Flux Application for Lead-Free Wave Soldering

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Abstract:
Lead-free wave soldering requires tighter process control than soldering with lead based alloys. A key area of the machine that impacts the ability to solder lead-free alloys without defects is the flux system. A large variety of fluxers are available for use with lead-free soldering - each having advantages and disadvantages. This paper compares the more popular flux systems in terms of through hole penetration, coverage accuracy, cost level, maintainability, and chemical compatibility. Ultrasonic, air atomization, and jet type flux systems are discussed and test data presented for each system.

Introduction:
The ban on lead in electronic assembly in Europe, Japan and pending laws in China and California has thrown the industry into a frenzy to develop a lead-free wave solder process that is reliable and defect-free. The flux delivery system's capability to apply flux uniformly with penetration into the through holes is critical to the rest of the process and is the first step in the wave solder process. Each of the fluxers tested were traversing systems that spray in only one direction. Data was collected across the width of the spray pattern to determine the velocity and the uniformity of the air flow at the board level. These two characteristics affect the penetration of flux into the through holes. Uniformity and hole penetration will also be measured using a fluxometer and pH paper on two test boards where one board has .037 holes and the second board has 3 different hole sizes, .013, .024 and .032.

Uniformity and through hole penetration:
The performance of the spray fluxers was based on 3 criterions;

1. Impact velocity at board level
2. Uniformity at a 3 inch spray segment with a board with .037 holes
3. Visual hole penetration on pH paper through 3 different hole size patterns .013, .024 & .032

The flux deposition was set to same level on all systems for all tests and a no-clean VOC-free flux was used during the testing.

The 3 inch spray width is important because it sets how many spray strokes must be made to uniformly spray flux on a given circuit board. It also affects the speed that the system must traverse in order to return to the home position in time for the next spray stroke. This number was chosen because it gives systems the flexibility to process boards up to 24 inches in width at conveyor speeds of 5 ft/min. Smaller spray widths required to achieve uniformity and hole penetration will diminish this flexibility and reduce the board width and/or conveyor speed that boards can be processed.

Velocity Test:
A Plexiglas plate was manufactured (Figure 1) in order to analyze air velocity at board level. 10 holes were spaced equally over a 3.5 inch distance that was centered over the fluxer nozzle.

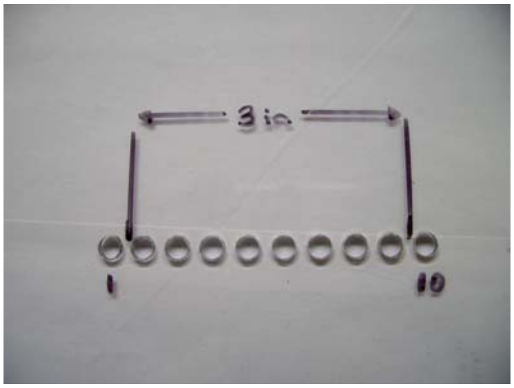


Figure 1

The flux head was manually positioned while reading the air velocity at the center hole of the pattern. The head position was fixed when the maximum velocity reading was achieved. Measurements were then taken at each of the 10 holes with an anemometer; 3 readings at each hole were averaged. The results of the air velocity measurements are shown in Figure 2.

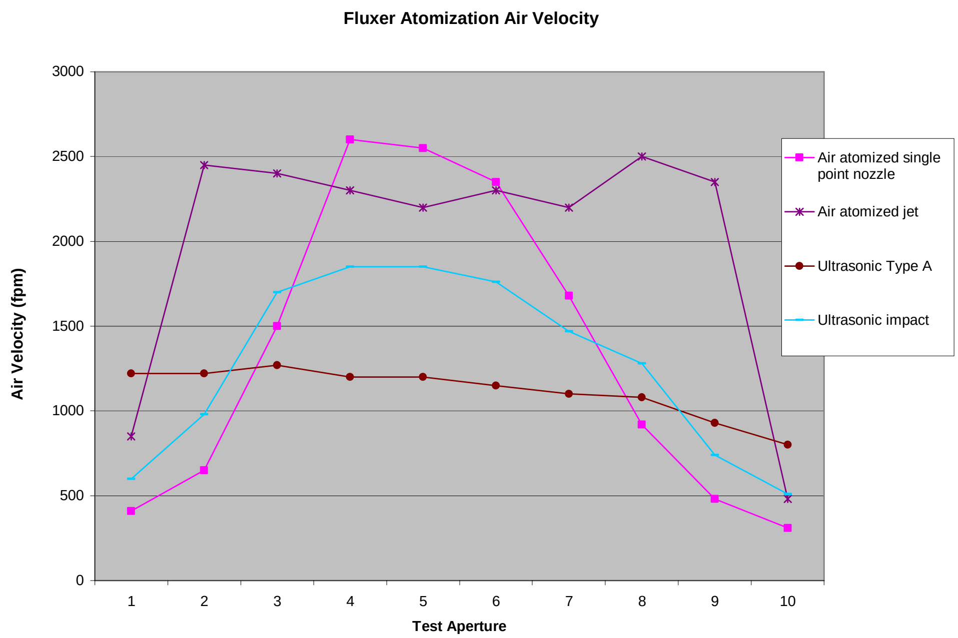


Figure 2

The 3 inch spray width is represented between the 2nd and 9th hole in the test plate. Both velocity and uniformity are important in achieving maximum, reliable flux penetration in the plated through holes. The air atomized jet fluxer had the highest air velocity as well as good uniformity and would be expected to be the best performer. Both ultrasonic fluxers had much lower air velocity with the impact type showing the highest velocity of the two. The air atomized single point fluxer had high velocity at the center but dropped off at the edges.

Flux Trajectory Geometry

One of the most important concerns in lead-free wave soldering flux application is hole penetration in complex, multi-layer circuit boards. From the following scale geometric sketches we can see that something as simple as the angle of flux application and multi-point sourcing of flux can go a long way in ensuring that flux finds its way to the top of each barrel. The following sketches show theoretical flux application from single and multi-point sources at 3 inches below a 0.125" board. Flux dispense orientation is shown both perpendicular to the fluxer base and perpendicular to the board (6 degree angle). The sketches in Figures 3 through 5 depict an overall flux application sketch and a magnified image of the flux dispersion at the board surface.

