



# IPC-5703

2013 - May

## Cleanliness Guidelines for Printed Board Fabricators

*A standard developed by IPC*

*Association Connecting Electronics Industries*



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# Cleanliness Guidelines for Printed Board Fabricators

Developed by the Bare Board Cleanliness Assessment Task Group  
(5-32c) within the Cleaning and Coating Committee (5-30) of IPC

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

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## Acknowledgment

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# Cleanliness Guidelines for Printed Board Fabricators

## 1 SCOPE

**1.1 Introduction** In many IPC standards development meetings, those individuals responsible for assessing the quality of incoming unpopulated printed boards have lamented the fact that bare printed board cleanliness is often an unknown quality parameter, often with undesired results. This is often due to the lack of understanding of materials and processes by the fabricator, or more often because the industry has driven margins so low that experienced process professionals cannot be retained by the fabricator.

Therefore, the IPC 5-32c Bare Board Cleanliness Task Group resolved to generate guidelines on those factors in the printed board fabrication process which can directly or indirectly affect the final cleanliness of packaged bare printed boards. This document is intended to be a general tutorial on items in the printed board fabrication process which can affect, directly or indirectly, cleanliness.

**1.2 Why Printed Board Cleanliness is Important** One of the aspects of printed board assembly reliability is electrochemical reliability, which is related to the residues left on an assembly. Some residues are benign while others are harmful. Electrochemical failure mechanisms are comprised of three elements: (1) an ionic residue; (2) an electrical potential or voltage gradient; and (3) moisture or humidity. All three must be present at some minimum level (which varies) for electrochemical failures to occur. Electrochemical failures are evidenced in two primary areas: (1) unacceptable leakage currents under humid conditions, and (2) electrochemical migration (dendritic growth). An example of dendritic growth can be seen in Figure 1-1.

The Venn diagram shown in Figure 1-2 is useful in understanding the relation between these three factors. The amount of impact can be visualized by considering the diameter of the individual circles to be proportional to the forcing function. As an example, if a device is operating in a very humid environment, the diameter of the humidity circle grows larger as does the electrochemical failure region. In addition, operating temperature and time can compound or accelerate these factors. Higher temperatures can increase dissolution of residues and can accelerate electrochemical reaction rates. If service lives are long, the risk of electrochemical failures increases.

Every printed board, or printed board assembly made from such boards, has a different cleanliness need. Unfortunately, not many assemblers or OEMs know how to determine how clean their assemblies have to be. There have been many instances where the present printed board cleanliness test methods, such as resistivity of solvent extract (ROSE) testing, have been inadequate to determine the true cleanliness of printed boards or assemblies.

