

Title: Dispensing Solder Paste with a NoFlex™ Linear Drive System

While the limitations of pneumatics in dispensing solder paste are well understood, higher board densities and smaller dot sizes are also challenging the performance abilities of more advanced types of dispensers, such as auger valves. AirFree™ Linear Drive technology offers promising benefits, including significant savings in material cost and high repeatability without concern for viscosity and the volume of paste remaining in the syringe.

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The process of dispensing solder paste began with pneumatics. Whether a hand-held gun, or an automated workstation, whether a diaphragm, spool, needle, or piston, such dispensers depend on a column of air under pressure to force material through a dispensing tip and onto a substrate. Heat, moisture, fluctuations in air pressure, contamination, changes in viscosity... all undermine the ability of air-driven dispensers to deliver prescribed amounts of solder paste consistently, especially in the small amounts required by high density electronic circuitry (typically, less than a milligram). While pneumatic dispensers were at one time the only method available for hand-held and automatic dispensing of solder paste, the demand for precise volume control and repeatability led to the development of alternative solutions in dispensing, the most notable being the auger valve.

Unfortunately, auger valves have limitations. Linear Drive technology, however, is unique, in that the amount of solder paste delivered—dot after dot after dot—is consistent, by design, and is unaffected by either changes in viscosity (Figure 1) or the amount of paste left in the syringe.* Moreover, cost savings can be substantial due to the ability to pre-package syringes with larger amounts of paste than is possible with other types of dispensers.

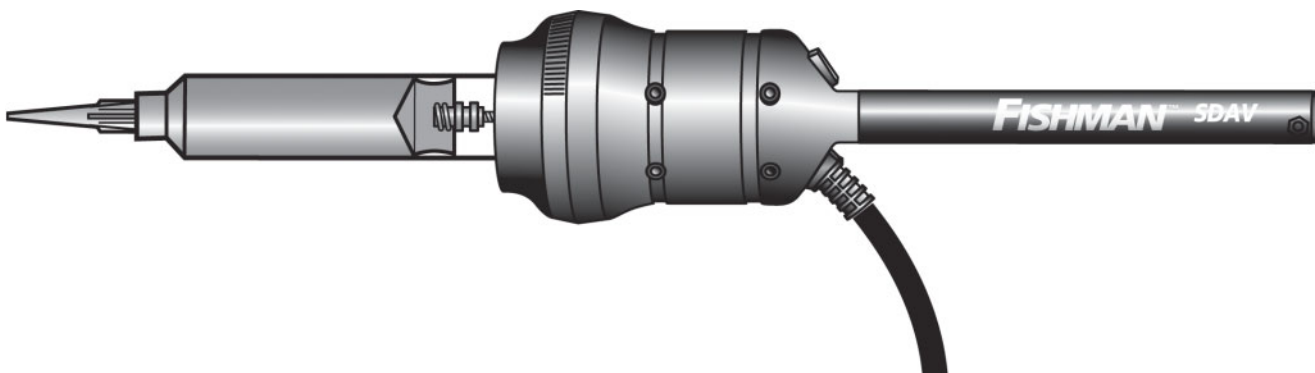


Figure 1. AirFree™ Linear Drive dispenser

* For the purposes of this article, references to dots, dot sizes, and dot volumes are intended to encompass beads, as well, the type of deposit depending on the requirement. The concept of a "dot" is employed simply to streamline the discussion in comparing the performance of augers with linear drive systems.

Comparison of Auger Valves with Linear Drive Technology

The adage that “if it looks like a duck, walks like a duck, and quacks like a duck, it is a duck” does not apply in terms of a Linear Drive System. Though it contains a precision-machined drive screw, it is not an auger! The differences can be seen in Figures 2 and 3. With an auger valve (aka, an Archimedes pump), the solder paste is supplied from a syringe under pressure directly to the threads of the auger, which can be either 8-pitch (eight threads per inch) or 16-pitch, depending on the required size of the deposit. A 16-pitch auger produces half the amount of an 8-pitch auger in a single rotation of the screw. Thus, paste deposits can be more effectively controlled. The downside is the dispense rate is about half the rate of an 8-pitch auger.

Figure 4 illustrates a problem unique to auger-driven dispensing, and that is the fact that the material is stressed by the motion of the auger. As the screw turns, the flux and metal particles comprising the solder are subjected to a shear force as the material is forced along the threads and out the dispense tip. The result of the churning can be a change in both temperature and homogeneity, which, in turn, can impact viscosity and the amount dispensed, as well as the quality of the dot. In addition to the shear force, depending on the rheology of the material, compression of the paste can also occur between the threads, the core of the screw and the side wall of the housing (even flattening of the metal particles).

