Advantages of Non-Contact Dispensing in SMT Assembly Processes

Anthony F. "Frank" Piracci
Asymtek
Carlsbad, California

Abstract
Dispensing surface mount adhesive (SMA) onto printed circuit board assemblies (PCBA's) with repeatable dot-to-dot quality and minimal assist time is a complex process. The demand for smaller PCB sizes with finer-pitch layouts, the range and mix of surface mount components as well as the increasingly shorter product life cycles and corresponding greater number of changeovers, presents challenges for the process engineer. It is important that the process engineer have a fundamental understanding of the different methods for dispensing SMA, especially the advantages and disadvantages of each dispensing method. Evaluating new innovations in dispensing, understanding how it works and its strongest and weakest attributes is essential in determining the benefit of implementing a new technology in the production environment. The key is to choose the dispensing method that lends itself most closely to the requirements of a specific production process.

This paper will outline the benefits and limitations of non-contact dispensing in production. Specific attention is paid to underboard support and board contact issues, the value of implementing a robust process, and the importance of understanding specific SMA attributes, in developing successful dispensing applications. An overview of the machine set up parameters and the control required to jet dispense various adhesives in production applications is provided in this paper. After reviewing the parameters and profile of this method of dispensing, the areas where this technology lends itself to production are explored. Specifically, yield, throughput, cost and setup time advantages from using this leading edge technology is explained.

Continuous Change Presents Challenges for Surface Mount Assembly Process
Surface Mount Technology (SMT) is the dominant electronics assembly process worldwide. The goals to manufacture smaller, faster, and more complex assemblies while reducing "conversion" costs **(see Table 1)** drive the electronics production industry to evaluate new assembly technologies that might provide a competitive advantage. Faster changeovers, requirements for higher yields, smaller PCB sizes; finer-pitch layouts, dense multi-layer circuitry and mixed technology boards, as well as the increasing range and mix of surface mount component sizes and types, pose challenges for the SMT process engineer. These challenges require the process engineer to review and understand all phases in the SMT assembly line as well evaluate new innovations and tools that will help move the process to the next level.

Product Sector	Metric	1999	2001	2003	2009
Low Cost	¢ per I/O	0.70	0.60	0.50	0.30
Cost/Performance	¢ per I/O	0.75	0.65	0.55	0.38
Hand Held	¢ per I/O	0.80	0.70	0.50	0.30
Harsh Environment/Military	¢ per I/O	0.90	0.70	0.60	0.40
High Performance	¢ per I/O	1.20	1.00	0.80	0.70

Table 1 - NEMI 1998 Roadmap: Conversion Costs by Product Sector

The technique for application of surface mount adhesive (SMA) is one of the in-line processes that are evolving, driven by the common goals to increase speed and to accurately dispense smaller dots resulting in less rework and improved reliability. The primary purpose for using surface mount adhesive during the assembly process is to keep the surface mount devices (SMD) in place before and during the wave or reflow soldering process. SMA can also provide the added benefits of mechanical strength, thermal conductivity, dielectric strength and chemical inertness throughout the life of the assembly.

Importance of Rheology of Surface Mount Adhesive
Surface mount adhesives are specially formulated for different application techniques. For both syringe and non-contact dispensing, the adhesive must readily flow through the dispensing heads. As soon as the adhesive reaches the PCB, the adhesive must recover to keep it from spreading and contaminating the circuit pads. These properties are part of the rheology of the adhesive.

Viscosity is the resistance of a fluid to flow and is one of the primary rheologic properties used to determine if an adhesive is dispensable. With non-Newtonian fluids like surface mount adhesive, viscosity decreases with increasing shear, which explains how the fluid flows easier as it moves through the fluid path of the dispenser. ***Figure 1*** graphically depicts how the viscosity of the fluid decreases as the shear rate increases. The adhesive must also have the ability to restructure and recover its viscosity as soon as it reaches the surface of the PCB. The property of the fluid that allows the material to return to its original viscosity is part of the thixotropy of the adhesive. The thixotropy of the fluid is another critical component in successful syringe dispensing.