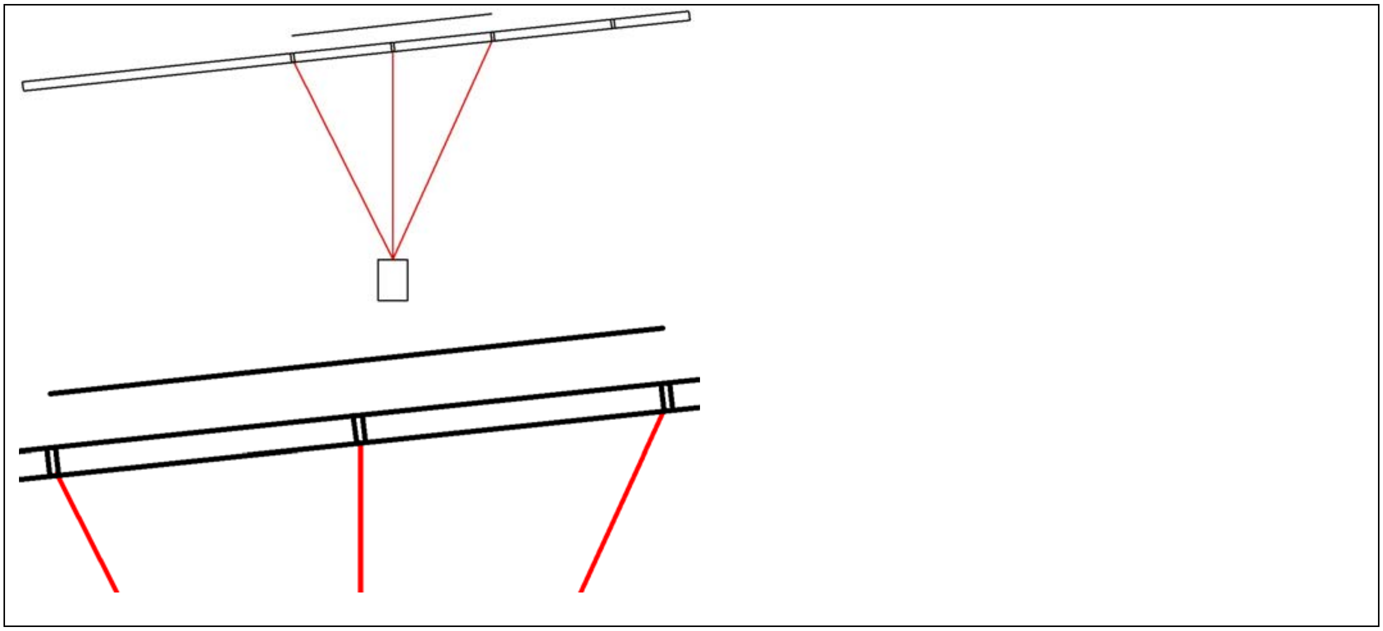


Figure 3 - Single Supply Point Nozzle at 0 Degree Angle

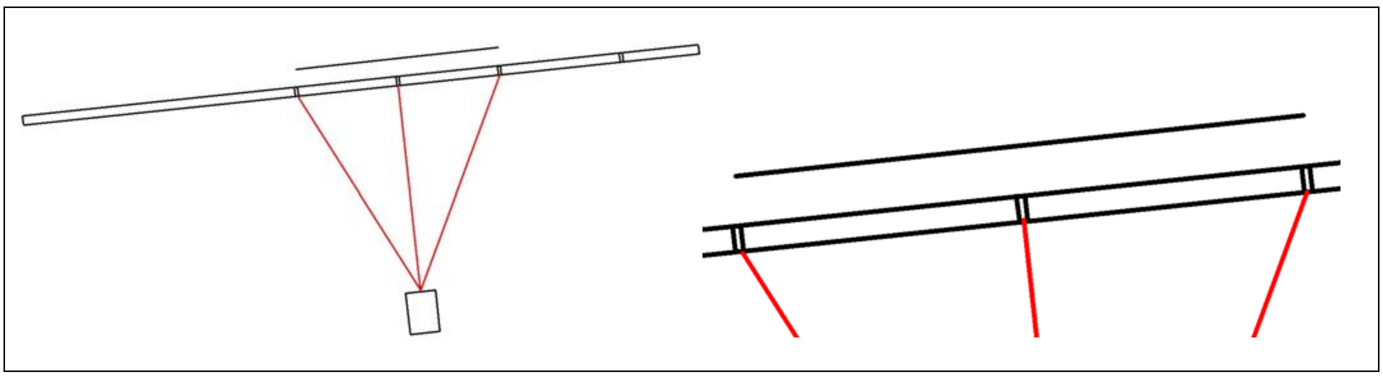


Figure 4 - Single Supply Point Nozzle at 6 Degree Angle

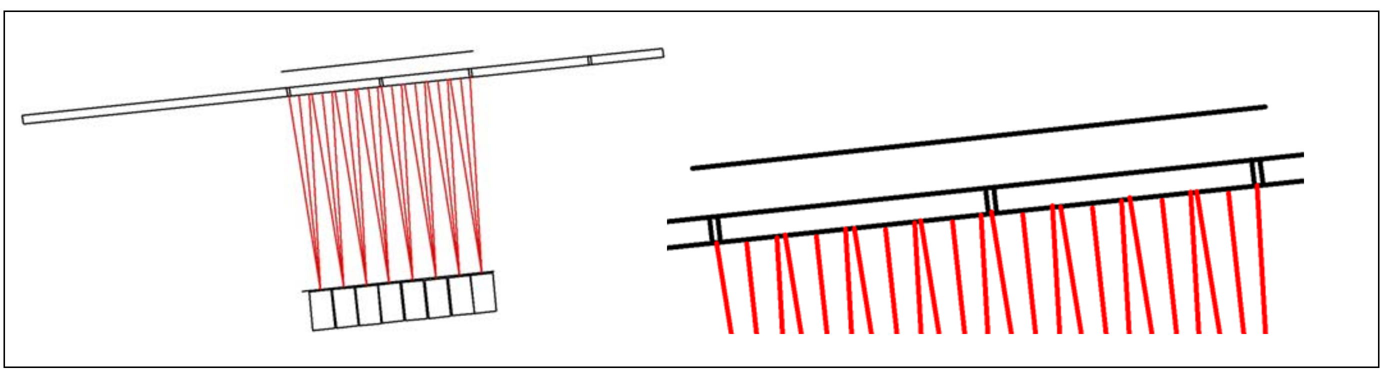
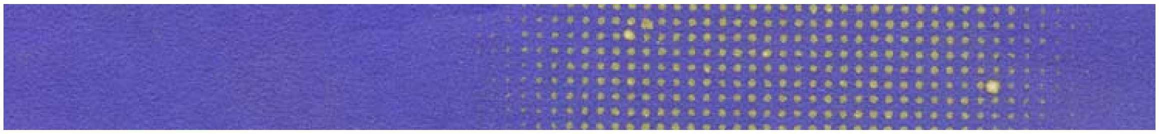


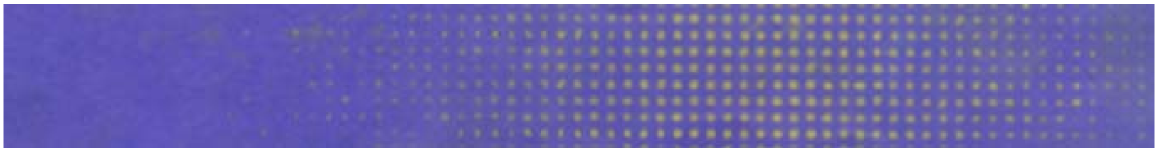
Figure 5 - Eight Supply Point Nozzle at 6 Degree Angle

Single Pass Performance

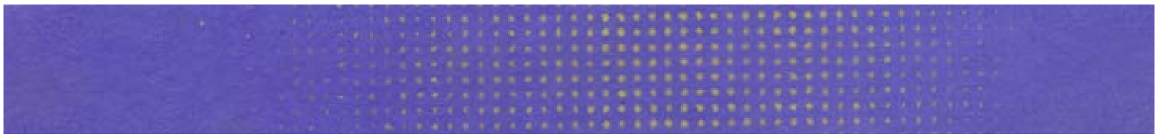
Each fluxer was tested for its performance in a single pass and the results are shown in Figures 6 through 9. This test was performed to illustrate the flux application width and the integrity of the pass at its extents. From field experience, we know that a minimum 3 inch pass is desirable, particularly for wide boards at relatively high conveyor speeds (to allow the servo to return the head to start position before the next pass must be triggered). We also know that sharp edges correspond to limited overlap in adjacent passes and reduced overspray at board edges.



