

THE CHARACTERIZATION AND COMPARISON OF SPRAY FLUXERS

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Abstract

The electronic manufacturing industry's move to no-clean fluxes has spurred new technology developments for the mechanisms of flux application. Wave or foam fluxers are no longer preferred for low-solids fluxes, because the evaporative nature of the flux requires frequent titrations and renders the process very operator-dependent. Spray fluxers are preferred, since their sealed systems eliminate the variable of fluctuating specific gravity. Spray fluxers have evolved over the years from simple pressure spray, to ultrasonic atomization, to reciprocating application heads, and, most recently, programmable microjets.

An evaluation of two fluxers, one with a reciprocating ultrasonic head and the other with microjets, was performed using nine independent criteria. The tests included objective variables such as variability of flux deposition (Cpk) by weight on metal plates and soldering defects on densely populated, mixed-technology circuit assemblies. Subjective variables such as ease of use and overall robustness of equipment were also among the criteria for consideration. Additional factors included maintenance requirements, VOC-free compatibility, serviceability and deposition uniformity tests.

Neither fluxer demonstrated superiority in all categories. Each type of fluxer had advantages and drawbacks. This paper details the pros and cons of each machine, and the tests and statistical methods associated with each selection criterion.

Theory of Operation

Opti-Fluxer[®]

The Opti-Fluxer consists of a single ultrasonic head that travels back and forth under the circuit board, as 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 avoid overlapped or skipped areas of the circuit board.

