Siemens Information and Communication Networks
Cherry Hill, NJ

Wave Solder Flux Evaluation
September, 1998

Introduction

Siemens Information and Communication Networks (SICN) manufactures a variety of complementary telecommunications equipment for private communication networks. The circuit assembly facility runs three distinctly different wave solder operations to produce PWA's for modern switching systems, desktop telephones, and field support of spares for existing systems in the field. Together, the three lines produce boards of different laminate constructions, surface finishes, and assembly technologies.

The goal of the flux evaluation was to identify one product that would meet the needs of all SICN's wave solder products and processes while producing high quality assemblies. At the outset of the evaluation, it was unclear whether a single flux chemistry could satisfy such a broad range of demands, particularly because SICN's utilization of less aggressive, low-impact chemicals.

The Products

The switching system boards are mixed technology assemblies, with both through-hole and surface mount components. Although some of the systems boards are very densely populated on the solder side, there are no active components on this side. The smallest components are 0805's. The boards are constructed of FR-4 fiberglass-epoxy laminate, with hot air solder leveled (HASL) pads and plated-through holes, and all have matte finish solder mask.

The telephone boards have a variety of configurations and constructions. The solder side population varies from only through holes and vias to moderate density active components. The smallest components are SOT-23's; the largest are 16-pin SOIC's. The constructions are both single and double-sided, and vary from product to product to include FR-2 phenolic-paper laminates, FR-3 epoxy-paper laminates, and FR-4 fiberglass-epoxy laminates. The surface finishes include HASL and bare copper dipped in an unidentified organic solderability preservative (OSP). Both matte and glossy finish solder masks are used on these boards.

The mature product line of spares employs strictly through-hole technology. The boards are FR-4 with HASL plated through holes, and matte finish solder mask.

The Processes

The switching systems circuit boards are soldered on a modern Electrovert Econopak Plus that is outfitted with an ultrasonic fluxer, three forced convection preheaters, nitrogen inerted turbulent and laminar waves, and a hot nitrogen knife debridging tool.

The telephone boards are soldered on a similar Econopak Plus, but this machine does not have a hot gas knife to break up solder bridges.

The spares are soldered on a 1980's vintage Electrovert Ultrapak 445 with a pressure spray (paint nozzle) fluxer, two infrared preheaters, and a single lambda/omega wave. There is no nitrogen inerting or debridging knife on this machine.

The spares area processes only 10 to 15% of SICN's total production and the product technology is less challenging. The focus of the evaluation was the primary production areas, with the assumption that a flux chemistry capable of producing high quality assemblies in this area would exhibit few compatibility issues on the spares line.   The flux compatibility would later be verified for the spares application.

Fluxing Equipment

The fluxers used in the evaluation were Opti-Flux models manufactured by Ultrasonic Systems, Inc (USI). The Opti-Fluxer consists of a single ultrasonic head that travels back and forth under the circuit board a seen in figure 1. Liquid flux is applied to the head where it is atomized by ultrasonic energy. Two air delivery systems (one to spread the stream and one to add upward velocity) assist the spray formation and penetration onto the circuit board. The spray head traverses on a rodless cylinder, whose speed is controlled by air pressure. The travel is precisely controlled by a PLC to av[illegible]d areas of the circuit boar[illegible]