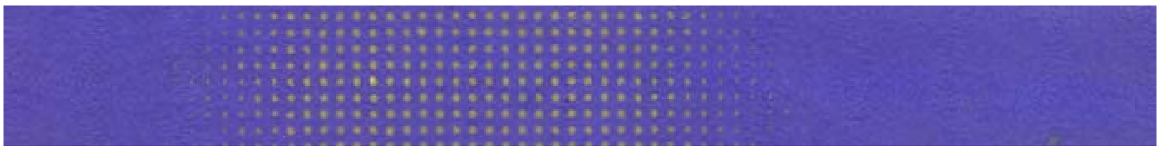
Air atomized jet **Figure 6**



Ultrasonic impact **Figure 7**



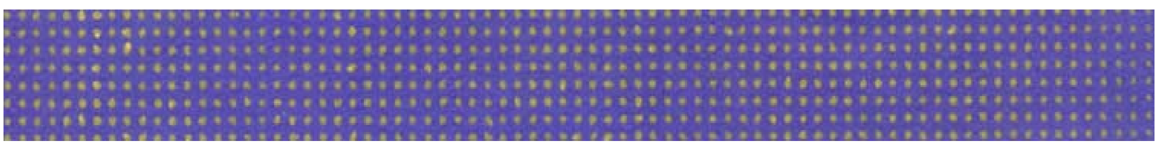
Ultrasonic type A **Figure 8**



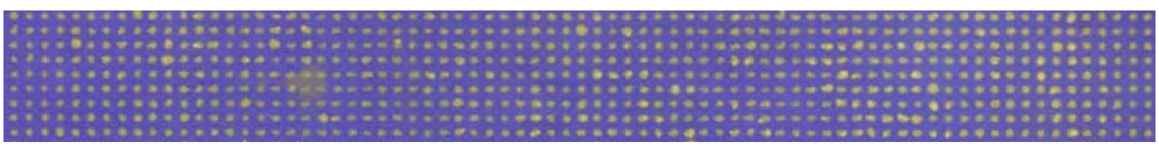
Air atomized single point nozzle **Figure 9**

Uniformity and Hole Penetration:

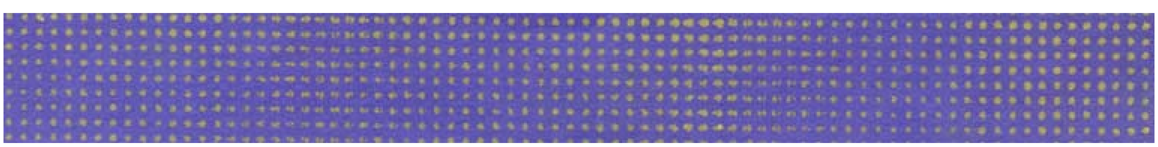
pH paper was used to determine the uniformity of the flux pattern with the fluxer set to traverse every 3 inches of forward board movement. Though air velocity and air uniformity are important factors in fluxer performance, flux must be distributed uniformly within the 3 inch spray width to obtain uniform penetration of flux at the board. The uniformity results are shown in Figures 10 through 13.



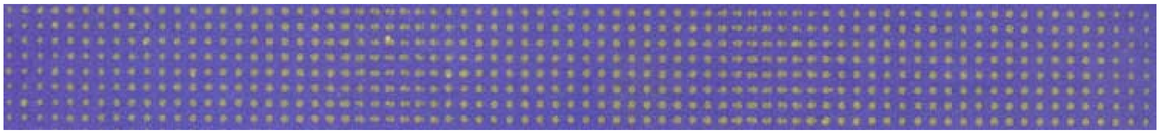
Air atomized jet **Figure 10**



Ultrasonic impact **Figure 11**



Ultrasonic type A **Figure 12**

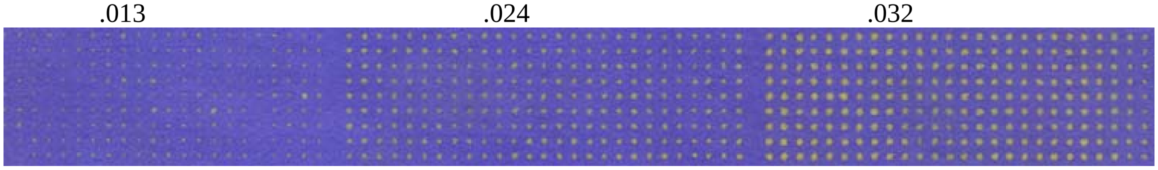


Air atomized single point nozzle **Figure 13**

The air atomized jet had the best overall uniformity followed by the ultrasonic impact. The ultrasonic type A and the air atomized single point nozzle appeared to have more flux in the center of the nozzle and less on the sides of the 3 inch spray width.

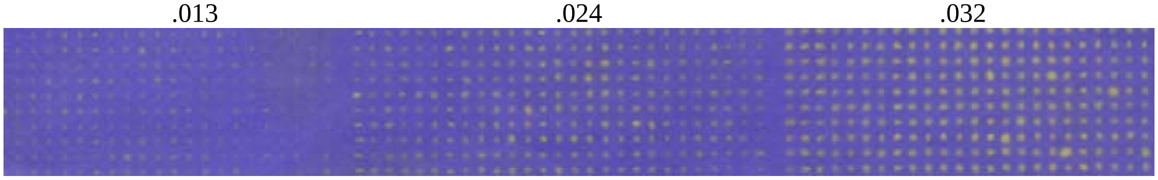
The next 4 figures show the uniformity and hole penetration of a single spray pass through the center of each of the three hole patterns.

.013 .024 .032



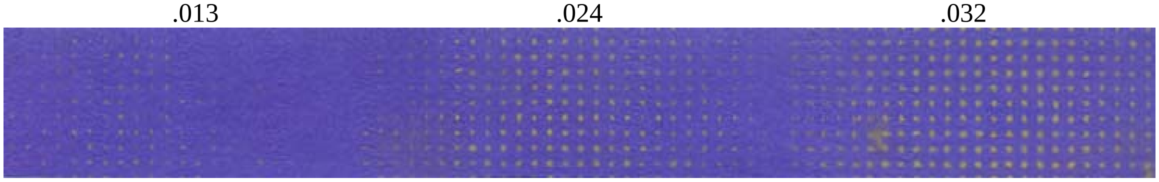
Air atomized jet **Figure 14**

.013 .024 .032



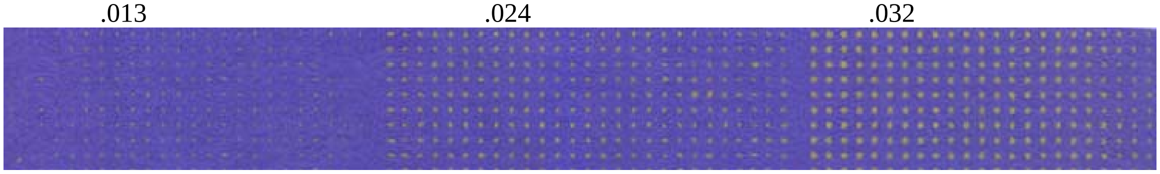
Ultrasonic impact **Figure 15**

.013 .024 .032



Ultrasonic type A **Figure 16**

.013 .024 .032



Air atomized single point nozzle **Figure 17**

The above figures show that the air atomized jet has the best uniformity and hole penetration followed by the ultrasonic impact. Notice that the ultrasonic impact starts getting lighter on the outer edges on the .024 hole pattern and even more so on the .013 hole pattern. Both the ultrasonic type A and the air atomized single point nozzle showed weak hole penetration on the .013 hole pattern, although the air atomized single point nozzle did show good uniformity across the .024 and .032 hole patterns.

