As originally published in the IPC APEX EXPO Proceedings.

Oscillating Nozzle Technology for Improved Cleaning Performance in Prewash Module

Eric Becker
Speedline Technologies
Camdenton, Missouri

Abstract
Implementation of lead-free soldering technology has created new interest in high performance cleaning of printed circuit assemblies (PCAs). Many studies have been commissioned regarding removal of flux residues from tight spaces; the effect of impact force on penetration; capillary action versus surface tension; and optimization of the pressure/flow balance in the wash module. Little attention, however, has been paid to the prewash section of an inline cleaner. The prewash is a key functional process in successful cleaning during which chemical reactions are initiated, PCA temperature is raised, and gross contaminants are flushed from the board. Traditionally, fan-type nozzles have been used in the prewash. The small droplets produced by fan nozzles are indeed effective at wetting open surface areas. However, since mass is a critical component of both force (mass x acceleration) and kinetic energy (1/2mass x velocity^2), they produce inherently low impact force due to their small size. This limits the ability of fan nozzles to break apart residue and to distribute wash chemistry beneath components on the board surface after initial impact. To address these issues, oscillating nozzle technology has been developed. These nozzles move the fluid stream back and forth providing a more effective spray pattern in terms of both coverage and impingement. The larger droplet size has more mass and increased impact force, enabling the nozzle to achieve better results at lower pressure with reduced water usage.

Introduction
The prewash is the most underrated module in any cleaning machine. Most of the emphasis is on the wash, rinse, and drying. In reality, the prewash is the most vital module in the machine. The prewash removes heavy contaminates that would end up in the wash tank, regulates cascade from downstream, and adds initial heat and cleanser (if chemistry is being used) to the product. The new oscillating nozzle technology improves cleaning performance, reduces consumption, and adds more heat to the product than conventional V-Jet nozzles.

Prewash Function
The prewash has several functions. First and foremost, in an aqueous application it removes the large contaminates from the product and transfers it to drain. This process keeps the wash tank clean and reduces maintenance. It also adds heat to the product. This helps break down the soil before it reaches the wash module. This added heat is vital to a chemistry application.

V-Jet History
The V-Jet nozzle has been used in the prewash since inline cleaning machines have been in service (see Figure 1). These nozzles commonly create a flow that tends to be heavier on the outside edges and more atomized (with smaller droplets) in the center. This provides a non-uniform impact profile on the product.

Figure 1 – Prewash with V-Jet nozzles and V-Jet spray pattern.

Most prewash V-Jet nozzles are 65 degree fan and 0.041in orifice on top, and 105 degree fan and 0.041in orifice on the bottom. Both nozzles spray 0.30 gallons per minute (gpm) at 40 pounds per square inch (psi) and 0.42 gpm at 80 psi. There are typically 12 nozzles in the prewash. The combined consumption at 40 psi is 3.6 gpm. See Figure 2 below for a complete range of consumption rates.