With the auger, then, the problem of stress comes not from steady pressure being applied to push a fluid through a tip against back pressure created by the needle hub and the dispensing tip, but rather from the shear and compression forces that result from the rotation of the auger. As stress levels rise, two very different problems can occur: 1) separation of the flux and metal particles in the solder paste, and 2) cold-welding of the material, which restricts flow through the auger and can lead to a complete blockage. Any restriction to the flow, of course, undermines the ability to pre-determine dot volume, and causes inconsistent dot sizes.

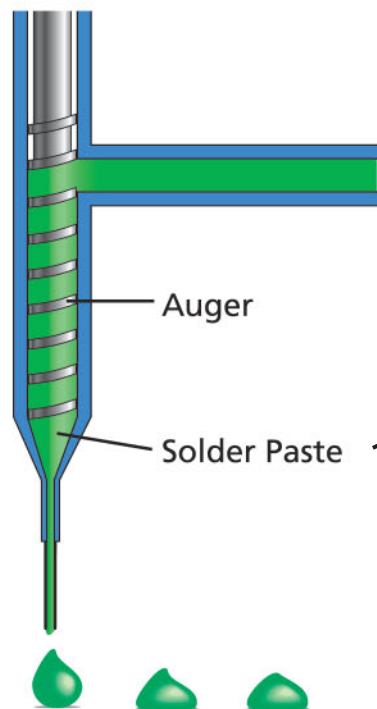


Figure 2. Cross-section of an auger valve

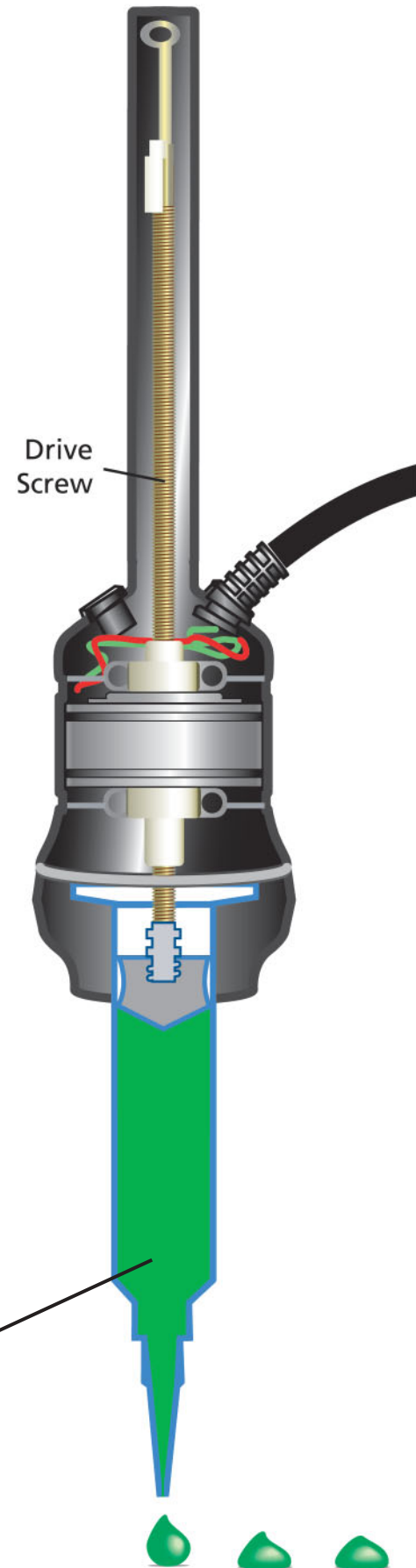


Figure 3. Cross-section of a Linear Drive System

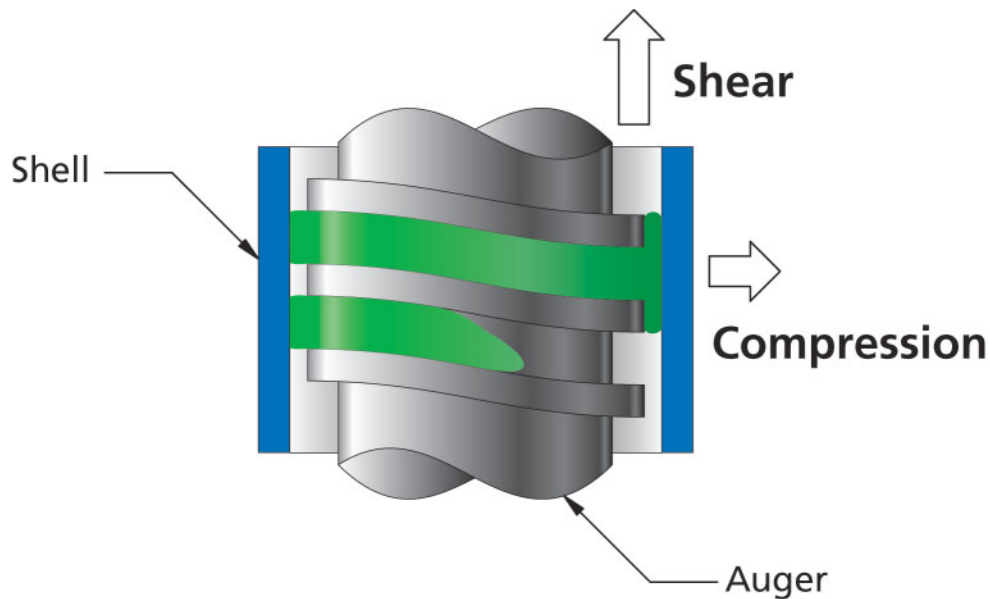


Figure 4. Stressing of solder paste by an auger valve

Another problem that can occur with an auger valve is that of cavitation, which arises when the air pressure to the syringe is too low (either consistently or momentarily), and, as a result, material fed to the auger is insufficient. Cavitation can be corrected by increasing the air pressure, and ideally, by making sure the pressure is steady. However, increasing the air pressure can also lead to drooling (dripping of solder paste from the needle tip without the auger turning), which must be corrected. This, of course, is possible to do, but adjustments—essentially, balancing of the auger dispensing setup—must be performed and routinely checked to ensure acceptable performance for the application. One method that can be used to compensate for high viscosity paste is a timed air-pulse coordinated to the turning of the auger. However, this method has its own limitations, as we will discuss.

A final, but significant, problem with auger valves is what happens when the fluid level in the syringe changes during dispensing. This phenomena is called *volumetric displacement*. As the syringe empties, the surface area of the material against the side wall of the syringe becomes less, which means that less air pressure is required to move a consistent volume of material through the syringe and into the auger. Hence, adjustments to air pressure must be made. At the same time, as the fluid level goes down, air pressure must be increased in order to accommodate the widening gap between the full level and the existing level in the syringe. Unfortunately, the increases and decreases do not balance out, and obtaining the correct air pressure is a matter of trial and error... which is rarely successful. Without adjustment of the air pressure, the volume of material dispensed as a syringe empties can be as much as 10% more than the amount dispensed when the syringe is full. The difference in dot volume, and in dot size, can be dramatic during a dispensing run, and repeatability is "out the window."

