

## Flux Residue & Selective Soldering

By Huy H. Pham, RPSA

During wave soldering, much of the flux is washed off the PCB during; this is not the case in selective soldering. During selective soldering, applied flux can spread beyond the solder path to where there is no solder-washing action to remove it or insufficient heat to turn the flux benign. Therefore, remaining flux residues can be active as concentrated ionic residues and produce latent defects. Current ionic cleanliness test methods will not reveal concentrated ionics remaining on the PCB when processed using selective soldering.

Flux is necessary in all automated soldering operations. It is formulated to remove tarnish films from soldering surfaces in preparation for soldering, and to protect cleaned surfaces from reoxidation. Flux assists heat transfer from the source to the solder joint area, allowing the solder to contact the base metal surface. Residues that originate from flux may also affect electronic functioning circuits. For instance, flux left around IC leads can cause electrical leakage between leads, resulting in shorts. This is the main reason that ionic test systems have a place on electronic assembly lines; it also keeps ion chromatography (IC) and surface insulation resistance (SIR) test labs in business. All flux formulas, even no-clean, have an acid component; and all no-clean must see a sufficient heat cycle to become benign or inactive, or must be washed away in a post-cleaning operation.

According to independent testing,\* most problems seen are due to flux residue in soldering applications. The problem is that flux spreads out over the surface of the electronic terminations and, in the field, time, temperature, and humidity bring them together. According to tests, this can happen with all flux formulas, but the worst cases are seen when the type of no-clean flux that has the capability to encapsulate itself as it goes through the heat cycle is used. In doing so, ionic contaminants are encapsulated so it is undetected by ionic testing, and the encapsulant hardens. Once this happens, active ingredients start to work, and the contamination starts to grow.

### Selective Soldering Application

Regardless of the formula, all flux create a unique issue for selective soldering applications. This is because flux never sees wide- spread heat of traditional wave or reflow soldering applications. The term selective soldering, or “single-point soldering,” pin- points heat to a small, specific area. Because soldering heat is so pinpointed, flux has the opportunity to spread and is not always heated enough to burn off completely.

A company experiencing a scrap rate of more than 20% with selective soldering, although production-line ionograph testing showed that boards passed, called in an analysis lab. At the test lab, technicians put boards into an accelerated life-cycle test chamber. Results showed rapid dendritic growth. The dendrites grew because of the accumulated flux residue on the boards

(Figure 1). This growth was occurring in the field as the product went through daily temperature and humidity changes.

Flux that migrates beyond the solder site could leave significant ionic residues (Figures 2 and 3). Current ionic test procedures apply the cross-sectional area of the PCB to arrive at Mg of ionic contamination/cm<sup>2</sup>.

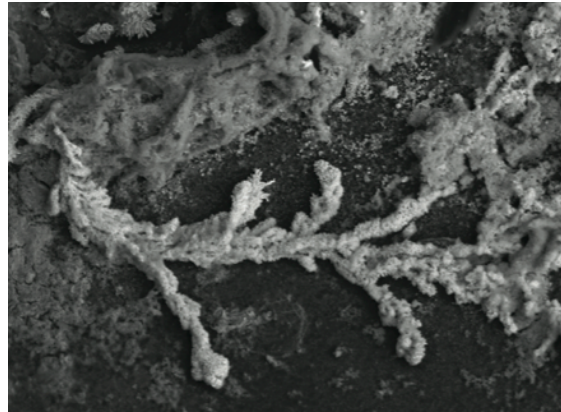


Figure 1. Dendritic growth

However, in selective fluxing, it makes more sense to apply only the area of the flux path defined to determine a more accurate concentration of ionic residues.

Modifying ionic test equipment will help find contamination in selective soldering applications, but the real goal is to eliminate or reduce flux contamination to a non-lethal level, while maintaining specific benefits of selective soldering. An area was set up to test the theory that preheating prior to fluxing would reduce flux spread and, therefore, reduce contamination. Once flux migration is controlled, there must be a method in place to adjust any production-line ionic test system to read specific contamination levels accurately. Earlier flux migration tests suggested that preheated PCBs showed less flux migration than boards fluxed at ambient temperature. This is because flux evaporates faster than it spreads. If this proved true, the hypothesis was that the ionic flux contamination should be lower when tested in this condition.