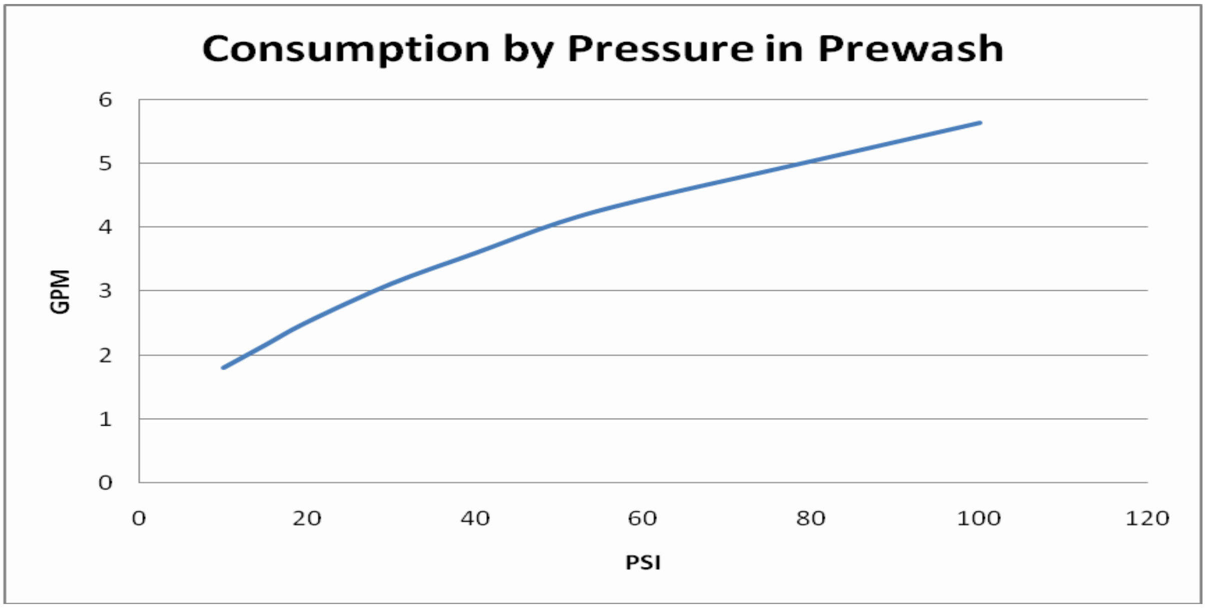

Figure 2 - Consumption rate of V-Jet nozzles in prewash by pressure.

S-Jet Oscillating Nozzles

The oscillating nozzle utilizes low and high pressures with a unique inner chamber that causes the water stream to oscillate back and forth in an S-pattern as it escapes the nozzle. The nozzle has no moving parts so there is nothing to wear out. The key to this system is that larger drops are created which drastically improves heat transfer. The result is a more uniform coverage and a more forceful stream of water moving in a rapid back and forth motion at 30 times per second.

Figure 3 – Oscillating nozzle spray pattern.

The oscillating nozzles work on a constant pressure. The nozzles are optimized at 15 to 20 psi. The normal configuration is six nozzles per spray bar (24-inch process) and five nozzles per spray bar (20-inch process). The spray bars are designed with a 5 degree angle so the spray pattern of the nozzles will not interfere with each other (see Figure 4). There are four spray bars in a typical prewash. The prewash is powered by the wash pump, so a regulator is placed between the high pressure pump and the spray nozzles. This regulator is set to 22 psi. This protects the nozzles and limits fluid consumption. Typically the top bars are set at 20 psi and the bottom spray bars are set at 15 psi. This keeps the product from shifting while moving through the module. Typical consumption for the entire prewash module is 4 to 4.5 gpm. The new nozzles provide a much higher volume than the V-Jet nozzles. The result is larger droplet size and increased heat reaching the product.

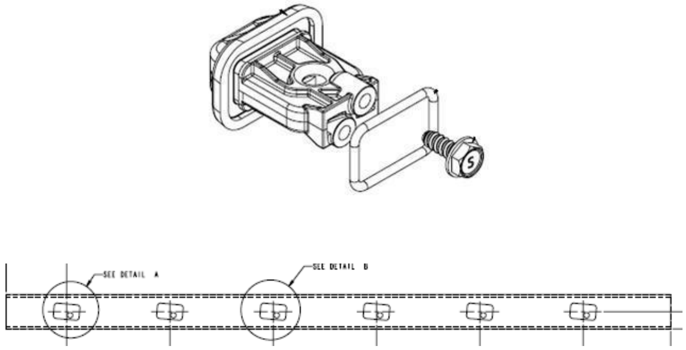

Figure 4 – Oscillating spray nozzle and manifold configuration.

Figure 5 – Oscillating spray pattern with manifold.

Analysis of Nozzles

There are a variety of different nozzles on the market today. The majority of cleaning systems use V-Jet nozzles in the prewash. Top nozzles are generally 65 degrees and an orifice diameter of 0.041 inches. These values were used to run the comparison of nozzle performance.

First, we determine the spray drop size. Drop size refers to the individual spray drops in nozzles pattern. All spray drops are not the same size. The VMD (Volume Median Diameter) scale is used to express drop size in terms of liquid sprayed. The median is the norm with 50% being smaller and 50% being larger.

