

# New Jetting Technology for Fluid Dispensing

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In jetting, fluid is rapidly ejected through a nozzle in discrete droplets. Jetting is a preferred method for dispensing fluids for a number of reasons, including: productivity increase through the reduction of up and down z-height moves, improved resolution for dispensed fluid weight and volume, and high, controlled fluid flow rates. Jetting has evolved to become a standard production process in the industry, and now accommodates a wide variety of fluids and applications. Everything from more intricate, emerging technologies — which include stacked die, fuel cells, LEDs, flat panel displays, and lab-on-chip — to MEMS packaging and more traditional packaging turn to an array of jet valves and complete dispensing systems with closed-loop process controls for mass production.

Automated jetting for fluid dispensing in electronics assembly and precision manufacturing was pioneered in 1994 by ASYMTEK (now Nordson ASYMTEK) as a replacement to traditional needle dispensing. Improvements to production consistency, accuracy, repeatability, reliability, and speed have been driving jetting technology developments for years. Advances in jetting processes have made it the default fluid dispensing method for advanced package designs that require placing very small dots of fluid into tight spaces. The high cost of these packages demands an extraordinary degree of dispense-volume accuracy to ensure high production yield. With so many jet valve and jetting system options available today, the question turns from whether or not to use a jet, to one of which jetting system is best for a particular project, or which system is most versatile and addresses the widest variety of possible applications.

Jetting is faster than traditional, contact-needle dispensing because Z- axis motion is not required for the dispensing and fluid break-off from the nozzle. The jet “flies” over the substrate and shoots precise, controlled volumes of material to form pre-programmed dots and line patterns. Nordson ASYMTEK’s patented Jet-on-the-Fly technology coordinates the motion of the automated dispensing platform in concert with the jet valve actuation to maximize throughput while maintaining precision accuracy of fluid placement.

Additionally, because jetting enables larger dispense gaps between the nozzle orifice and the substrate and the fluid breaks off from the nozzle in a thin stream, dispensed fluid can be targeted closer to a component, or the edge of a die, and into tight places. This enables smaller keep-out zones around mounted board components, especially useful for underfilling flip-chip, package-on-package (PoP) or stacked-die applications. To create different dot sizes, the jet hovers over one location, depositing additional dots. Actuation frequencies of most of today’s jet valves typically vary between 200 and 1000 dots per second, which enables quick multi-dot dispense patterns.



***Nordson ASYMTEK’s NexJet® 8,  
a pneumatic-style jet***

## Choosing a Jet

Jets are typically selected and configured for a given fluid and application. Factors such as the fluid viscosity, composition, required dot size, dispensing pattern, fluid temperature, and others impact the appropriate selection of a jet valve and dispensing system. Required closed-loop process controls, ease of setup and maintenance, ease of use, training requirements, technical support responsiveness, and the cost of operation further have an effect on the choice of supplier. Jets for flux and biologic reagents typically need to handle viscosities of 1 to 100cps and perform dot and area coating. Underfills and encapsulants require jets with 1 to 25,000cps viscosity capability. Jets for these materials may also need to handle larger flow volumes with high accuracy. For surface-mount adhesives and other glue materials, the jet has to handle viscosities of 20,000 to 80,000cps. Also, anaerobic fluids and abrasive materials require jets of specific material construction to avoid corrosion or short useable lifespans.

Ease-of-cleaning is another important consideration. Valve maintenance can be time-consuming, expensive, and disruptive to manufacturing, especially if the entire jet has to be removed, disassembled and repaired or replaced. If the fluid is quick-curing, the valve may have to be cleaned often to avoid fluid hardening in the valve, which can clog the nozzle or prevent the jet from actuating properly. A number of new jet valves improve the ease-of-cleaning by using cartridge-type, consumable parts. These cartridges are easily removed from the jetting system while the jet valve actuator remains mounted on the dispensing platform. Well-designed cartridges can be swapped out in less than 30 seconds, or taken apart, cleaned and inspected to ensure that there is no cured fluid in the wetted feed path.

## Types of Jets

Jet type is often classified by the mechanism that drives the internal actuation of the jet valve to propel the fluid. There are essentially two types of jet drive systems: pneumatic and piezoelectric.

The majority of jets for electronic assembly use some form of electro-pneumatic actuation. Electronically-actuated solenoids create the pneumatic force to drive the jet needle, expelling the fluid from the nozzle to the surface. Although once limited in operational frequencies due to the characteristics of the solenoids, newer versions have become the workhorse of the industry for fast-paced production environments. Wide range of fluid applicability, good precision and long-term reliability are important factors that led to the adoption of pneumatic jets. These jets have been used for board-level underfill, chip-scale packaging, BGA, PoP underfill, precise coating, silicone jetting, and adhesive dispensing. Most pneumatic jets have to be replaced or undergo major servicing to replace the solenoids after 1 to 2 billion jet cycles, but most parts servicing can be performed on-site in a user's facility.