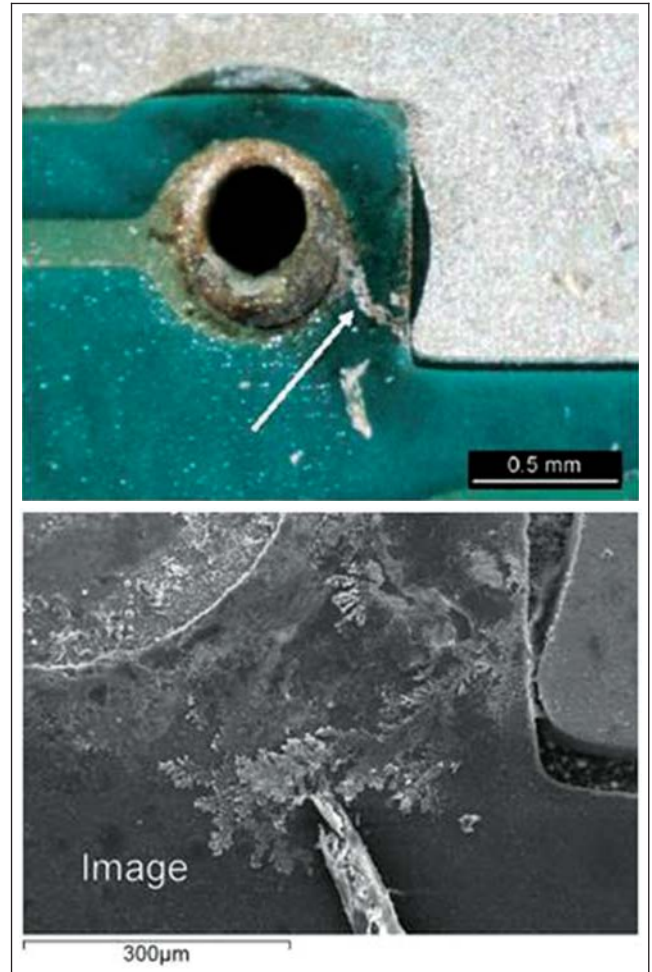


Figure 1-1 Examples of Dendritic Growth

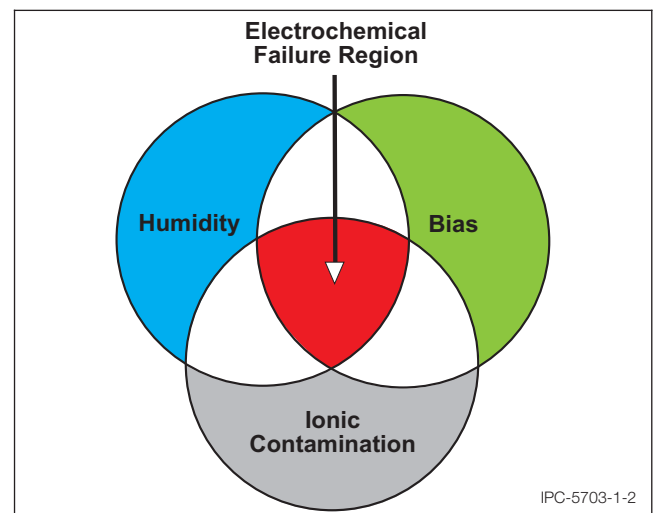


Figure 1-2 Venn Diagram Illustrating Variables Affecting Electrochemical Failure



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How clean a printed board or a printed board assembly needs to be for a particular application or end use environment depends on a number of factors. Among them:

- As circuit densities increase (e.g., smaller lines and spaces), the electrical bias across the smaller space results in a higher voltage gradient across this space. Consequently, the bias circle shown in Figure 1-2 expands, and the risk of failure increases.
- For an assembler who utilizes some form of cleaning, the increased circuit density often means a greater challenge to complete cleaning.
- For an assembler who does not utilize any cleaning processes (i.e., “no-clean”), the cleanliness of the bare printed board becomes critical as there is no opportunity to remove harmful residues in the printed board assembly process.

From the perspective of the assembler or user of the printed board, the use of process control methodologies in the manufacture of printed boards is very important, especially for high reliability applications. Because printed boards for these critical applications are often very sensitive to contamination, showing consistency in the fabrication processes involving cleaning is often of great interest. To an experienced printed board assembly auditor, if there are no metrics in the fabrication process which focus on board cleanliness, a red flag is generated.

Such an auditor will also look for objective evidence that the resulting cleanliness of the printed boards has been evaluated as part of the qualification process, whenever major changes in materials or fabrication processes are made. New technologies, such as new plating solutions or methods, may add undesirable residues to the printed board. It takes more than just a word from a salesman to say a new material or process is “clean.” Factors which have never impacted cleanliness before can become factors as technology advances. The vigilant fabricator keeps evaluating the cleanliness of the process as new technologies come on line.

From the perspective of the assembler, tracing field failures to the cleanliness of incoming printed boards is often exorbitant in terms of time and cost. Often, an assembler has to examine the cleanliness of each step of the entire manufacturing process to determine where a cleanliness-related fault originates. If the expertise or equipment to do this evaluation does not exist in the assemblers’ organization, then the task must be subcontracted or there is a need to have specialized consultants brought in. What may only be a difference in pennies in a printed board fabrication process can cost an assembler hundreds of thousands of dollars to track down.

While this document goes over the various fabrication processes and how they impact printed board cleanliness, the single greatest factor for printed board cleanliness is the quality of the water used for washing and rinsing operations.