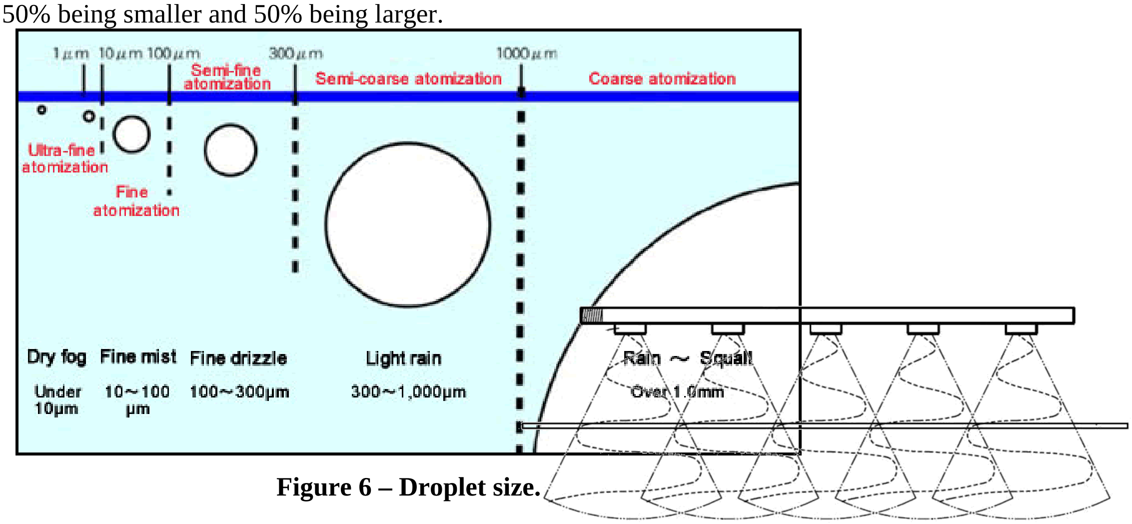

Figure 6 – Droplet size.

A V-Jet nozzle with an orifice size of 0.041 has a range of VMD values based on pressure. For example, at 10 psi and 0.15 gpm the VMD is 350, and the same nozzle at 100 psi and 0.47 gpm has a VMD of 200. Figure 6 shows the entire range for this nozzle. To put this into perspective, the droplet size gets smaller as the pressure increases.

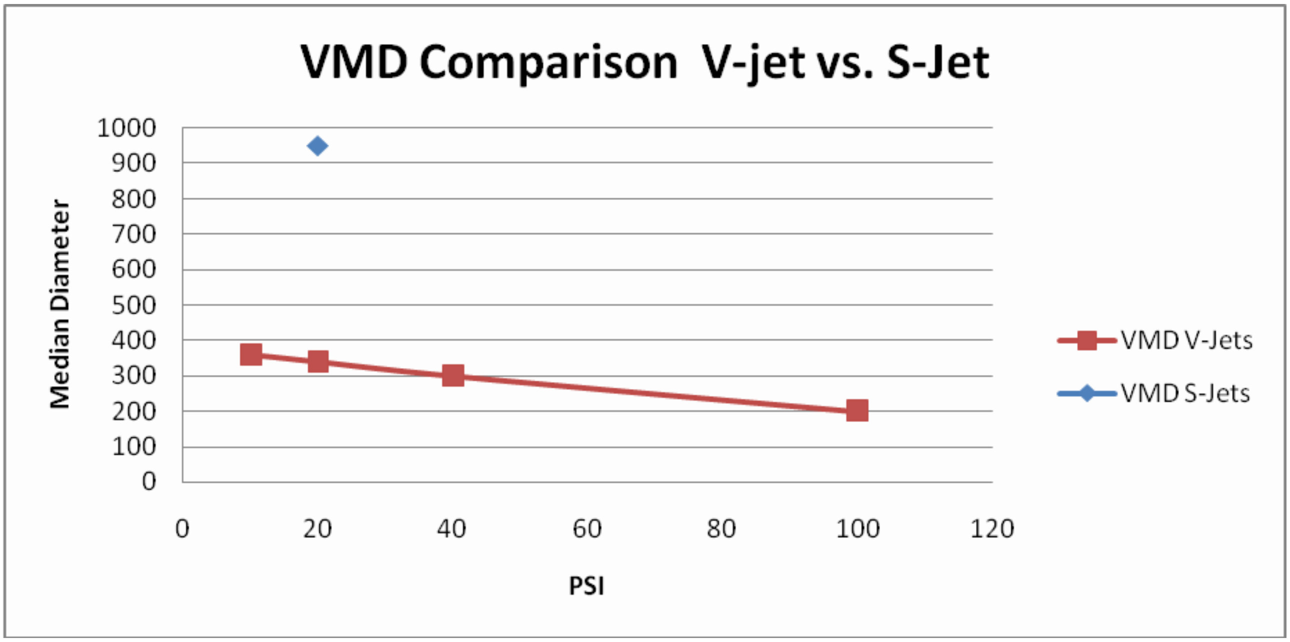

Figure 7 – Droplet size change with pressure.

Now, looking at the new nozzle, the pressure is a constant. This takes out a variable when setting up a production profile. The VMD for the new nozzle is much higher than the V-Jet nozzle because the orifice size is larger, thus, the droplet size is larger. With no pressure change, the VMD will now be a constant. This helps with calculating consumption and recovery rates.