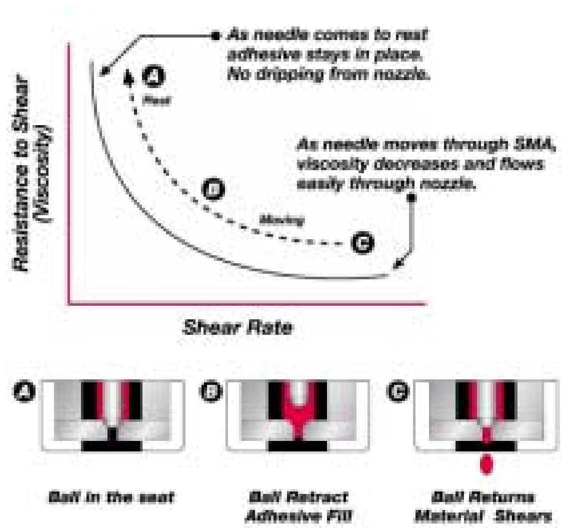

Figure 1- Relationship with Adhesive Rheology

There are many formulations of adhesives from a number of suppliers. Characterizing different materials and determining the best dispensing parameters for a specific application are important factors for implementing a robust dispensing process.

Dispensing Surface Mount Adhesives
Surface mount adhesives are applied using one of three methods: dispensing, printing or pin transfer. Pin transfer and printing are both methods of mass dispensing adhesive on a printed circuit board and are used in less than ten percent of total applications. Needle and jet dispensing are two methods to selectively dispense adhesive on a printed circuit board. Since more than 90 percent of the SMA dispensed in SMT assembly lines is performed using syringe dispensing, the focus of this paper will primarily be on the attributes and characteristics of selective dispensing techniques.

Mass Dispensing
Pin transfer is one of the fastest methods of applying adhesive to a printed circuit board. A dedicated tool with an array of pins is designed to match the adhesive dot pattern on the PCB or substrate. The pins are dipped into a tray of adhesive, which wets the pins in predictable amounts. The pins are then touched to the PCB and the adhesive transfers to the board. Pin transfer is used in high volume applications that have very long production runs.

Stencil or Screen-Printing is also a very fast method of applying surface mount adhesive on a printed circuit board. A stencil or screen with holes (voids) that correspond to the desired adhesive dot pattern is carefully aligned over the PCB. A squeegee wipes a wave of adhesive over the stencil that forces the adhesive through each hole, depositing the adhesive dots on the board.

The majority of the time, mass dispensing can only be accomplished on an unpopulated printed circuit board. Other points to consider when evaluating mass dispensing versus selective dispensing techniques are provided below.

- For raw speed on applications that are non-complex, very high volume and have relatively stable designs, mass dispensing methods for the deposition of adhesive on a printed circuit assembly has a distinct advantage over selective dispensing.

- Applying adhesive to land patterns for components smaller than 3216 (1206) is difficult using the pin transfer method.
- Storage space is required to store stencils and tooling when not in use.
- Exposure of the adhesive to air and moisture in an open tray or on a stencil makes it susceptible to contamination.
- Cleaning the stencil or tooling (both during and after a production run … clogged stencils can lead to missing dots) is a tedious process when using adhesives.
- Costs (in time and dollars) to retool each time the dispense pattern is revised can become significant over time. Multiple revisions of the same assembly requires a good configuration management system be in place.

The use of stencil printing to apply adhesive has grown slightly in the past 24 months, mostly as a replacement for pin transfer.

Selective Dispensing

Selective dispensing can be used on both populated and unpopulated boards. It is also compatible with processes that require another material, such as solder paste, to be applied to the board prior to dispensing adhesive. The adhesive is discretely dispensed using an X-Y-Z positioning system with a specialized dispensing head compatible with the requirements of the application. Currently, needle or syringe dispensing is the preferred method for dispensing adhesive in the SMT production process (see **Figure 2**). The three dominant contact-based methods for discrete SMA dispensing are Time/Pressure (also known as Air/Over), Auger Pump, and Positive Displacement.

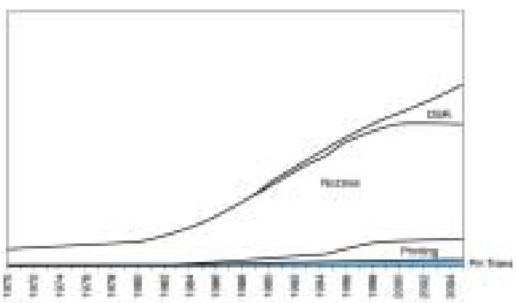

Figure 2 - Needle Dispensing Preferred Method for SMA

Time/Pressure dispensing is the oldest of the three technologies and is still an acceptable method of dispensing in applications where high speed and smaller dot sizes are not a requirement. A syringe of material is pressurized and controlled with a needle valve to control the amount of adhesive to be dispensed.