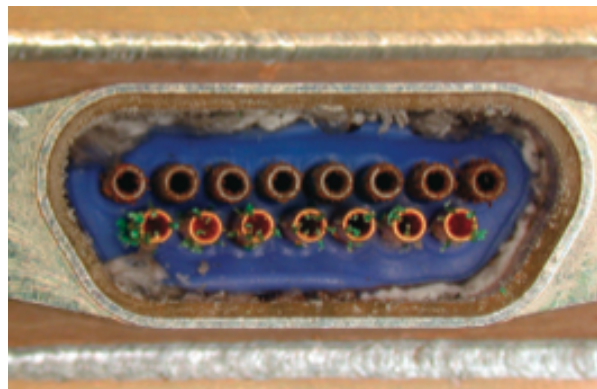


Figure 2. Connector with flux residue corrosion.

Solder samples were set up consisting of 6" × 6", FR-4 laminate-clad coupons with solder mask applied to both sides. Lead-free 96.5Sn/3.5CuAg solder was used. A small batch oven was set up on the soldering feed line, and a dynamic ionic test system tested coupons before and after each solder run. Two similar selective soldering systems were used to conduct actual soldering applications. To see if the method of flux application had any effect on the flux migration, one used a spray-flux nozzle and the other used a jet-flux nozzle. Other than these nozzles, operating parameters of the two systems were identical.

Three commonly used flux formulations (Flux A\*\*, Flux B\*\*\*, and Flux C\*\*\*\*) and three heating methods were selected:

- Ambient temperature,
- Pre-heating PCB to 125°C before flux application,
- Post-heating PCB to 125°C directly after flux application.

Tests were conducted during the selective flux application and subsequent soldering. Next, the same tests were applied using one or both board-heating methods. An in-line batch oven was used for board-heating tests.

#### Test Results

Table 1 shows results of ionic quantity present on sample coupons soldered first in the normal fashion (ambient temperature), and then compared with resulting flux residue when conducting the same test using heated boards. All flux formulas were tested, as were both flux-application methods.

In ionic testing, ions that originate from flux cause a conduction in the test solution, which is reported back as contamination. Therefore, these tests are designed to measure the quantity of ions remaining on a particular area of the board. The system holds the test solution in a tank, where the solution is pumped from the reservoir and sprayed onto the test sample. It then returns to the reservoir and passes resistivity probes on the way back to the pump. At the end of the procedure, results are calculated and displayed. Normally, contamination levels would be averaged across the entire PCB area, which is where the problem comes in with testing small areas processed during selective soldering. For an accurate test, the board area was adjusted from the calculated area to only the area covered by the flux. In this case, the area was changed from 36 in<sup>2</sup> to 5.8 in<sup>2</sup> for the 6- × 6-in<sup>2</sup> test coupon.

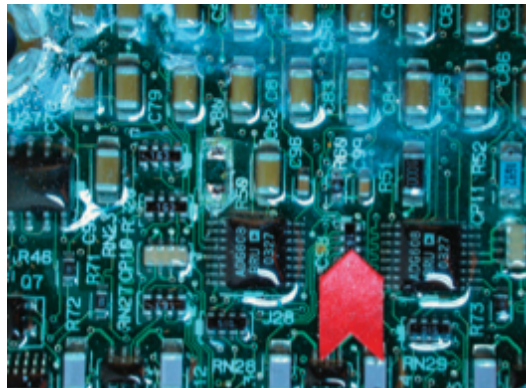


Figure 3. Populated PCB showing extensive flux residue corrosion.

Following this concept, anyone using selective soldering technology can obtain accurate ionic cleanliness results by calculating the actual flux pattern/soldering area, duration, time, and solution volume. The user must enter the actual flux path, not the size of the overall board, as is the case in wave or reflow application testing.