The other factor in analyzing nozzle spray is the impact of the spray on the product. The impact or impingement of a spray onto the target is best described by the performance of impact per square inch. To obtain the impact per square inch of a given nozzle, first determine the theoretical total impact using the formula:

(Pound-Force) = .0526 x (gpm at psi) x √psi

V-Jet nozzle 20 psi, .21 gpm

=.0526 x .21 x √20

=.0493 psi

Oscillating nozzle 20 psi, .187 gpm

=.0526 x .187 x √20

=.0441 psi

From the fan chart, the percent impact based on spray angle can be determined. The V-Jet is a 65 degree nozzle and the new nozzle is a 30 degree nozzle. The percent for a 65 degree nozzle is 7 percent and the percent for a 30 degree nozzle is 18 percent. Taking this into the equation, the impact force for the V-Jet nozzle is .00345 psi and the impact force for the new nozzle is .00793 psi.

The data shows the new nozzles have twice the impact force as the V-Jets. When factoring in the oscillation and the larger droplet size, the impact force increases by a factor of three. This makes the nozzle six times more effective at the product surface than a V-Jet nozzle. The larger droplet size also holds more heat which is then transferred to the product. In a chemical process that requires a certain amount of heat to activate, the new nozzle boosts the temperature before the product reaches the wash module. This enables the wash to more effectively clean the product.

Applications

The application setup for the prewash is simple to define: the best cleaning performance possible with the least amount of cost and consumption. All applications have a cost associated with them.

In a cleaning system the cost is in the consumption rate. If a deionized water bed is used, then great care needs to be taken in setting up the process. The incoming clean water enters the final rinse. The final rinse empties into the rinse tank. There is a cascade from the rinse into the wash tank (in aqueous applications only). The wash tank feeds the prewash which goes to drain. A balance between the incoming final rinse and the outgoing prewash must be established. With this, there are several factors to define. Is this an aqueous application or is it a chemical application? Is the incoming water deionized of just filtered? What kind of pressure does the incoming water have?

Application 1 – Aqueous application with deionized water at 30 psi. This setup will have a small incoming volume and a lower pressure in the final rinse. With this, the new nozzles in the prewash will optimize the system more efficiently because of impact force and volume.

Application 2 – Aqueous application with Deionized or Filtered water at 65 psi. This application has more volume in the final rinse, which allows more volume in the prewash. This will allow either of the nozzles to work efficiently. The V-Jet nozzles are effective above 65 psi as long as the final rinse can keep up with the demand and the facility can handle the load and the added cost of operation.

Application 3 – Chemical application with any incoming water and any pressure. Since the prewash is drained back into the wash, the balance of the machine is not dependent on the prewash setup. The prewash can be run at full pressure with V-Jet nozzles or 20 psi with our new nozzles. This application is product dependent. Some products clean better with our new nozzles and some clean better with V-Jets.

Actual Application

Comparisons were made while running a chemical application in a facility outside of factory control. V-Jet nozzles were used as a baseline, running baskets with six boards in each basket. There were five baskets processed. After the run, the wash tank had to be decontaminated and refilled. This took 20 minutes. At 1.5 feet per minute, five baskets produced a total of 30 boards in 19 minutes. A total of 39 minutes (includes decontaminating and filling) divided by 30 boards at 1.3 minutes a board, is 46 boards an hour.

The same process with our new nozzles produced 15 baskets or 90 boards before the wash tank had to be decontaminated. The machine produced 90 boards in 30 minutes with 20 minutes of cycle time. 50 minutes total and 90 boards equals 0.5 minutes a board, or 120 boards an hour. Our nozzles produced almost three times the amount of boards that the V-Jet nozzles did in the same time period.

The facility has a machine overhead of $65.00 an hour. With the V-Jet nozzles the $65.00 divided by 46 boards equals $1.41 in operating cost per board. Our nozzles produced 120 boards, resulting in $0.54 in operating cost per board improving production and reducing manufacturing costs by 62%.

Conclusion

In any inline cleaning application, the prewash is the first module to start the cleaning process. This should be the most important starting point for the application setup. The prewash is defined by the type of process and the facilities feeding the machine. The type of nozzle used in the prewash should be determined by testing and application development. To achieve great cleaning results, the process needs a great start. Do not overlook the prewash module when setting up and running a cleaning application. Utilizing our new nozzle technology can significantly improve production rates and reduce operating costs.

References,

1. Hobart Corporation (Troy, OH, U.S.) – Opti-rinse nozzle, patent-pending.
2. Spraying Systems (Wheaton IL, U.S.) Publication – Engineering Discussions.
3. Bex Nozzles (Livonia, MI, U.S.) Catalog 45 - flat nozzle specifications.

Special thanks to:

Speedline Electrovert Applications Engineer John Neiderman.

When evaluating a new cleaner machine, work with the applications engineer for that product, and optimize the application before the machine is placed in your facility. If an analysis of your current process is needed, contact your sales rep for information on how to evaluate the application.