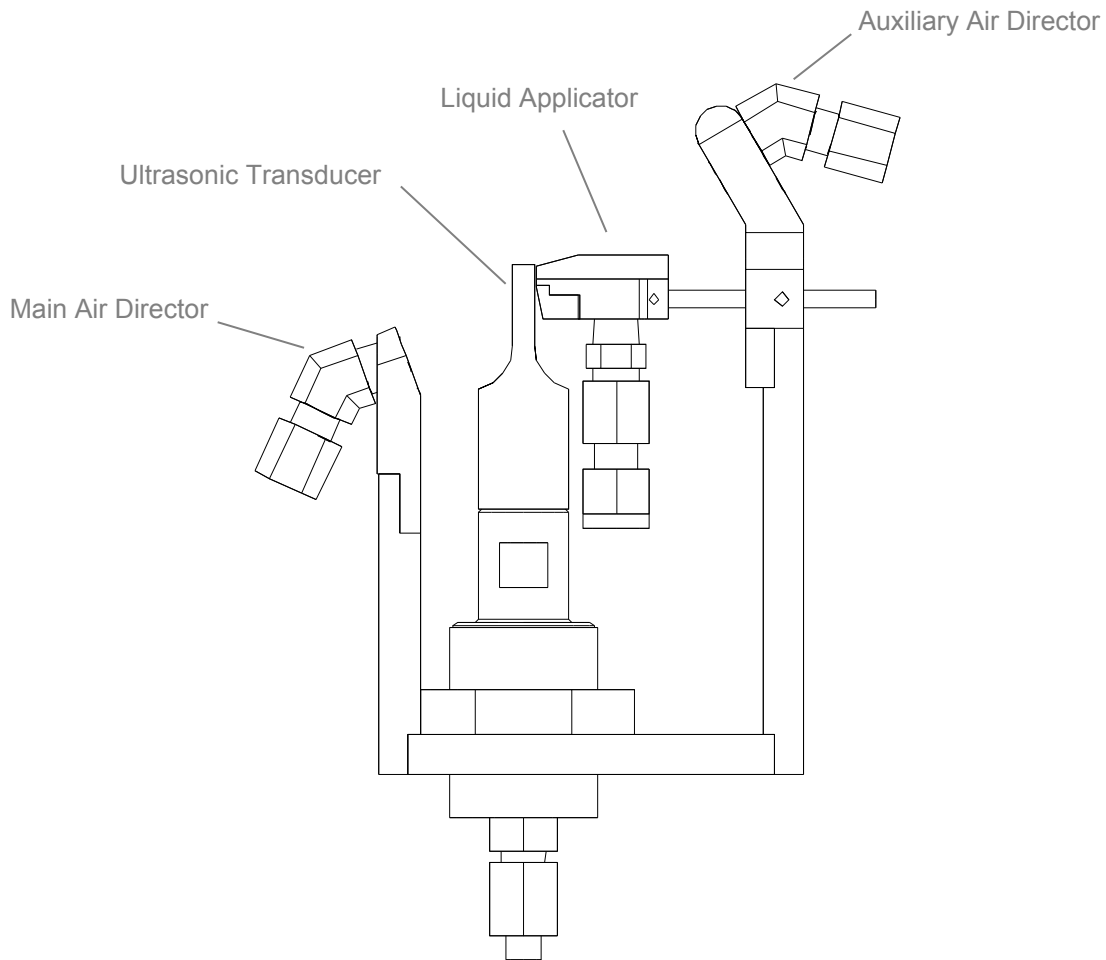


Figure 1
Opti-Fluxer Spray Head

Jet Fluxer®

Precision microjets are mounted linearly below the machine conveyor. There are 8 jets per inch. Each group of eight is called a segment. The segments can be programmed to turn on and off in 1 millisecond increments. A typical program will turn them on for .006 seconds and off for .100 seconds. This quick, precise pulsing action provides accurate flux deposition on the circuit board. In addition to its high precision, the Jet Fluxer also enables selective fluxing of circuit boards, by programming certain segments not to turn on during the course of PCB travel over it. Figure 2 shows a section of the Jet Fluxer's Spray Heads.

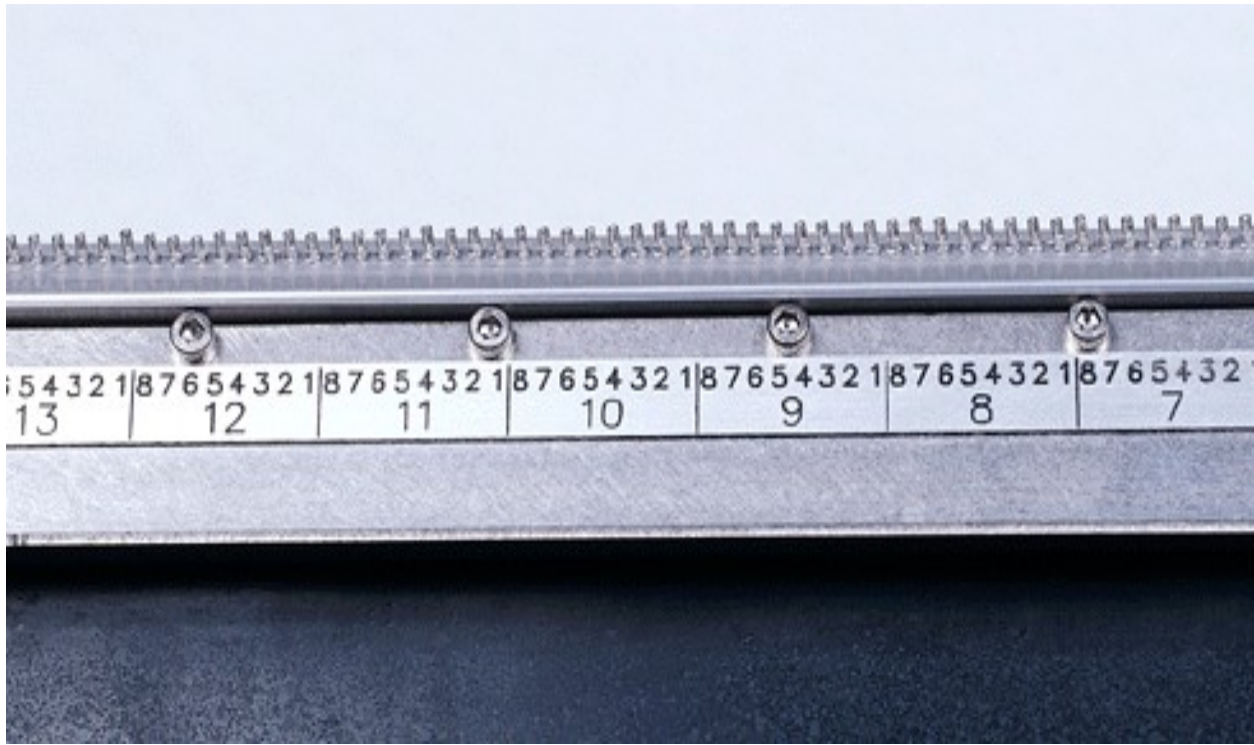


Figure 2
Jet Fluxer Spray Heads

Tests and Results

General Information

Date of Tests: March 10-11, 1997
Location of Tests: Electrovert Center for Advanced Technology and Training,
Grand Prairie, Texas

Evaluations
performed by: Chrys Shea and Vince Lewis (Siemens)
Chris Kelly and T.J. Jeitler (Electrovert)

Soldering
Equipment: EconoPak Plus with three forced convection preheat zones,
rotary chip wave, and CoN₂tour nitrogen inerted solder pot.
A Hot Nitrogen Knife was not available for the evaluation

