounts or case studies where reliance on the 1.56 value as a measure of "acceptable" cleanliness resulted in products failing in the field. That class of failure, and the increasing frequencies of such failures, initiated this improvement of the residue

requirements. On the other hand, there are many manufacturers who have used the historical 1.56 value and have acceptable field performance, or who have done their own studies to determine what ROSE values should be used. The latter class of manufacturer should not have the burden of additional testing levied upon them. Therefore, the task group desired to keep a "if it ain't broke, don't fix it" option. Note that the second paragraph does not have a SHALL requirement associated with it. It is a cautionary statement that ROSE data **alone**, without other supporting data, is not viewed as acceptable. If ROSE data is all a manufacturer has, then that manufacturer really does not have a good idea of the residue condition of the assembly.

The following three scenarios should help illustrate how this requirement should be viewed.

1. 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. In this case, the manufacturer can point to the history of the product as acceptable objective evidence and no additional testing is required or warranted.
2. Company B, is a medium contract manufacturer which is generating a new product line with new materials and processes. Judging the acceptability of the newly manufactured product using nothing more than ROSE data (we meet the 1.56 value, we must be good), would not be considered as acceptable objective evidence. There are too many unknowns from a chemical perspective. However, if the new product was based on an existing manufacturing line with existing materials, which **had** accepted objective evidence, then the ROSE testing would be supported by that other objective evidence.
3. Company C, a large defense contractor has new products that go through a battery of qualification testing, incorporating function in anticipated end use environments at elevated levels of temperature and humidity. ROSE data on the new product has the supporting objective evidence of the qualification testing and so would be considered acceptable without the need for additional testing. If the qualification testing does not incorporate elevated temperature and humidity conditions, then electrochemical failure mechanisms are not likely to manifest and so that link to the ROSE data is not as desirable.

Unless otherwise specified by design, or by the User, the acceptability of the residue condition shall [N1D2D3] be determined at the point of the manufacturing process just prior to the application of conformal coating, or on the final assembly if conformal coating is not applied.

In theory, the ROSE testing can be done at almost any point in the manufacturing process and is commonly used at multiple points for process control. The residue condition of greatest interest is that which exists after all manufacturing processes, prior to conformal coating (if used). Once conformal coating is applied, the residues cannot be extracted for chemical analysis. Consequently, ROSE or other chemical analysis is done on the state just prior to conformal coating.

If the product(s) in question are made with no-clean assembly processes, and are conformally coated, a prudent qualification plan would incorporate conformally coated no-clean qualification samples to demonstrate that the combination of conformal coating and flux residues are not detrimental to reliability.

8.1.1 Cleaning Designator *Unless otherwise specified by the User/Design Authority, the Manufacturer should specify a cleaning designator that establishes the cleaning option and process control tests for manufacturing residues. The cleaning designator is a 2-digit (minimum) code that describes the cleaning and process control testing required for assemblies under this standard. The code begins with the letter "C" and then a dash followed by two or more digits. The first digit represents the cleaning option:*

Table_8-1 Designation of Surfaces to be Cleaned

0	No surfaces to be cleaned
1	One side (solder source side) of assembly to be cleaned
2	Both sides of assembly to be cleaned