System cost:
The cost of a spray fluxer does not always reflect the level of performance. Generally speaking, higher cost systems will be of better quality and have more optional features (e.g.: selective fluxing capabilities, dual flux option, etc.). However, lower cost systems often perform as well or better than more expensive systems. When selecting a spray fluxer, performance and features should be evaluated before considering the cost of the system. The average cost of the systems evaluated in this paper can be found in Table 1.

Table 1 – Fluxer Cost Comparison

Ultrasonic type A	$33,500-$35,500
Air atomized jet	$27,500-$29,500
Ultrasonic impact	$18,000-$20,000
Air atomized single point nozzle	$15,500-$17,500

Maintainability:

- The ultrasonic type A fluxer:
  - Uses a stepper motor and a belt driven actuator
  - Has wearable parts
  - Requires mechanical adjustments to the spray head
  - Uses an external cleaning method that results in a large amount of liquid waste
  - Self tuning Ultrasonic generator requires manual tuning at times

- The ultrasonic impact:
  - Uses a servo drive and a ball screw actuator
  - No wearable parts
  - No mechanical adjustments to the spray head
  - Unique internal air orifice cleaning system produces little or no waste
  - Ultrasonic generator is closed loop and never needs tuning

- Air atomized jet :
  - Uses a servo drive and a ball screw actuator
  - No wearable parts
  - No mechanical adjustments to the spray head
  - Unique internal nozzle and air orifice cleaning that produces little or no waste

- Air atomized single point nozzle:
  - Uses a servo drive and a ball screw actuator
  - No wearable parts
  - No mechanical adjustments to the spray head
  - Unique internal air orifice cleaning that produces little or no waste

The items listed above do not reflect the complete maintenance requirements of each system. The amount of maintenance a fluxer requires is directly affected by board production levels and operation frequency. Maintenance requirements and costs associated with operating the fluxer (flux consumption, waste disposal, etc.) are all part of the cost of ownership and should be considered in any fluxer evaluation.

Chemical compatibility:

All of the systems tested had a very high level of resistance to the chemicals found in most types of flux. However, some fluxes contain chemicals that will damage any fluxer over a period of time. Fluxes that contain hydrochloric acid, hydrobromic acid as well as halogenated OA fluxes should be avoided as they will damage both the fluxer and the soldering machine over time.

Conclusion:

The data and charts presented in this paper show that, for equal flux volumes, each of the spray fluxer systems tested had different levels of performance. Individual fluxer performance can be improved by reducing the spray stroke timing to overlap the spray pattern. This will improve uniformity and hole penetration in situations where board width and conveyor speed are not a limiting factor. Other factors, such as increasing the flux volume, can also improve fluxing results. As such, a lower performance fluxer may be more than adequate in a specific production environment.

This paper shows that some flux systems inherently provide better uniformity and hole penetration because of their design and operating characteristics. In selecting a spray fluxing system, one must consider the complexity of the circuit boards being processed in a lead-free environment. Cost of operation (flux consumption, reliability and maintenance requirements) must also be considered in the decision. The data collected shows that for high performance production environments, an air atomized jet flux system provides superior performance at a low cost of ownership.

Speedline technologies

Flux Application for Lead-Free Wave Soldering

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Flux Application for Lead-Free Wave Soldering

- Four systems of different technologies
  - Air Atomized Jet
  - Ultrasonic Impact
  - Ultrasonic Type A
  - Air Atomized Single Point Nozzle

Flux Application for Lead-Free Wave Soldering

- Fluxing is the first step in the wave solder process
- Select the right flux
- The more difficult the board gets requires the activity level of the flux to be increased

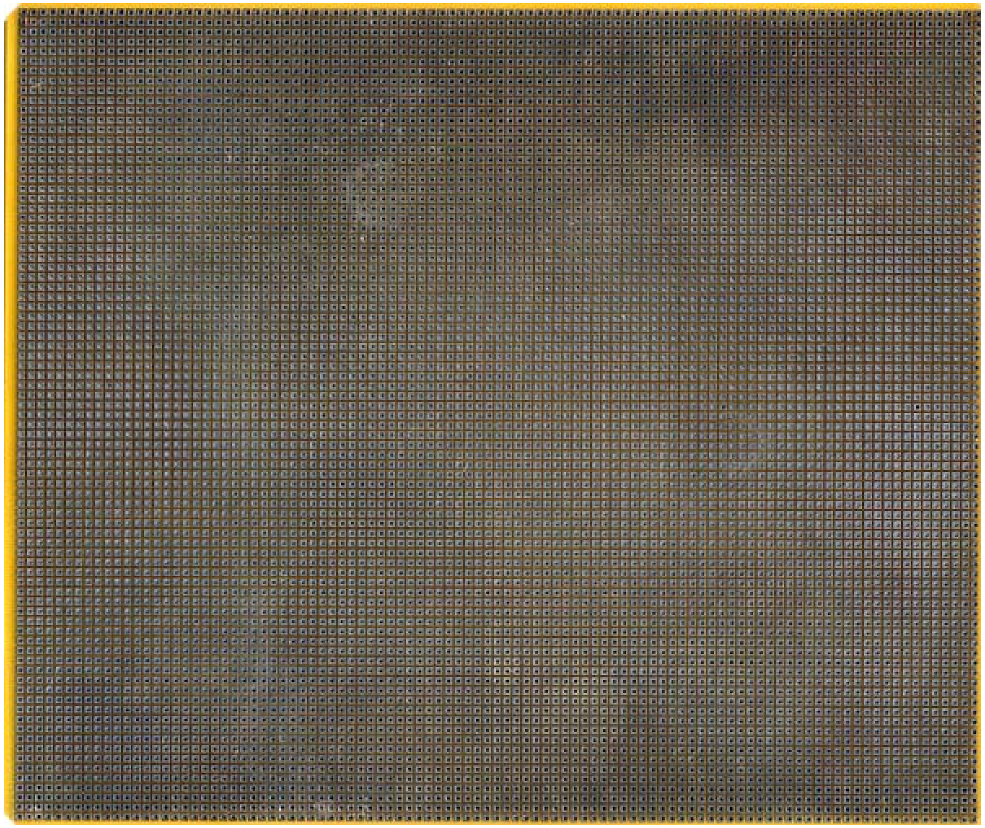
Flux Application for Lead-Free Wave Soldering

- Equipment Evaluation
  - System capability
  - Uniformity
  - Through hole penetration
  - Maintainability