Auger pump dispensing is a much more repeatable way of dispensing adhesive at a higher rate. The auger pump's primary component is an "auger" feed screw that can be turned on and off by a motor (see **Figure 3**). The motor is turned on for a set time, causing the auger screw to move a precise distance. As the screw turns, it shears the adhesive, forcing the material down the thread and out the needle, producing a very precise and consistent adhesive dot.

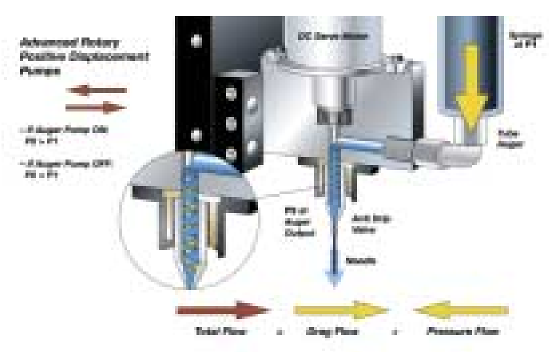

Figure 3 – Auger Pump Operation

True, Positive Displacement pump dispensing provides a method where changes in viscosity will have no effect on the quality and repeatability of the dots. A piston is used to change the volume of a reservoir that is fed from the main syringe. The displacement of the piston in the reservoir results in an equivalent positive displacement of fluid through pump. Since the pump's flow rate is a function of the piston's speed and diameter, changes in viscosity, needle size and supply pressure have no effect on the flow rate.

Contact-based, needle dispensing of adhesive can achieve fairly high dispense rates (greater than 40,000 dots per hour) if the application requires only single, small diameter dots be dispensed on the board. Real-world applications typically require many different size dot diameters to accommodate the different size components that populate a board. A larger surface mount component may also require multiple dots of adhesive to be dispensed at a single placement site. Both of these factors will negatively impact product throughput in terms of units per hour (uph). Non-contact, jet-dispensing can help minimize the impact on uph since no z-motion is required and the jet can dispense multiple shots of adhesive faster than the "on" or "dwell" time required for a traditional needle dispenser to dispense a nominal diameter dot.

Other factors that should be considered when deciding which method of contact-based needle dispensing to employ include:

- For all three methods of contact-based SMA dispensing, repeatable and good quality dots require the dispense gap (the distance between the needle and the substrate or PCB) be the same from dispense to dispense. Maintaining a consistent dispense gap requires contact with the board, increases cycle time and complicates the process. It also requires a positioning system that can make accurate moves in the z-axis.
- The number of dots per hour will degrade for larger dots, since a longer "on" time is required to dispense more material.
- The primary advantage of time/pressure is that it is a simple and inexpensive method to dispense adhesive.
- With time/pressure, as the syringe empties, the air to adhesive ratio changes. The air compresses easily, acting like a shock absorber, resulting in a slower and less accurate response to the air pulse leading to less repeatable dispenses. Dot sizes will vary depending on the amount of fluid in the syringe.
- Pressure cycling of time/pressure causes heating in the air of the syringe, which in turn changes the viscosity of the fluid, resulting in inconsistent dispensing.
- Auger pumps are less sensitive to viscosity variations in the fluid compared to time/pressure which can cause poor dot repeatability.
- The piston pump is more expensive than the time/pressure and auger pumps. The method for cleaning the piston pump is more complex compared to the time/pressure.

Non-contact Method for Selective Dispensing

The newest technology for applying adhesive to the surface of a substrate or printed circuit board is non-contact jetting. Jetting offers many advantages over traditional methods of dispensing SMA, but it also has certain limitations. It is important to have a fundamental understanding of the theory of operation of the valve to appreciate the advantages of this technology in the production environment.