Objective Tests

Soldering Tests: A total of 15 mixed technology circuit assemblies were soldered for the evaluation. The first six were soldered using the Opti-Fluxer depositing 900 $\mu\text{g}/\text{in}^2$ flux solids with excellent topside wetting. An average of three bridges were found per board in repeating locations between adjacent 1206's. The presence of a hot nitrogen knife would have eliminated these bridges. Ionic contamination tests showed 10.49 $\mu\text{g}/\text{in}^2$ NaCl contamination. The maximum allowable is

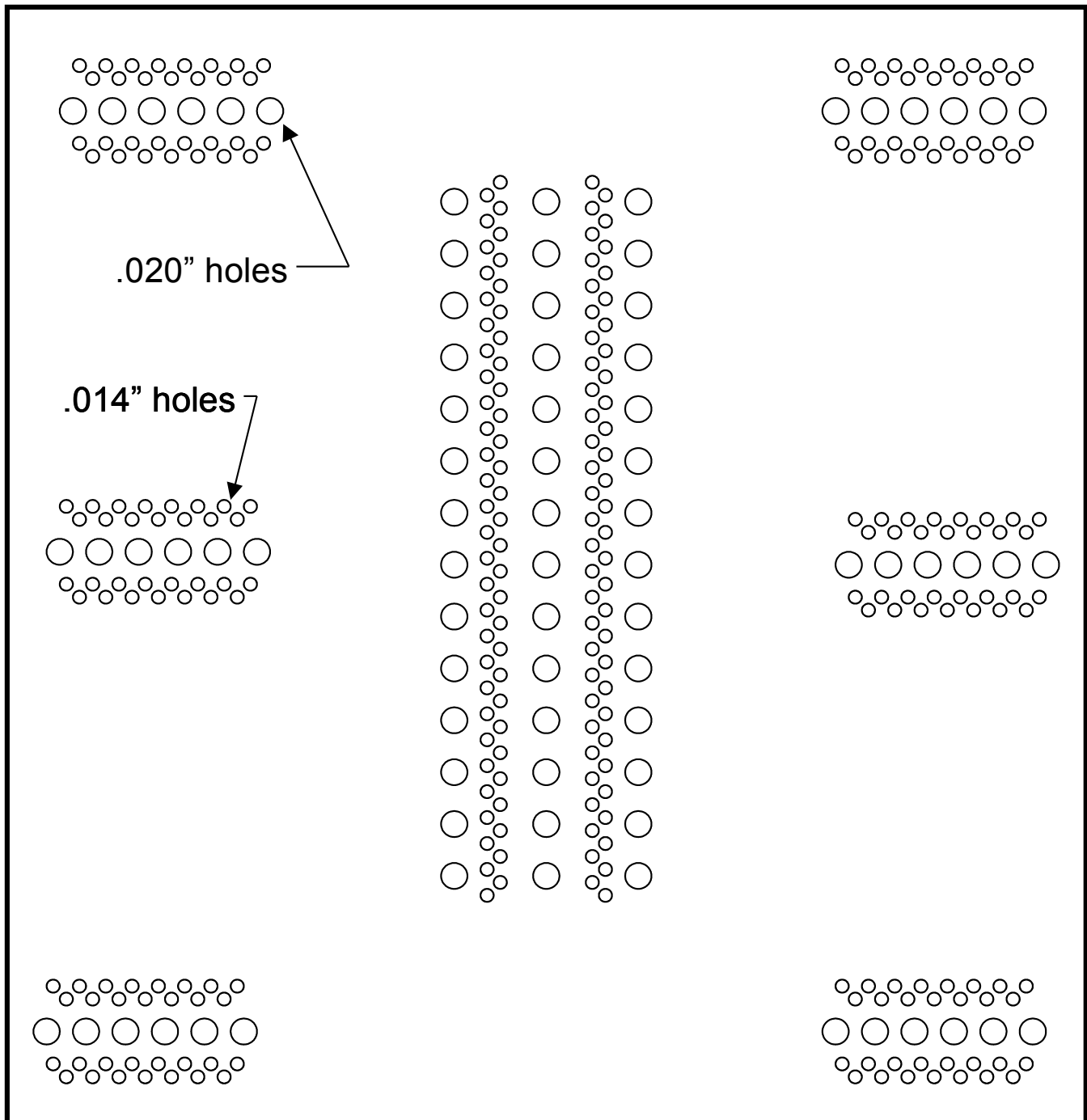
20. The next six boards were fluxed on the Jet Fluxer depositing $850 \mu\text{g}/\text{in}^2$ and soldered under the same parameters. Topside wetting was acceptable, but not preferred. Again, the same bridges repeated due to the lack of the hot gas knife. The remaining three boards were fluxed on the Opti, depositing $685 \mu\text{g}/\text{in}^2$ of flux and again showed excellent (100%) topside wetting and the expected three 1206 bridges.