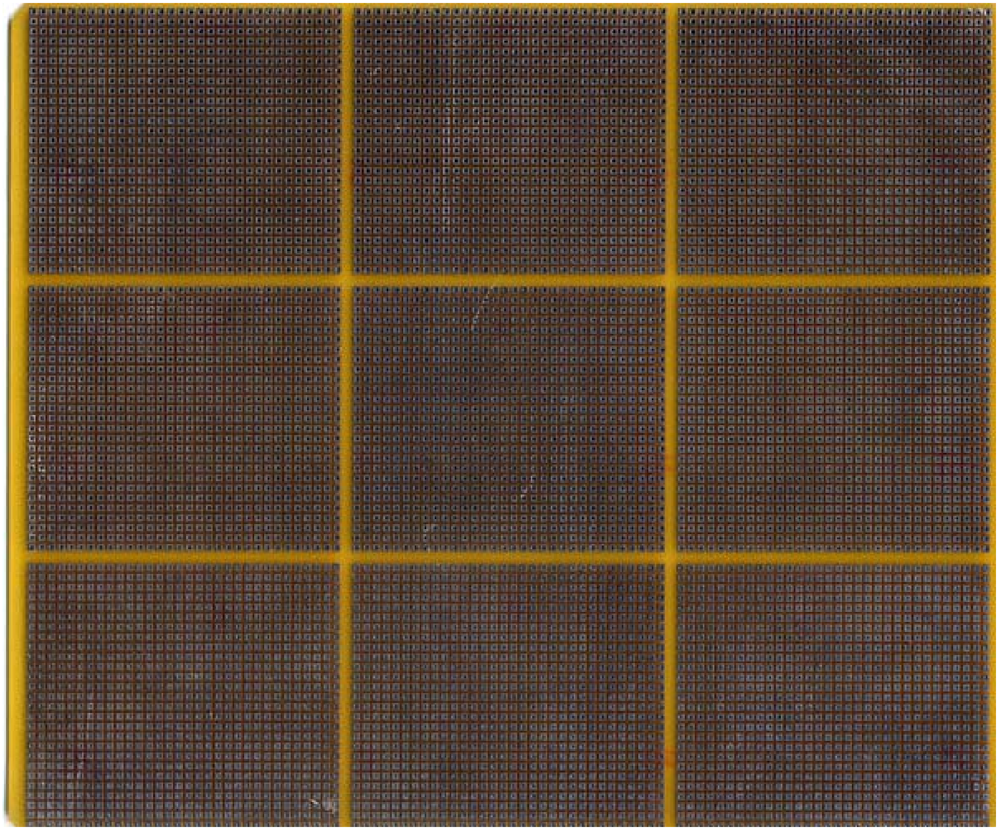
Uniformity and Through Hole Penetration

- Impact velocity at board level
- Uniformity at a 3 inch spray segment with a board with .037 holes
- Visual hole penetration on pH paper through 3 different hole size patterns .013, .024 & .032