Essentially, jet dispensing utilizes a closed-loop, positive shut-off piston to dispense adhesive (reference **Figure 4**). The fluid is pressurized at the syringe to ensure a constant flow of material throughout the fluid path of the dispenser. The chamber at the end of the fluid path is heated and the temperature controlled to achieve optimal and consistent viscosity. Using a ball and seat design, adhesive fills the void left by the ball as it retracts from the seat. As the ball returns, the force due to acceleration breaks the stream of adhesive, which is jetted through the nozzle. The broken stream of adhesive strikes the substrate from a distance of 1.0

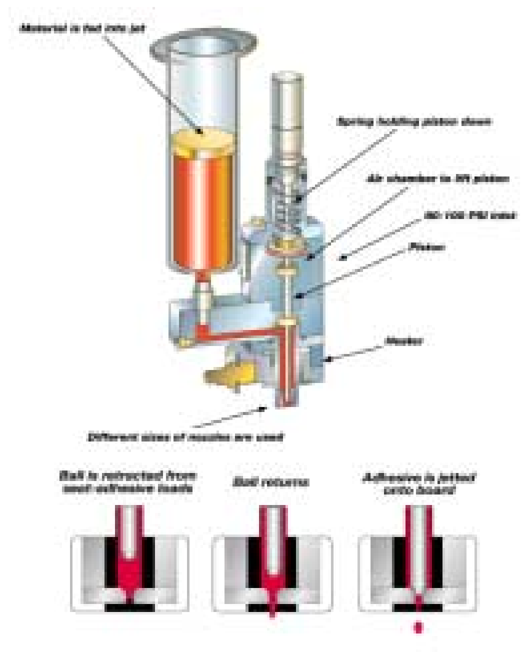

Figure 4 - Concept of Operation

mm to 3.5 mm above the board and forms an adhesive dot. The uniformity and shape of the adhesive dots are unaffected by variances in the PCB planarity or discrepancies in the needle surface and board surface tension since it never comes in contact with the board.

The jet's spring-driven ball and seat mechanism allows the jet to shoot precisely controlled volumes of adhesive onto the PCB. Since there is no motion in the z-axis, the cycle time from dispense to dispense is significantly reduced (see **Figure 5)**. The time between shots is typically 15 milliseconds compared to 90 milliseconds with conventional needle dispensing.

Figure 5 - Comparison of Contact versus Non-contact Dispensing Cycle

The raw speed of jetting also gives the system an inherent flexibility for delivering different dot sizes from a single dispense head. Unlike traditional needle-based systems that require different diameter needles to change dot sizes, jet dispensing can increase the size of the dot by simply applying from one to five shots of adhesive in rapid succession (see **Figure 6**). This greatly reduces the time-consuming effort of changing needles or using a cumbersome multi-needle dispense head. Eliminating all of the wasted vertical motion, repeated height-sensing steps and wetting dwell times allows non-contact dispensing systems to run at nearly the maximum speeds of their X-Y positioning systems and keep up with high-speed placement systems.

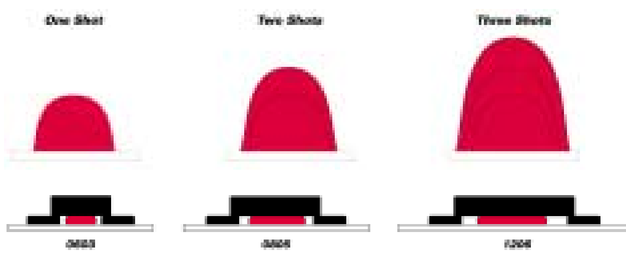

Figure 6 - Multiple Shots Make Higher Profile Dots

The primary limitation of jetting technology is the inability to jet materials such as solder paste. Solder balls in the paste will "coin" when they are struck with the ball of the needle. This eventually leads to clogging and requires high levels of operator assistance. Solder paste is an example where an auger pump is the preferred method of selectively dispensing a fluid on the PCB.

Advantages of Non-contact Dispensing in Production

In application, the jet is able to "fly" above the board at a fixed height and "jet" the material onto the dispense site without having to contact the board. This presents a number of additional advantages over traditional needle dispensing. Since there is no contact with the board, underboard support is not required. Not only are the mechanics of the machine simplified, both process engineering time and setup time is reduced each time a new board is run through the line. Mechanical contact with the board results in significant vibration that must be dampened out using a good underboard support configuration if repeatable, consistent dot shapes are desired. Jet dispensing removes this source of variability.