A piezoelectric jet, also referred to as a piezo jet for short, converts an electric charge to mechanical displacement using the piezoelectric effect in crystal stacks to drive the jetting action. The expansion and contraction of the crystal stack is very fast and allows piezo jets to actuate at much higher frequencies than pneumatic jets. Most piezo jets operate at continuous



***IntelliJet® piezoelectric jet with  
ReadiSet™ jet cartridge***

frequencies of up to 500Hz, though may be able to run at frequencies up to 1000Hz or higher in short bursts. These higher frequencies are necessary for maintaining high flow rates when jetting micro-deposits of fluid. For larger dot volumes, the higher frequencies extend the range of fluid flow rates, and in turn enable higher productivity output from the dispenser.

Early versions of piezo jets had problems some initial design issues, leading to slow adoption of the technology to replace pneumatic jets. Initial use of piezo jets was somewhat limited to lower duty cycle applications (fewer total dots per hour) and applications where dot weight consistency and valve-to-valve consistency were not as critical. Many of the first piezo jets on the market had issues with the long-term reliability of the piezo stack (as low as only 100 million jet cycles) and required the user to send the valve back to the manufacturer for service with specialized jigs and tooling. Applications that required a high number of discrete dots, like underfill applications, were typically avoided due to this servicing issue. In addition, the lifespan of the jet's consumable parts, like the needle/tappet/poppet and nozzle, had limited life cycles depending upon the abrasiveness of the fluid being dispensed. As a result, operational costs of these early piezo jets were high.

Today, the technology behind piezo jets has improved. Most piezo jets on the market today are warranted for an actuator life of 1 billion jet cycles and thus can be more realistically considered for higher duty cycle applications. However, in high-volume, high-cycle count production applications, possibly running as many as 1 million dots per hour, this could result in a lifespan of less than two months. Tighter controls on the manufacture of the valves help to improve valve-to-valve consistency, but it is still common to see >20% variation in average dot weight for dot sizes below 30µg.

Recent advancements in piezo jet technology have led to the development of Nordson ASYMTEK's new IntelliJet<sup>®</sup> jetting system. The piezoelectric drive system of the IntelliJet has been proven to last as much as 6 times longer than other valves, running for over 6 billion jet cycles before requiring service. Internal, automated calibrations of the actuation drive system further help to maintain valve-to-valve consistency. Additional studies by ASYMTEK have led to advancements with the Readiset<sup>™</sup> jet cartridge system to improve average dot weight consistency and long-term reliability of the cartridges when jetting even heavily abrasive fluids.



***Tilt and rotate jetting allows for five axes of motion***

## Process Controls

To take full advantage of jetting technology, a jet valve needs to be part of a complete dispensing system. Total system solutions will implement a number of companion technologies for accurate motion system positioning, vision targeting for accurate fluid placement, and closed-loop process control systems for ensuring consistent results and high production yield. Software controls are another key feature for a total system solution for not only driving the actuation of the jet, but also monitoring the operation and providing the feedback loop and coordination between the valve and the other subsystems to ensure a uniform production process.

For a consistent, high-yield dispensing process, error sources such as changes in fluid viscosity over a longer production run need to be monitored and corrected. The dispensing process should be maintained in the center of the process window to keep dispense results the same over time. Dispensing issues, including satellite formation, fluid accumulation and splashing, should be

reduced or eliminated to further improve the process capability index ( $C_{pk}$ ). Properly controlling the fluid velocity and correcting for viscosity and other process changes with a closed-loop system is absolutely necessary to achieve yield results to meet  $C_{pk}$  goals  $\geq 1.0$ ,

ASYMTEK's patented calibrated process jetting (CPJ) technology, in conjunction with mass flow control (MFC), automatically measures jetted fluid mass flow rate and corrects for such error sources to keep the system consistent over long production runs. New auto-calibration features also help to correct dot placement errors that result from the jet valve and interaction with the vision targeting system. These process controls ensure high wet-dispense accuracy, smaller wet-out areas, round, uniform dots, better line quality, and an improved knit line.

The dispensing platform further contributes to the effectiveness of the production operation. Platforms can be equipped with dual lanes, dual valves, substrate heaters and heat control systems, height sensors, and vision systems. The new Monocle™ vision package uses five-channel independent substrate illumination controls, which improve image contrast and increase clarity and brightness. This allows for more consistent and exact fiducial finds. Improved optical lens options and a high-resolution megapixel camera in the package increase the accuracy of fiducial recognition at the edges of a wider field of view.

For densely-populated PCBs, semiconductor packages, 3D-stacked die, and thermal applications such as polyurethane reactive (PUR) hot melt adhesives, some programmable tilt capabilities are available. Nordson ASYMTEK's award-winning tilt and rotate option enables five axes of automated control instead of the usual three. It provides jetting at varying angles, along all sides of a device, including up the side of a substrate, and dispenses thin lines into tight corners around tall components.

Jetting technology is an essential part of dispensing for most electronic packaging and circuit board assembly applications. Jetting allows designers to rewrite their design rules to make smaller, less expensive, and more capable devices. However, the differences between jets and the variety of jetting systems available today are significant, and proper selection is necessary to make full use of the technology's advantages. The results of this careful attention to various jets and jetting systems are lower production costs, higher yields, higher production rates, and an improvement in quality.

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