.037 Test Board



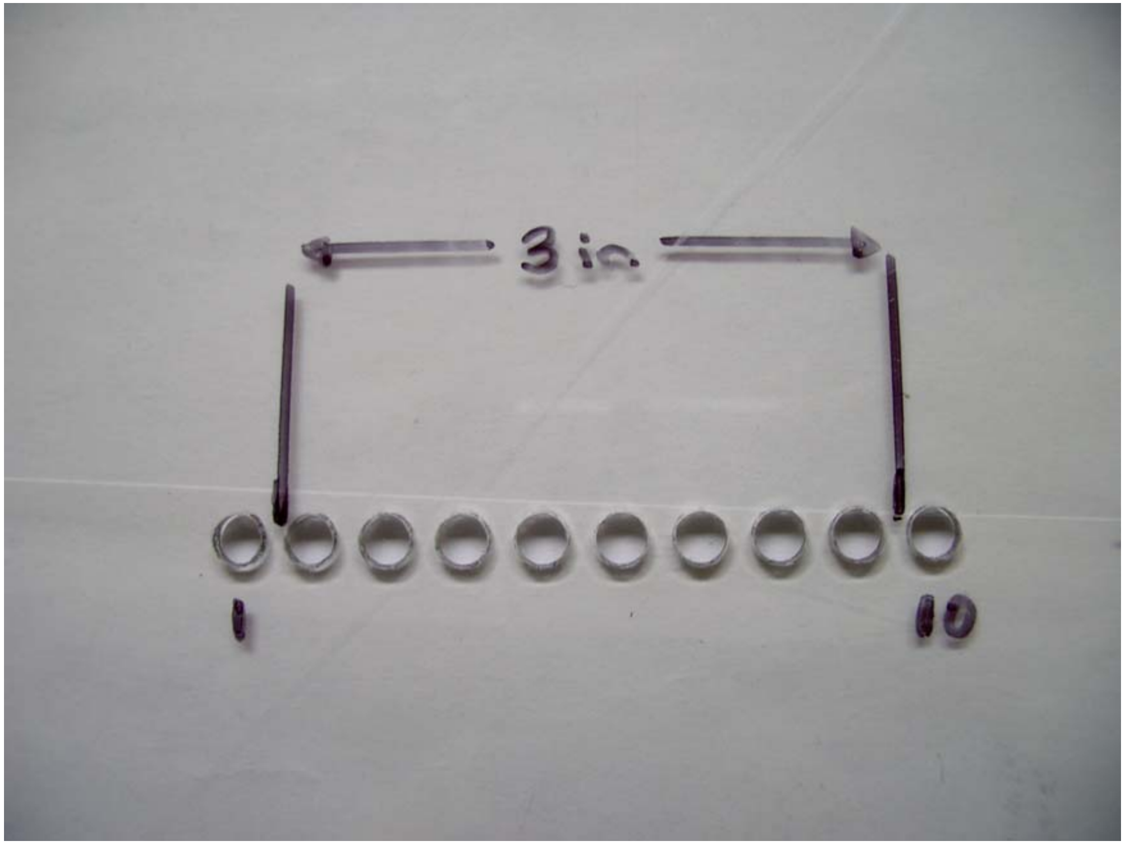
.013, .024 and .032 Test Board



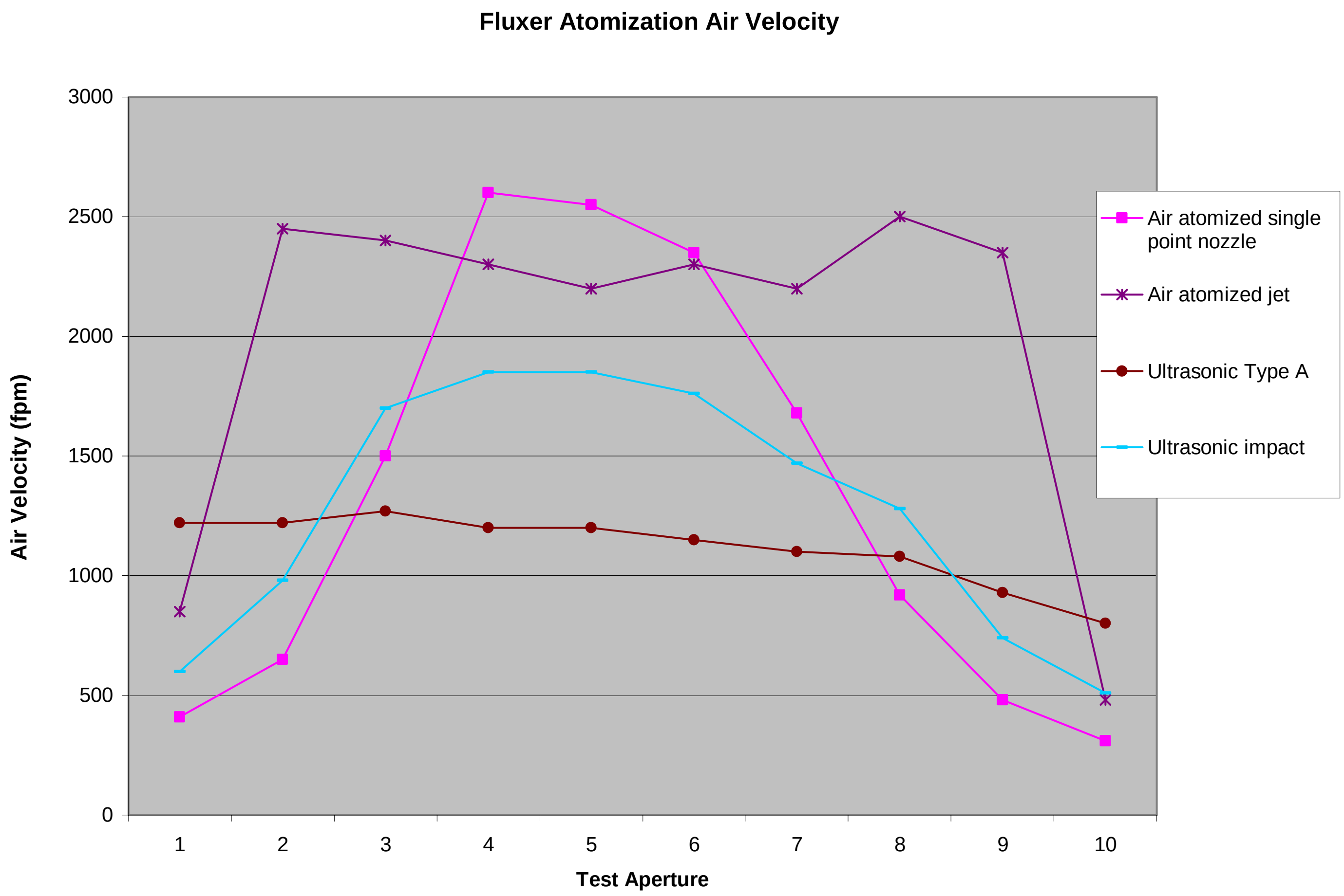
3 Inch Spray Width

- Spray width determines number of spray strokes required to uniformly spray a board
- Affects the speed that the system must traverse
- Smaller spray widths diminish the conveyor speed and board width that can be processed

