

IPC-WP-019B

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An Overview on Global Change in Ionic Cleanliness Requirements

A White Paper Report Developed by IPC



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- Minimize time to market
- 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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- Increase time-to-market
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An Overview on Global Change in Ionic Cleanliness Requirements

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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. This WP-019B was created to support the IPC J-STD-001 Revision H document.

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 as a cleanliness test, nor as a test for product acceptability, but only 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 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 affect 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,” “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 (listed alphabetically by company) were involved in this effort:

Company	Name	Category
	Kathy Johnston	Assembly SME
Alpha Metals	Jason Fullerton Karen Tellefsen	Flux Supplier
BAE Systems	Erik Bjerke Joe Kane	Aerospace OEM
Celestica	Jason Keeping	Class 2/3 EMS
Dell Computers	Michael Sosnowski	Consumer Electronics OEM
Emma Hudson Technical Consultancy	Emma Hudson	Cleanliness Consultant
Foresite	Eric Camden	Test Lab / Ionic SME
Gen3 Systems Ltd.	Chris Hunt Graham Naisbitt Mark Routley	Cleanliness Tester Mfr, IEC leader
IPC	Debora Obitz Teresa Rowe	IPC Staff Liaison
Kyzen Corporation	Mike Bixenman David Lober	Cleaning Chemical Supplier
Missile Defense Agency	Dan Foster	Class 3 user
Plexus	Josh Huetner Rick Kraszewski	Class 2/3 EMS
Raytheon	James Saunders	Aerospace OEM
Raytheon Missile Systems	Norman Armendariz Jim Daggett	Aerospace OEM
Robert Bosch GmbH	Lothar Henneken Udo Welzel	Automotive OEM
Rockwell Collins	Doug Pauls, Chair	Aerospace OEM
Soldering Technology Intl	Mark McMeen	Class 2/3 EMS

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 of J-STD-001H 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 J-STD-001, Section 8, references are shown ***bold black 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.

J-STD-001H, 8.1 Qualified Manufacturing Process

In the text below, “Examples” are given to illustrate the key concepts of particular points in the standard. Users of this white paper are not “expected or “required” to take any of these actions. They are there for educational purposes only.

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 an easy exercise. Residues that may have no impact on one assembly may have significant impacts on other assemblies. Residue levels that are acceptable for one industry (e.g., consumer electronics) may not be acceptable for another industry (e.g., medical devices). 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.

Section 8.1 specifies that it is the burden of providing the objective evidence falls on the manufacturer of the electronic assemblies. However, the cost of that burden should be shared with the User of the assembly.

Example: A contract manufacturer, who has a preferred material set (e.g., surface finish, flux, cleaning chemical), generates objective evidence for that material set and has it available for review. The cost of that qualification becomes part of the overall cost for services. An OEM can choose to have the contract manufacturer use that chosen material set. If the OEM elects to have the product made with a different material set, then the cost of generating the objective evidence should be a shared cost between the manufacturer and the customer. In this situation, the contract manufacturer generates additional data that can be used in the future and the OEM gets assurance that the alternate material set will result in acceptable residue levels. If the OEM does not accept the contract manufacturer's objective evidence, and requires different testing or additional testing, then the OEM should bear the cost of that additional testing. All of these are, of course, negotiable items.

Extraction based tests, such as ROSE or ion chromatography (IC), may determine if ionic material is present, and in the case of IC may tell you what specific ions are present, but they do not indicate the effect of that ionic material on electrical performance. This is why the emphasis in section 8 of the standard emphasizes SIR testing, which is an electrical test performed under hot and humid conditions.

The user of this document might refer to IEC 61189-5-504:20 - General test methods for materials and assemblies — Process ionic contamination testing (PICT) published in 2020 that describes using a modified and updated version of the ROSE test. However, PICT, like ROSE, is inappropriate for product acceptance; its use is solely for process control as originally intended.

Several companies have successfully used ion chromatography to troubleshoot and optimize manufacturing processes. Does this clause in the specification indicate that companies can no longer take this approach? Absolutely not. The key element in the specification is “with no supporting evidence.”

Example: An OEM has electrochemical failures during product burn-in testing, which utilizes cyclical temperature and humidity. The OEM has ion chromatography work performed that highlights high levels of some ionic residues, such as chloride or bromide. The OEM changes the manufacturing process to minimize those suspect ions and the resulting product no longer experiences the issues in burn-in testing. In this case, the electrical performance in burn-in would be the supporting objective evidence.

Example: A medium contract manufacturer generates 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 line 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.

With the publication of J-STD-001 Revision G Amendment 1, many companies have struggled with what kinds of data were and were not acceptable forms of “objective evidence.” Therefore, in Revision H, additional examples were provided. Note that the listing of the items below are recommendations. There are **many** acceptable forms of objective evidence.