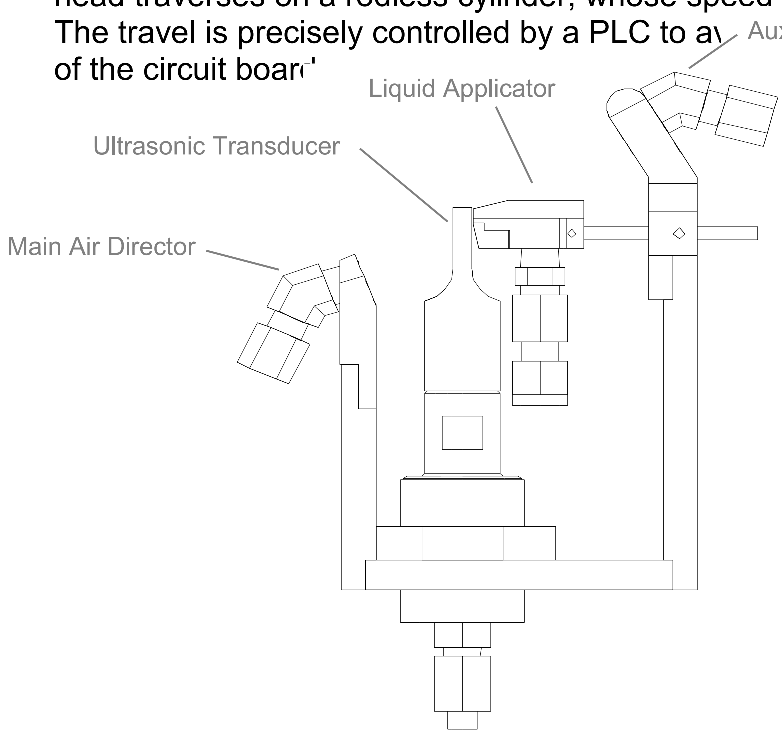

Figure 1
Opti-Fluxer Spray Head

The amount of flux applied to the circuit board is set by electronically regulating the pressure in the flux reservoir. Flux deposition measured in micrograms per square inch. To determine how much flux is applied to a circuit board at a particular pressure setting, an aluminum plate is weighed, fluxed, and weighed again while wet. The deposition is then determined by multiplying the weight difference by the percent solids in the flux, converting the difference to micrograms, and dividing by the area of the plate. Previous capability studies on the fluxing equipment indicate a six-sigma repeatability of the fluxer, or a Cp of 1.94. Therefore, one weight measurement was taken at each of several predetermined settings for each flux used.

Test Vehicles

Two assemblies were identified as test vehicles for the flux evaluation. They were: a double-sided FR-4, plated through hole, hot air leveled board (Board A) and a single-sided FR-3, bare copper finish dipped in unidentified OSP that had exceeded its recommended shelf life (Board B). Together, the two assemblies represent worst case soldering scenarios. The wave solder machine without a hot gas knife was chosen because it runs a tighter process window.
Board A is the highest volume board produced on the line. Although it has no bottomside surface mount components, it has many through-hole pins oriented parallel to the wave with a high probability for bridging. It also has glossy soldermask with a high probability for solderballing. Although SICN's current flux chemistry provided adequate soldering, topside solder fillets were not

common (preferred but not required in Class 1 workmanship standards) on many leads, bridging occurred on approximately 20% of the assemblies, and micro-solderballing occurred on the glossy mask at acceptable levels.

The solder side of Board B is moderately populated with 1206's, SOT-23's, and 16-pin SOIC's, in addition to through hole components and test points that require good hole fill. The soldermask is a silk-screened semi-gloss finish. These assemblies historically showed terrible solderability, yielding upwards of 50 opens per panel using the currently approved OSP flux chemistry.

Forced convection preheaters use hot air to heat the circuit boards, evaporate the water carrier of the flux, and activate the fluxes. The Board A assemblies used in this evaluation are preheated to a topside board temperature of 220°F with a maximum differential of ± 3°F across the surface of the board. The Board B assemblies were similarly preheated to a topside temperature of 240°F.

Evaluation Criteria

OSP Solderability (Board B) – The flux should provide good to excellent solderability on oxidized, protected copper at deposition rates less than or equal to the manufacturer's recommended rates for passing ionic contamination tests.

Topside Solder Fillets (Board A) – Full 360° circumferential wetting on the *secondary side* of the circuit board as described in IPC-A-610B is the target condition. Additionally, full solder fill and circumferential wetting of the annular rings on the vias on the secondary side of the card is considered a preferred condition, as the electrical test fixture probes from the secondary side. Full wetting on the secondary side of the board is not required by the Class 1 standards to which these boards are inspected, but facilitates throughput at the test stage of the manufacturing process.

Visible Residues – Visible residues are acceptable but not preferred. Tacky residues are highly unacceptable, as many of the products have graphite contacts for the telephone keypads. Although the residues may be considered "safe" from electrical and electromigration perspectives, tacky residues may attract dust and other particulates that impede the long-term reliability of the telephone keypads.

Solderballing – Micro solderballing is considered acceptable by SICN's addendum to the recently adopted IPC workmanship and quality standards. This addendum cites the diameter of the largest allowable solderball to be 0.008." For purposes of evaluation, minimizing solderballs is the preferred condition; with zero solderballs as the target. The rational behind mitigating solderball creation addresses the fact that the evaluations are performed under controlled circumstances with engineering's involvement. If a flux produces solderballs under extremely controlled conditions, the possibility exists for the process to go out of control in a production situation and produce solderballs that do not comply with SICN's specification. Although operators should inspect product to the stated workmanship standards, the possibility exists that problems could arise undetected, as our inspectors are not accustomed to gauging solderball size or accumulation.

Board Cleanliness – The only in-house method of gauging board cleanliness is Ionic Contamination as measured in a Kester Ionex 2000. Ionic contamination is an indicator of the cleanliness of the entire assembly including the incoming materials, not just the results of the soldering process. Some components such as transformers are known to have higher degrees of contamination in their "as-received" condition. To gage the amount of contamination contributed to the final assembly by the flux, circuit boards were assembled, their parts were clinched to the boards, and the boards were tested pre-soldering to indicate a baseline of ionic contamination. Soldered assemblies were then tested in the same manner and the difference from pre- and post- soldered assemblies were calculated.