<b>Table 1. Process A – Spray Fluxer</b>			
<b>Flux A</b>	<b>Sample 1 (MG NaCl/cm<sup>2</sup>)</b>	<b>Sample 2 (MG NaCl/cm<sup>2</sup>)</b>	<b>Sample 3 (MG NaCl/cm<sup>2</sup>)</b>
<b>Test 1</b> Flux, solder, ionic test	2.48	2.34	2.33
<b>Test 2</b> Preheat (125°C), flux, solder, ionic test	1.10	.85	1.29
<b>Flux B</b>	<b>Sample 1 (MG NaCl/cm<sup>2</sup>)</b>	<b>Sample 2 (MG NaCl/cm<sup>2</sup>)</b>	<b>Sample 3 (MG NaCl/cm<sup>2</sup>)</b>
<b>Test 3</b> Flux, solder, ionic test	2.88	3.12	2.73
<b>Test 4</b> Preheat (125°C), flux, solder, ionic test	0.65	0.88	0.98
<b>Flux C</b>	<b>Sample 1 (MG NaCl/cm<sup>2</sup>)</b>	<b>Sample 2 (MG NaCl/cm<sup>2</sup>)</b>	<b>Sample 3 (MG NaCl/cm<sup>2</sup>)</b>
<b>Test 5</b> Flux, solder, ionic test	10.85	1 <sup>1</sup> 1.22	12.16
<b>Test 6</b> Preheat (125°C), flux, solder, ionic test	8.91	9.50	9.92
<b>Process B – Jet Fluxer</b>			
<b>Flux A</b>	<b>Sample 1 (MG NaCl/cm<sup>2</sup>)</b>	<b>Sample 2 (MG NaCl/cm<sup>2</sup>)</b>	<b>Sample 3 (MG NaCl/cm<sup>2</sup>)</b>
<b>Test 1</b> Flux, solder, ionic test	5.40	5.52	5.60
<b>Test 2</b> Preheat (125° C), flux, solder, ionic test	3.22	3.60	3.15
<b>Test 3</b> Flux, post-heat (125° C), solder, ionic test	2.73	2.67	2.71
<b>Flux B</b>	<b>Sample 1 (MG NaCl/cm<sup>2</sup>)</b>	<b>Sample 2 (MG NaCl/cm<sup>2</sup>)</b>	<b>Sample 3 (MG NaCl/cm<sup>2</sup>)</b>
<b>Test 4</b> Flux, solder, ionic test	5.00	5.40	5.10
<b>Test 5</b> Preheat (125°C), flux, solder, ionic test	2.20	2.29	2.33
<b>Test 6</b> Flux, post-heat (125°C), solder, ionic test	2.56	3.30	3.33

Test results prove that heating the board — before or directly after flux application and before soldering — will greatly reduce flux migration, with the preferred method being pre-heating before fluxing.

Results indicate that pre-heating mitigates concentrated ionic residues remaining as a result of selective soldering. However, the issue of solderability and the potential compromising of solderability must be addressed. Questions remain regarding how much heat can be used, and with which flux formulas. With some formulations, higher temperatures may not only reduce flux migration, but can inert the flux entirely; and consequently, board solderability. This is particularly applicable when using no-clean flux formulas, which have demonstrated high flux-persistence problems. Unlike many other organic acid fluxes, it will lose its fluxing ability under heat. This is a delicate balance that needs to be approached with caution.

Maximum pre-heating rates generally are accepted at 2°C/sec. Raising board temperatures from ambient to 100°C would take about 40 sec. Once heat-level-to-flux ratios are studied enough, a system can be developed to address this.

It has been noted that 10 µg of NaCl/cm<sup>2</sup> will produce 100% failures in 24 hours at 75°C/95% relative humidity (RH). A clean condition often is considered <1 µg NaCl/ cm<sup>2</sup>. Therefore, aside from all other potential actions to reduce flux contamination, it is best to clean boards thoroughly after processing. In addition to regular ionic testing using a method tailored to selective soldering applications, it is also recommended that a sample be taken at periodic points in any run and sent out to a lab for thorough IC testing. Although this is not practical on a production line, it is a good fail-safe measure, and particularly important if a company begins experiencing increased field failures.

## Conclusion

Most manufacturers do not experience extensive problems with existing process parameters of selective soldering, yet reasons for concern are evident. When performing ionic cleanliness testing for selective soldering processes, it is important to correct test process parameters for PCBs undergoing selective soldering to collect all data. If unacceptable contamination levels are shown, adjust the process accordingly. While tests show that pre-heating the board will reduce the potential for flux contamination, this should not be done unless a full test is performed to determine that the high temperature will not nullify the flux and compromises board solderability. Production time must also be evaluated. However, post-cleaning process should always be in place. That is the only way to reduce flux contamination without potential damage to the solder process itself. When flux residues remain on the board, failures will occur. While further tests are being conducted into the viability of stable heat control for various flux formulas, this issue can be mitigated by correct testing for ionic contamination and thorough board cleaning. Quality ionic testing for selective soldering requires a minor adjustment to any standard industrial ionic test system. It provides a fail-safe way to reap the benefits that selective soldering can bring to boards that cannot be soldered using other methods. The bottom line is: clean boards after wave, reflow, or selective soldering

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