Surface Insulation Resistance (SIR) testing is the preferred way (but not the only way) of demonstrating the impact of residues on electrical performance. IPC-9202 is one acceptable method. In IPC-9202, ion chromatography test is required, but no pass-fail levels are established. This benchmarks what ionic residues are present that correspond with acceptable electrical performance. It should be stressed that similar SIR-based studies are acceptable. Such data can then be used later for providing objective evidence supporting major and minor changes.

Example: A high volume automotive manufacturer takes the IPC-B-52, the standard test assembly for IPC-9202, and modifies it to better represent their design rules and component technology. The company does SIR testing with that modified B-52 assembly, using the criteria of IPC-9202, and uses that data as the objective evidence. In parallel with the studies, the

manufacturer runs ROSE testing on assemblies manufactured with the candidate process to establish ROSE data for process control purposes.

Example: A contract manufacturer chooses an SIR test substrate that the manufacturer feels is more representative of their product. That test substrate could be one available for use in the industry, or they could use an internally designed test substrate. The manufacturer works with the customer, in this example a customer in the medical devices industry, to develop what is an acceptable level of SIR for that test substrate and the candidate process. The resulting body of research becomes the objective evidence package for that process. In this example, the contract manufacturer runs the sample test coupon every day to establish the process control criteria, which is then used to meet the Upper Control Limit requirements described below.

Example: Company A is required to qualify a product with a new customer, and the plan needs to include monitoring the accepted assembly process. For initial process qualification, SIR and IC analysis were used to establish an optimized set of materials and equipment parameters. Company A chose test coupons that were most representative of their final product, with a mix of SMT and PTH components. They then assembled boards using the proposed combination of materials and equipment to be used for final product. Along with two bare reference samples, the assembled boards were tested per IPC 2.6.3.7, and if they passed that test, they were then tested with ion chromatography to determine the average levels of specific anions, cations, and weak organic acids (WOAs) to create a set of baseline data. They next assembled a set of 20 samples of the actual product. A set of 10 boards were tested using global extraction and ion chromatography, the second set of 10 were tested in a ROSE tester. If the IC results were similar to the test board results, the average of the 10 ROSE test results were used as acceptance criteria for process monitoring of live product. Some Users may also perform elevated heat and humidity exposure testing with normal operating voltages to further validate the acceptance criteria.

A manufacturer may claim “our customers have never had a problem with our product,” and that claim may be true. But if there is no feedback mechanism between product performance in the field and the manufacturer, the claim rings hollow. Tracing a field issue caused by residues, back to the manufacturing source is often a very complex issue.

Example: An aerospace OEM receives a field return from an airline customer indicating intermittent performance of the product or undesirable performance of the product in flight. The aerospace OEM analyses the unit in a controlled environment lab and the failure mechanism cannot be duplicated. The unit works as specified. The aerospace OEM issues an initial finding of No Trouble Found (NTF) or No Fault Found (NFF).

The OEM does additional work and functionally tests the unit under hot and humid conditions and the fault condition manifests. This often (but not always) is an indication of an electrochemical related failure. The OEM takes the unit apart and observes contaminants across the assembly surfaces. It often takes a very sophisticated chemical analysis to determine if such observed residues were from the end use environment (such as salt air), deposited in service, or are residues from the original manufacturing process.

Example: An OEM or CM has a 3 to 10 year history of the same product line with no major changes to the manufacturing/processing of the electronic hardware. For this manufacturing line, there is supporting test data from their automated test procedure (ATP) and corresponding warranty data that shows low returns. These desirable results between the manufacturer and their end customer would be considered acceptable supporting objective evidence. Illustration: Company A has a product line that has been running for 17 years with a sub 1% return rate for fielded units, with an average life expectancy of 7 years in a harsh environment setting. The in-house ATP results, supported by low warranty returns from fielded units, shows that the material selection and manufacturing processes are in control and that they meet the requirements of Section 8.

Example: A supplier to the automotive industry (high volume electronic manufacturing) has designed a new airbag control unit. In addition to layout changes compared with earlier versions and the implementation of new functions, a new printed circuit board (PCB) base material and a new surface mount device (SMD) solder paste will be used. The PCB will be sourced from two different suppliers in Asia. The assembly and interconnect technology is a no-clean process involving both surface-mount and through-hole soldering technology typical for the automotive industry.

In a first step, the base material was selected and investigated regarding its conductive anodic filament (CAF) performance according to IPC-TM-650, 2.6.25. First samples of CAF (customized test board) and SIR test coupons (B52-testboard), including solder mask application and final finish were then ordered for production from the two printed board (PB) suppliers. Through typical automotive long-term tests at 85°C, 85% RH for 1000 hours, the capability of all PB materials and the PB manufacturer as well as their interactions within the production part approval process (PPAP), were demonstrated with regard to CAF and SIR performance of unpopulated PCBs.

In parallel, the new solder paste was released based on positive results of an SIR test according to IPC-TM-650, 2.6.3.3 and interaction tests according to IPC-9202.

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