Due to the cumbersome nature of the ionic contamination tests, the tests were performed only for the flux that fared the best in other evaluation criteria, and only on the assemblies that required the greatest amount of flux for good soldering.

Products Tested

No-clean, VOC-free fluxes designed to act on OSP's or oxidized surfaces were sampled from five manufacturers, for a total of seven fluxes. The solids content ranged from 2.7% to 4.5%. A summary of the results is shown an tabular form at the end of the document.

Results

Most of the fluxes demonstrated excellent adherence to one or more of the criteria to which they were tested. Two fluxes, however, met all the demands in every evaluation category. Heraeus SURF 11 and Alpha NR-310 B-2 promoted excellent wetting for hole fill and topside solder fillets, left no visible or tacky residues, produced less solderballing than our current chemistry, and showed excellent solderability on OSP's. In fact, all other fluxes have been able to mitigate solderability issues on the Board B assemblies to the level of 1 – 4 opens per panel, but the SURF 11 and the NR-310 B were the only products that actually produced perfect, defect-free panels.

The solderability improvement on the production line was so dramatic that Siemens immediately began using the SURF 11 on the day of the trials. Within several weeks, NR-310 B was introduced, and it compared very favorably with the SURF 11. From an engineering perspective, the two products were functionally equivalent. To break the deadlock, additional tests from an operational perspective were devised.

Bacterial growth is not uncommon in water-based products. The formation of bacteria can clog microfilters in the flux delivery lines and cause less flux to be dispensed to the circuit boards than desired. A bacterial growth test was conducted by filling two beakers with each product, tightly covering them with plastic wrap and a rubber band, and setting them on the inside deck of the wave solder machine for one week, where the temperature hovers around 100 degrees Farenheit. Both fluxes passed the bacterial growth tests.

Solids precipitation upon freezing is another issue commonly associated with water-based fluxes. To perform a freeze test, sample beakers were filled with the products and placed in the freezer of a refrigerator over a weekend. After freezing to a solid block of ice, the products were thawed at room temperature. The solids of both products had precipitated out, but went back into solution without any agitation. This return to solution without agitation is a highly preferred condition, but not a common one with water-based fluxes. The Heraeus flux did have a small film of oil on top of the liquid after the thawing process, which did not return to solution. It is thought that the oil is a foaming cessation agent to stop the formula from foaming when air is introduced to the product.

Finally, the teams working on the shop floor were asked to make a list of criteria on which they would judge the best flux. Wave solder operators, product inspectors, post-wave assemblers, and test personnel were asked to list items of importance to them (table 2). The fluxes were scheduled to run throughout the factory for a full week, in succession. After a week with the SURF 11 and a week with the NR-310 B-2, a deadlock existed. The fluxes ran again and again, and finally, after six weeks, Alpha NR-310 B-2 was chosen. Some of the primary driving factors from the wave solder operators were the cleaner appearance of the fluxer cabinet between maintenance intervals and less dross formation on the solder pot. The product inspectors felt that the joints formed with the NR-310 were slightly shinier, and therefore easier to inspect.

Siemens Information and Communication Networks in Cherry Hill, NJ, is now using the NR-310 B-2 in all three wave solder operations. Heraues SURF 11 is also approved for production use as an alternative to the AlphaMetals product.

Wave Solder Flux Evaluation Summary

Flux Formulation	OSP Solderability	Topside solder fillets	Visible residues	Solderballing	Ionic Contamination	MSDS on file	Comments
Multi-Core EU1339	Excellent (at 1400 $\mu g/in^2$)	Y	Acceptable	Micro-balling on glossy mask		Engr's office	Developmental product. Only 5 gallons formulated for SICN application. 1400 $\mu g/in^2$ is 12% higher than max suggested (1250)
AlphaMetals NR310-M	Excellent (at 1200 $\mu g/in^2$)	Y	Tacky, highly visible	None noted		Engr's office	Max suggested deposition is 1500 $\mu g/in^2$
AlphaMetals NR310 – B	Excellent	Y	Acceptable	Micro-balling on glossy mask		Engr's Office	Performs similar to Heraues SURF 11. Putting both fluxes into production trials for long-term evlauation.
AIM 273	Excellent	Y	Tacky, visible	Not evalutated on glossy mask		Engr's office	Material had foaming agent in it that may interfere with ultrasonic application. Tacky residues are highly undesirable.
Kester 970	Poor	N	Acceptable	Some balling on glossy mask		MSDS Book	Current product for HASL boards (slightly less balling than Multi-Core EU1339)
Kester 973	Marginal	N	Acceptable	None noted		MSDS Book	Current product for OSP boards
Heraeus SURF 11	Excellent at low deposition rates	Y	Acceptable Lowest residue of all chemistries	Micro-balling on glossy mask		MSDS Book	Lowest for solderballing. Lowest residue. Same solids content as current chemistry. Actually soldered HRO's with no defects.