Deposition Tests: Ten trials were performed on each fluxer. For each trial, an aluminum plate was weighed, fluxed, and weighed again while wet. The deposition was determined by multiplying the weight difference by the percent solids in the flux (2.7%), converting the delta to micrograms, and dividing by the area of the plate (two different size plates were used). The averages and standard deviations were calculated for each machine. The machines' capability, C_p , was determined by dividing the process window's width of $400 \mu\text{g}/\text{in}^2$ (+/- 200) by 6 standard deviations. The Opti-Fluxer demonstrated a C_p of 1.94, (nearly a six sigma process). The Jet Fluxer demonstrated a C_p of 6.63 (a 20 sigma process!)

Subjective Tests

Uniformity Tests: Thermal fax paper was sandwiched between two pieces of G-10. The piece that faced the fluxer was .062 thick and had holes of diameter 0.020" and 0.013" drilled in it, to simulate a circuit board. Figure 3 illustrates the basic layout of the fixture. 0.013" holes were meant to simulate vias; 0.020" holes simulated the maximum clearance between component leads and plated holes. The patterns on each of the four corners of the board allowed evaluation across the entire process width. The strip of holes down the middle of the fixture indicated overlapping patterns or skips. When the flux sprayed the board and penetrated the holes, it stained the fax paper underneath. Examination of the fax paper showed no overlaps or skips produced by either fluxer.

Figure 3
Diagram of Fax Paper Test Fixture



Overall Robustness
of Equipment:

Robustness ratings are based on the experience and opinions of the equipment evaluators when considering the environment of the proposed installation. The robustness rating given the Jet Fluxer was good; the rating given the Opti-Fluxer was excellent. The Opti-Fluxer fared better than the Jet for several reasons: larger flux delivery lines, less connections in the flux delivery circuits, less delivery orifices that can clog, stainless steel “nozzles” as opposed to plastic, and a self cleaning feature to prevent flux from drying on the spray head.

Ease of use:

Setup, programming and cleanup are the primary factors contributing to the ease of use rating. Other factors include the control system, error message delivery, and on-line help. The Jet Fluxer received a rating of fair, due primarily to its control system. In all installations except the newest models, the control system is not integrated into the wave solder machine. Programs must be written, stored as four-character names, and loaded at the fluxer’s console, not the wave’s. Additionally, if a microjet were to get clogged with dried flux, it must be carefully cleaned to prevent further clogging or nozzle damage. The Opti-Fluxer received a rating of *excellent*, based on the integrated control system. Flux parameters are part of a regular wave solder recipe. Cleanup, although more time consuming on the Opti-Fluxer than on the Jet-Fluxer, is easy and poses little risk of equipment damage.

Additional Factors

Maintenance
Requirements:

Regular cleaning, draining, filter changeouts, and equipment inspections are included in maintenance requirements. The Jet Fluxer had nearly no maintenance requirements, except draining the catch pan and inspecting the flux lines and nozzles. The Opti-Fluxer requires similar maintenance, plus the cleanup of oversprayed flux solids from the inside of the unit’s enclosure. Overall weekly maintenance on the Jet Fluxer is estimated to be about 5 minutes; weekly maintenance on the Opti-Fluxer is estimated at one hour.

VOC-Free
Compatibility:

Both machines were run with 2.7% solids, water based flux. No performance issues were noted with Kester 970 flux.

Field Serviceability:

The number of systems in the field service and the amount of training and experience the local technicians have on the equipment were the considerations for the serviceability

rating. In the northeast region, many Opti-Fluxers were in operation for over a year. No Jet Fluxers were installed in the region. The regional technicians were trained by the Jet Fluxer's original manufacturer, but did not have much work experience on the equipment.

Spray Integrity

and Containment: Effect of full exhaust pressure on spray, spray getting pulled into first preheat blower, and drips outside of chassis of the machine contributed to the spray integrity and containment classification. Neither fluxer demonstrated any spray integrity or containment problems. The Opti-Fluxer, however, did have a containment problem upon installation. Two extra mounting holes in the fluxer's cabinet allowed flux to leak onto the floor under the machine. The holes were later sealed by a field service engineer.