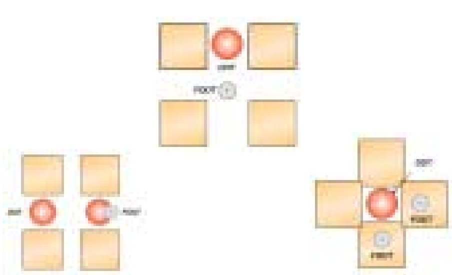

Figure 7 - Standoff Location is Critical

Figure 7 identifies reasons why the landing area for the standoff must be considered when using a mechanical standoff. The process engineer must predict which orientation of the standoff to the needle will not land on a trace, pad or previously dispensed adhesive dot. This challenge becomes even more difficult when multiple PCBs are processed in the same production line or when component size variations require a range of dot sizes that exceeds the capabilities of a single needle.

Since needle dispensing is critically dependent on board flatness and accurate z-height to work properly, there is a constant balancing act between the degree of warp in the PCB and the state of wear in the dispenser's mechanical standoff (reference **Figure 8**). Non-contact jetting eliminates these variables from the process control equation.

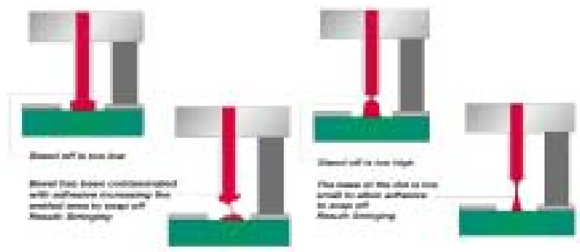

Figure 8 - Dispense Gap Variations can Cause Stringing

Non-Contact Dispensing – The Solution for Today's and Future Production Requirements

Today's real-world SMT production environments require equipment that is flexible and easy to use. It must also address the issues of setup time versus overall throughput. Selective dispensing has the flexibility to be deployed now and fit within the overall production process, addressing both current and future process requirements.

Each method of selective dispensing also has its advantages. Time/pressure dispensing is inexpensive and easy to clean. Auger pumps offer good dispensing control and can dispense a wide range of materials, providing the best value in some applications. The piston pump provides good process control for dispensing precise amounts of fluid, independent of changes in fluid viscosity. The common weakness of each of these methods when dispensing SMA is that they all require contact with the board. Dot quality and repeatability are very dependent on the dispense gap, which introduces a number of critical parameters into the process control equation. It has been long acknowledged that the stability of any process varies inversely to the number of parameters that must be controlled. For this reason alone, process engineers evaluating ways of incorporating non-contact jetting solutions of fluids into their process.

Non-contact jetting has resulted in an overall simplification of the process by providing easier programming, faster setup and more robust process control. The advantages of non-contact jetting include the following:

- Reduced setup and assist time. No needles to change or adjustments are made during production.
- No underboard support is required.
- Dispense gap repeatability no longer an issue.
- Dispensing larger dots does not impact throughput as significantly as other methods of selective dispensing.
- Flexibility with board changeovers.
- Needle/standoff orientation is not an issue.
- Needle standoff location (trace, pads, tracks through adhesive) is not an issue.

Just as all successful new technologies grow to suit a larger range of used, jet dispensing applications are rapidly expanding. For example, jetting has promise in the selective application of silver-filled epoxy, flux and no-flow reflow. These applications can benefit from the ability to shoot fluid at elevated speeds without touching the board.

Jetting surface mount adhesive is rapidly gaining acceptance in real-world production environments, especially in the high volume, high mix world of contract manufacturing where the speed, flexibility and programmability of jet dispensing provide a competitive advantage over time and expense of traditional dispensing techniques.

References:

1. National Electronics Manufacturing Initiative (NEMI), Inc., "National Electronics Manufacturing Technology Roadmaps, December 1998", p. 175 et.al.
2. Piracci, Anthony F., "Practical Production Applications for Jetting Technology", *APEX 2000 Conference Proceedings*

3. Williams, P. and Surface Mount Council, “Surface Mount Technology - Status of the Technology and Industry Activities and Action Plan”, August 1999.
4. Van Den Bosch, A. and DeBarros, T., “Step-By-Step SMT, Adhesives/Epoxies & Dispensing, *SMT*, May 1997, pp. 102-107.
5. Lewis, A., Reighard, M. and Suriawidjaja, F., “Noncontact Dispensing Achieves Practical Results”, *SMT, May 1999, pp.66-67.*
6. Reighard, M., “Non-Contact SMA Jetting: Reliability and Performance Enter the Manufacturing Environment”, *NEPCON West 1999 Proceedings.*
7. Ness, C.Q. and Lewis, A.R., Adhesives/Epoxies & Dispensing, *SMT*, Supplement, Pathways to SMT, July 1999, pp. 28-32.