**1.3 Terms and Definitions** The definition of all terms used herein shall be in accordance with IPC-T-50.

## 2 APPLICABLE DOCUMENTS

### 2.1 IPC<sup>1</sup>

**IPC-WP-008** Setting up Ion Chromatography Capability

**IPC-TM-650** Test Methods Manual<sup>2</sup>

2.3.25 Detection and Measurement of Ionizable Surface Contamination

2.3.25.1 Ionic Cleanliness Testing of Bare PWBs

2.3.28 Ionic Analysis of Circuit Boards, Ion Chromatography Method

2.3.28.2 Bare Printed Board Cleanliness by Ion Chromatography

2.6.14.1 Electrochemical Migration Resistance Test

**IPC-HDBK-840** Solder Mask Handbook

**IPC-1601** Printed Board Handling and Storage Guidelines

**IPC-5704** Cleanliness Requirements for Unpopulated Printed Boards

**IPC-6012** Qualification and Performance Specification for Rigid Printed Boards

**IPC-9191** General Guideline for implementation of Statistical Process Control (SPC)

1. [www.ipc.org](http://www.ipc.org)

2. Current and revised IPC Test Methods are available on the IPC Web site ([www.ipc.org/html/testmethods.htm](http://www.ipc.org/html/testmethods.htm))

## 2.2 American Society for Testing and Materials<sup>3</sup>

**ASTM F21** Standard Test Method for Hydrophobic Surface Films by the Atomizer Test

**ASTM F22** Standard Test Method for Hydrophobic Surface Films by the Water Break Test

## 3 WATER QUALITY

Water quality varies tremendously around the world. Tap water, used by many fabricators for rinsing and cleaning, may have minerals, particulate matter, pollutants, or additives like chloride or sulfur that are used to reduce bacteria. Hard water (heavy in mineral deposits) is often limited in its ability to clean. The minerals in the water can chemically interact with manufacturing solutions in fabrication, resulting in a residue that may be difficult to remove. The cleaner the water, the better the cleaning ability, which lowers the risk of unintended residues.

Effective aqueous cleaning in printed board fabrication is a combination of time, temperature, and solvating ability of the water or cleaning solution:

- Hot water cleans better than cold water.
- Water quality may vary by season or by water source (e.g., river).
- Clean water cleans better than polluted water.
- Water with a detergent or cleaning agent additive works better than plain water, provided you have adequate rinsing.
- Printed boards exposed to a longer cleaning cycle will be cleaner than those with a shorter cleaning cycle.
- A thorough cleaning process, incorporating cleaning agents and rinsing, is better than a mild or low cost cleaning process.

In consideration of overall water quality, the following grades of water progress from least desirable as a cleaning agent to most desirable. As water quality rises, the cost per unit volume also increases:

- Unfiltered tap water: as indicated above, unfiltered tap water may have many materials which are both detrimental to printed board reliability and which reduce the effectiveness as a cleaning agent.
- Tap water that has been pH altered: In some portions of the world, the natural pH of the water may be alkaline and fabricators have sometimes added acids to reach a more neutral pH. While this may balance the pH, the acid itself is detrimental to cleaning.
- Filtered tap water: Simple filtration with activated carbon can greatly reduce undesirable materials in the water, as well as reduce particulates in the water. Undesirable contamination levels can still remain.
- Softened water: The water softening process will remove minerals from tap water and is often effective at reducing particulates in water. The purpose of water softening is to remove divalent metals like calcium and magnesium, exchanging them for sodium. Water softening operations do not imply carbon filtration. The softening process involves processing the water through salt brine. Consequently, softened water is often high in sodium and/or chlorine. Both of these elements are known to be detrimental to printed board cleanliness. If softened water is used in a cleaning process, it is highly recommended that subsequent rinses be with reverse osmosis or deionized water.
- Reverse osmosis (RO) water: RO water is generated using membrane technology. RO water is free of particulates, minerals, and most ionic material, and is an effective cleaning agent. RO water has a resistivity range of 100 kilohm-cm to 2 megohm-cm. One of the drawbacks of RO water is that it usually takes 10 gallons of tap water to generate 1 gallon of RO water.
- Deionized (DI) water: DI water is the most desirable of water grades for purposes of cleaning. Deionized water is generated by taking RO water and passing it through ion exchange columns, removing any residual ionic material. Deionized water has a resistivity range of 2 megohm-cm or higher. Laboratory grade DI water will be around 18 megohm-cm. A resistivity of 2-8 megohm-cms is desirable for most aqueous cleaning. If water resistivity is significantly higher than 10 megohm-cm, it can become too aggressive a cleaning agent, especially for semiconductors and similar microcircuits.