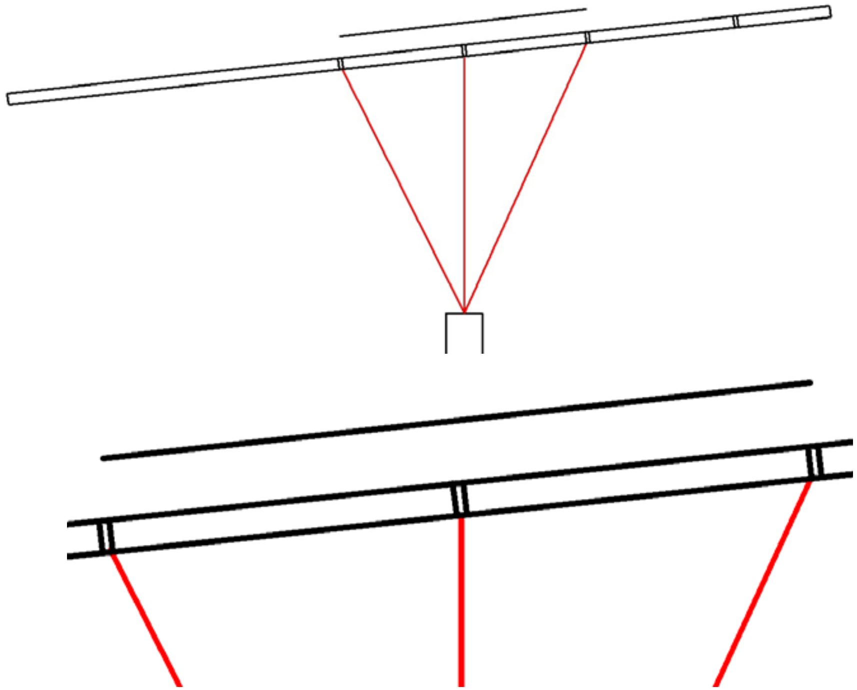
Velocity Test



Velocity Test

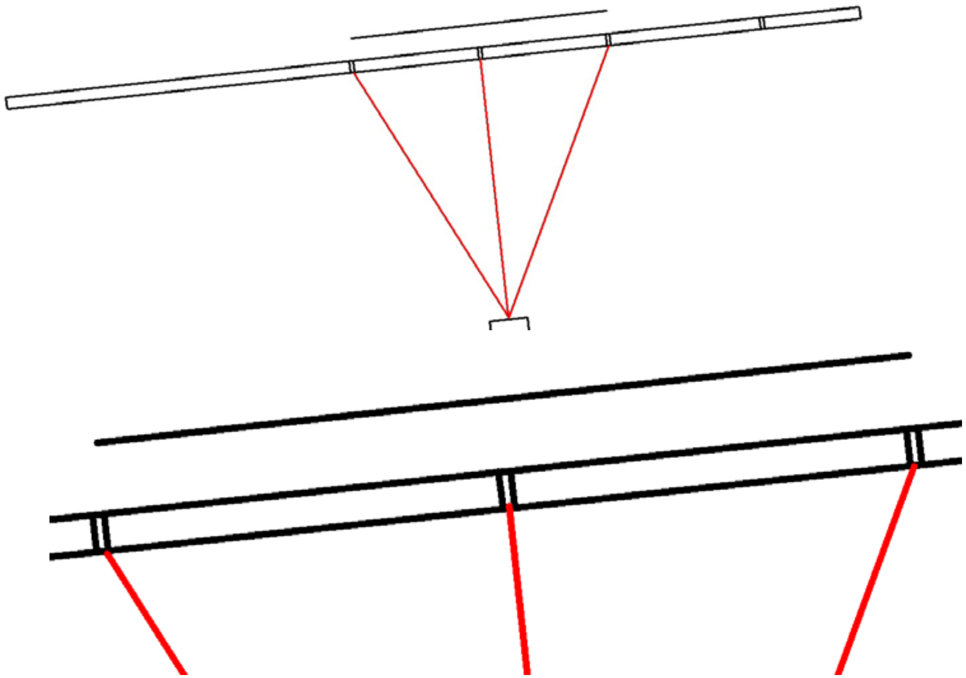


Flux Trajectory Geometry



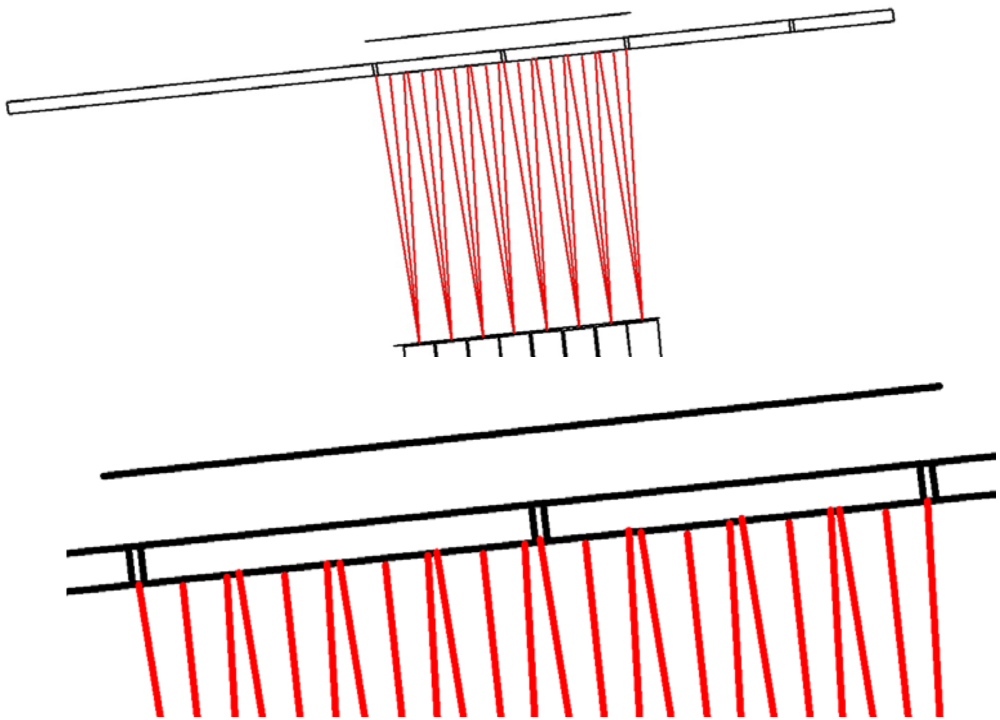
Single Supply Point Nozzle at 0 Degree Angle

Flux Trajectory Geometry



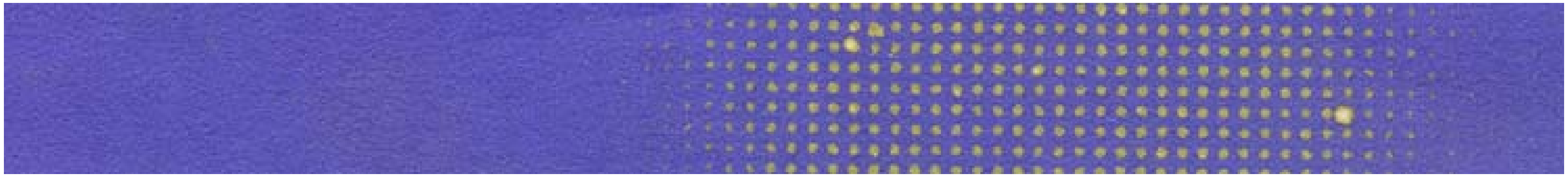
Single Supply Point Nozzle at 6 Degree Angle