Results & Recommendations

Summary

The Opti-Fluxer is the spray fluxer of choice for the application under consideration. Its good repeatability, excellent penetration, low maintenance, and integration into the wave solder control system make it the best option currently available. It was selected over the Jet Fluxer based on nine evaluation criteria. Both fluxers are highly capable machines. In weight deposition tests, the Opti-Fluxer demonstrated excellent repeatability; the Jet Fluxer demonstrated outstanding repeatability (six times that of the Opti). The Opti-Fluxer, however, provided better topside wetting and a higher degree of user friendliness. Maintenance concerns from previous USI ultrasonic fluxers have been addressed through redesign activity over the past three years. Additionally, the fluxer's control system has been integrated into the machine software to provide seamless, single setup operation. Operational concerns based on previous experience with similar fluxers such as overspray and overlap were not witnessed during fax paper or soldering tests. Although the Jet Fluxer outperformed the Opti-Fluxer in deposition capability, the Opti shows sufficient capability and equaled or outperformed the Jet in most other considerations. A summary of the results is shown in table 1.

Table 1
Fluxer Comparison

Criteria	Jet Fluxer®	Opti-Fluxer®
Deposition Uniformity (fax paper test)	Excellent	Excellent
Topside Wetting (solder fillets)	Good 95%	Excellent 100%
Control of Deposition (Cp)	Outstanding (6.63)	Excellent (1.94)
Maintenance requirements	nearly nil	1 hour/week
Overall robustness of equipment	Good	Excellent
Ease of use	Fair	Excellent
VOC-Free Compatibility	Excellent	Excellent
Recommendations from other users	not available yet	not available yet
Field serviceability	- no other systems in this region - local technicians have been trained by OEM	- many systems in region - local technicians have been working with equipment for a year
Spray integrity & containment	no issues	no issues

Selective Fluxing

One of the Jet Fluxer's advantages over the Opti-Fluxer is its capability to selectively flux areas of the circuit boards. The one-inch wide jet segments can be turned off and on to flux (or not flux) particular areas of a circuit board or selective soldering fixture. The Opti-Fluxer can be programmed to start or stop spraying at a particular location across the board width, but the start and stop points remain constant for the entire length of the circuit board.

Concerns about Opti-Fluxer from experience with earlier models

- **Assembly of ultrasonic head:**
Head assembly has been redesigned to become engineer-friendly. The parts count has been reduced to 2. It is self-aligning and self-gapping.
- **Cleaning of ultrasonic head:**
A new self-cleaning function has been added. It's a rinse from above the head to clean up areas that the purge function cannot reach. It's essentially a showerhead at the home position.
- **Blowing the signal generator:**
The most common cause of blown generators is head assembly misalignment. Misalignment is now nearly impossible. Additionally, the tolerance band width for the frequency has been opened up to prevent fuse blowing.
- **Timing errors:**
Timing errors like overspray or no spray were attributable to marginal conveyor speed sensor design (an inductive sensor and a sprocket). Integrating the control systems now allows the fluxer to get its conveyor speed data directly from the wave solder machine's computer (which uses a glass encoder wheel).
- **Buttons, knobs, and dials:**
All gone. Important spray parameters like flux and air flow rates, tank overpressure, an ultrasonic frequency have all been removed from the chassis of the machine. Flow rates have been hard tooled in at their optimum settings, frequency control has been moved inside the cabinet where it is protected by a lock on the door, and tank pressure is set and controlled electronically.
- **Degeneration of travel cylinder:**
Original band cylinder has been replaced with new model rated for over 2X the stroke life of the previous one. (7 million cycles)
- **Clogging of input photocell:**
The closer, traversing nozzle dramatically decreases the amount of excess flux falling outside the cabinet and onto the photocell, and the photocell design has changed to become a reflective sensor that is made by breaking a beam.

Concerns about the Jet Fluxer

- Jet nozzles clogging:
The fluxer has a self-purge feature which runs flux through the nozzles at pressures higher than operational pressures to clear out any solids which may be clogging it. Solids settled out on the top of the nozzles may be purged off, but trying to rub them or clean them with a brush will clog them.
- Jet replacement:
Jets are held in place by the tube delivering the flux. To change a jet, pull it out of the tube and push a new one in. The tubes come from the segment control solenoids, where a series of Y's branch one tube into eight to feed the jets. This scheme is slated for a redesign to incorporate a manifold to feed the jets.
- Not integrated into machine control software:
Each flux program must be pulled up individually. The programs can only be named by four-digit numbers. This fluxer will be integrated into the new *Electra* model wave solder machine, and eventually the other models.
- Ease of use:
This fluxer is not as easy to use or program as the Opti-Fluxer. There are many parameters and only one level of password control.
- Board penetration:
The Jet provided acceptable solder fillets over 90% of the time. However, better, more consistent topside wetting was obtained with the Opti-Fluxer.

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