An industrial aqueous cleaning operation will typically have tap water plumbed first into a particulate trap and then into a carbon filtration column. The output of this column will feed into a series of deionizing columns which make the water progressively cleaner. In-line resistivity monitors can show either a numeric readout of the water resistivity or a simple red light / green light arrangement if the resistivity falls below a set value, usually 2 megohm-cm. Most often, these lights are located at the DI source. Monitoring lights or meters are most effective when placed at the point of use (where the rinsing is performed). These monitors need some flow through them to be effective.

3. [www.astm.org](http://www.astm.org)

As the ion exchange resins in the column become expended, the first column in line is removed and taken for resin regeneration. Each column is moved up in the rotation and a fresh column added at the end of the line.

In some cases, highly polished deionized water (18 megohm-cm at the source) has been used successfully for specialty aqueous cleaning operations. It is difficult to maintain this high level of resistivity. Carbon dioxide in the atmosphere will rapidly degrade water resistivity from 18 megohm-cm to 2-8 megohm-cm. Resistivity of the deionized water will also drop the farther it is piped from the deionizing source (columns), placing the resistivity in the desirable 2-8 megohm-cm at the point of use. This resistivity drop should be considered when determining the placement of deionizing columns and plating tanks or aqueous cleaning equipment. If the source and destination are widely removed, and high resistivity water is required, a small polishing column can be implemented at the destination.

Piping for deionized water is recommended to be electropolished 316 stainless steel (not 304 alloy), or Schedule 80 gray polyvinyl chloride (PVC), chemically resistant PVC (CPVC) or polyvinylidene fluoride (PVDF). It is recommended that the following NOT be used for piping deionized water: copper, unpolished stainless steel, garden hoses, or Tygon® tubing. Tygon® tubing can, over time, leach material from the plastic, and may contribute to organic growth (e.g., algae).

A RO and DI water setup should incorporate ultraviolet (UV) irradiation of the water. This will keep algae out of the water system and can greatly reduce the amount of bacteria in the water. Algae and bacteria can have undesirable results in printed board fabrication and their presence will not be detected by simple conductivity cells. An RO/DI system involves membrane technology which requires periodic maintenance to the membrane to keep it clean.

It should be noted that the RO and DI process does not remove everything from the water. Most public water treatment plants use sand as a filtration media. Consequently, most deionized water contains some soluble silica. Standard filtration methods will not remove it and since silica is not ionic, deionizing columns will not remove it. Soluble silica can accumulate with time, making preventative maintenance problematic and can eventually transfer to circuit assemblies.

It has been debated in the industry on whether or not all rinsing in a fabrication process has to be with DI water. Some fabricators use tap or RO water to knock off the bulk of the chemical residues, followed by a hot DI water rinse. While this is possible in some operations, impurities in the tap or RO water can cause some chemicals to become insoluble in a later rinse.

While many of the chemical analysis methods focus on the presence of ionic contaminants on printed boards, the presence of non-ionic contaminants can be just as harmful to board quality. These non-ionic materials can cause problems in plating, with solder mask adhesion, mass lamination layer separation, solderability problems with plated metals, and conformal coat adhesion.

Highly deionized water does not negatively impact most electronic assemblies. DI water in manufacturing rapidly drops from the 18 megohm-cm level to the 2-8 megohm-cm level. Repetitive cleaning with DI water is not detrimental. Long term exposure to highly polished (18 megohm-cm) DI water (e.g., soaks for extended periods) may microetch electronic surfaces, but this is a rare occurrence.

One exception to this may be the cleaning of microelectronics, such as wafers and semiconductor die, where the wire bonding pads are pure aluminum. Highly deionized water can quickly attack such surfaces, oxidizing them and interfering with subsequent wire bonding. In such cases, it is common to bubble carbon dioxide through 18 megohm-cm water to bring it down to 2-3 megohm-cm resistivity. This assures that the water is very clean but not so aggressive as to etch the aluminum pads.

In short, with some limited exceptions, all water used in printed board fabrication should be DI water.

**3.1 Cleaning Additives** There are a variety of chemical additives designed to improve the effectiveness of water in an aqueous cleaning process. These additives are generally detergents or saponifiers and should be chosen for the soils involved. While commercial grade detergents, such as dishwashing detergent, are attractive from a cost standpoint, they are not designed for cleaning electronic materials and often leave undesirable residues such as surfactants.

Some cleaning agents can be corrosive and may pose a risk to some board finishes if not completely removed during the rinsing process. Care must be taken in selecting the cleaning agents for the particular application.