Flux Trajectory Geometry

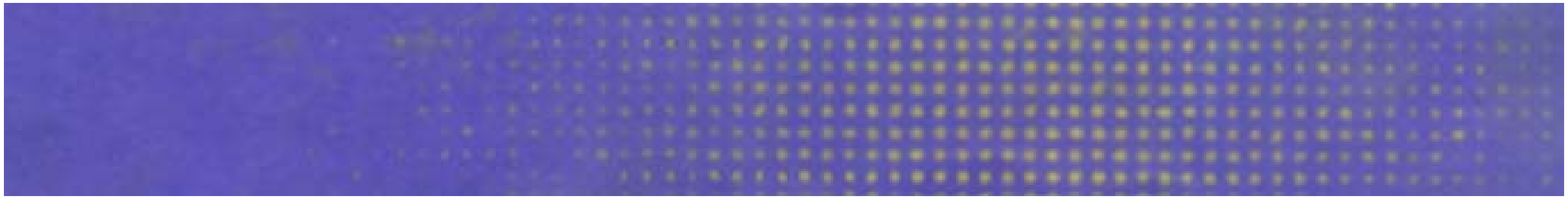


Eight Supply Point Nozzle at 6 Degree Angle

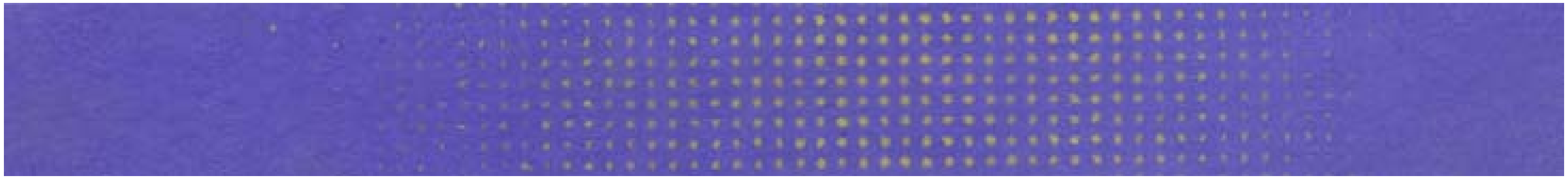
Single Pass Performance



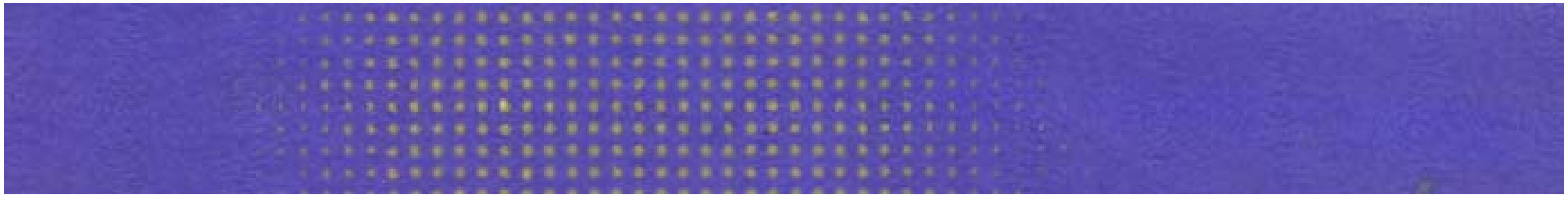
Air atomized jet



Ultrasonic impact

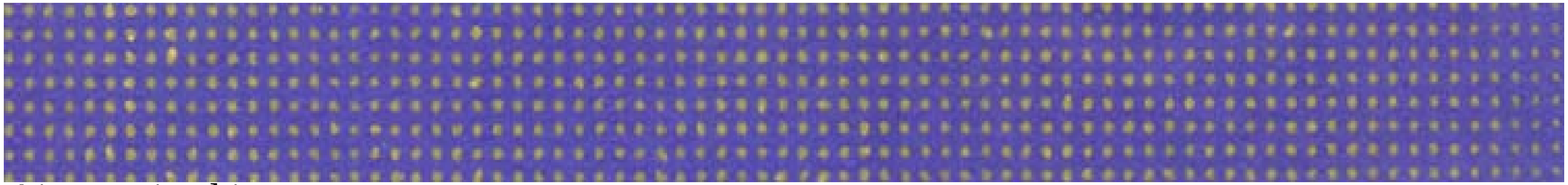


Ultrasonic type A

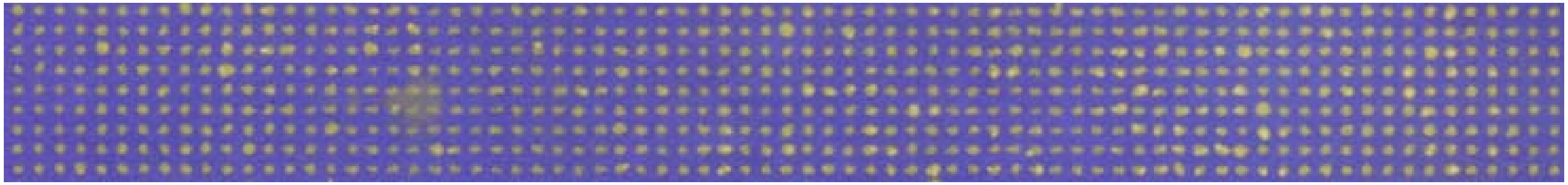


Air atomized single point nozzle

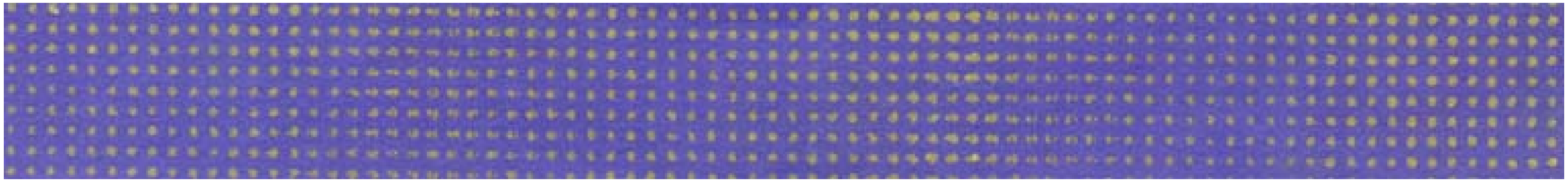
Uniformity and Hole Penetration .037



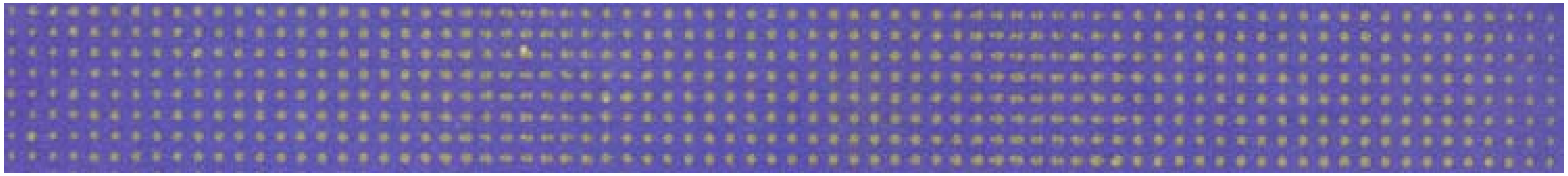
Air atomized jet



Ultrasonic impact



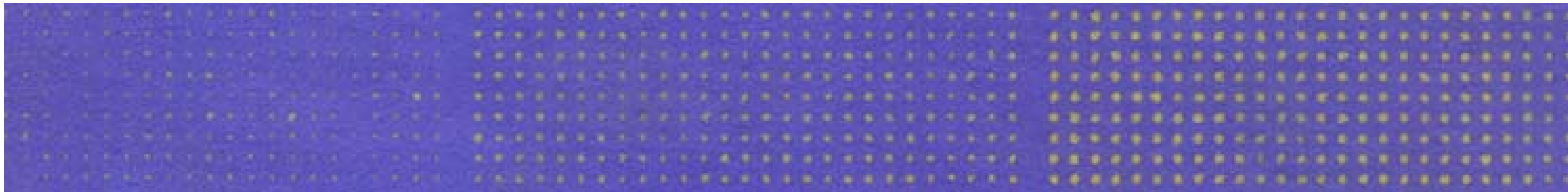
Ultrasonic type A



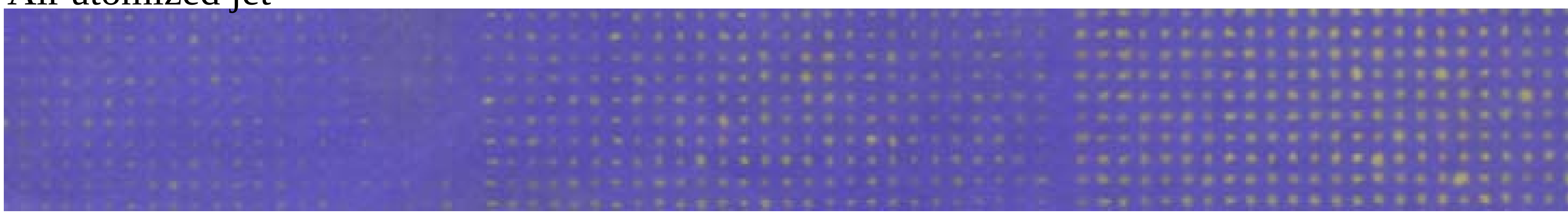
Air atomized single point nozzle

Uniformity and Hole Penetration

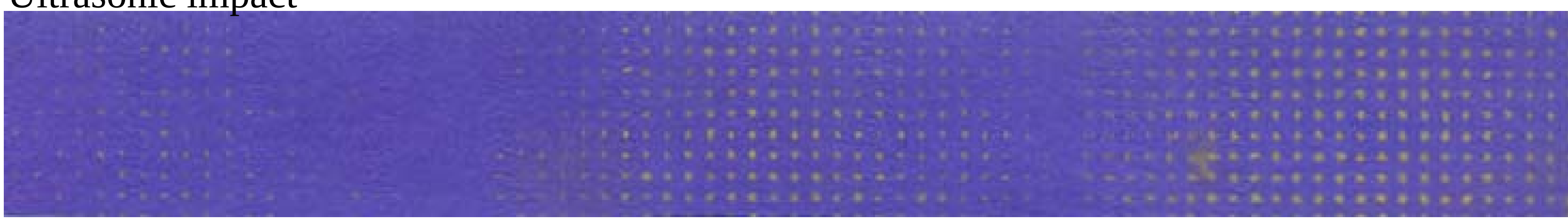
.013 .024 .032



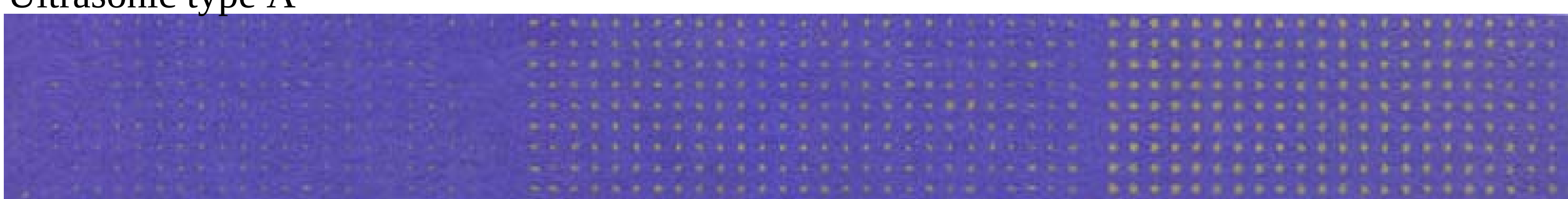
Air atomized jet



Ultrasonic impact



Ultrasonic type A



Air atomized single point nozzle

System Cost

- The cost of a spray fluxer does not always reflect the level of performance

Ultrasonic type A	$33,500-$35,500
Air atomized jet	$27,500-$29,500
Ultrasonic impact	$18,000-$20,000
Air atomized single point nozzle	$15,500-$17,500

Maintainability

- Type of traversing system and drive
- Does the spray head require adjustment
- Are there wear items on the spray head
- Is there a self cleaning system and how much waste does it produce
- Ease of repair