As can be seen in Figure 3, the NoFlex™ Linear Drive System differs both in terms of internal design and functionality from the auger valve. To begin with, the dispenser is AirFree™, which means that the solder paste is not supplied from an auxiliary attachment under air pressure. Instead, the syringe is secured directly to the dispenser housing, and the fluid flows through the syringe and out the dispensing tip under mechanical pressure provided by a piston.

The most notable difference is undoubtedly the case-hardened drive screw—which is actually a lead screw—machined with threads designed not to carry paste, but rather to rotate through a fixed block, or nut, mounted in the housing. As the screw threads through the block, it changes the linear position of the piston at the end of the screw, applying pressure on the paste in the syringe in one direction and releasing pressure in the other direction.

Movement of the piston is precisely controlled by a stepper motor-driven linear actuator housed in the dispenser. The actuator directly engages the screw, eliminating lags and backlash in the drive system. Rotation of the actuator is programmed and controlled by software, the motor stepping in 3.5-degree or 7.5-degree increments, with the lead screw having either a 0.012 in. or 0.024 in. thread. The increment of rotation combined with the selected screw thread for the dispensing gun enables volumes ranging from 0.00023 cc to 30 cc and dot diameters as small as 30 mils for mounting of semiconductor components.

Other performance features of the dispenser include the following:

- Quick-disconnect, state-of-the-art cabling for clear signal transmission and trouble-free performance.
- Patented NoFlex™ locking mechanism to prevent flexing of the syringe as the piston applies pressure to the fluid during dispensing, thereby eliminating the possibility of inconsistent results.
- Precision-machined NoFlex™ piston stabilizer to prevent flexing of the piston.
- Stainless steel luer thread connecting the PosiLok™ piston to the lead screw, to prevent flexing at the connection point and possible pressure loss.
- End-of-dispense-cycle programmable “draw-back” to prevent drooling of the solder paste.

The NoFlex™ Linear Drive System is a true positive displacement pump. While auger valves are sometimes called positive displacement pumps and are reasonably consistent in dispensing pre-determined amounts of solder paste, dispensing volume depends on the viscosity and flow characteristics of the material. The NoFlex™ Linear Drive System, on the other hand, meets the definition of a positive displacement system, in that a specific volume of material is displaced—each and every time, even during ramp up and ramp down—within a specific mechanical actuation.

Finally, with a NoFlex™ Linear Drive System, the smooth motion of the linear actuator and the resulting movement of the PosiLok™ piston enable the syringes to be filled with more solder paste than is possible with auger valves. What this means is less syringes are required to dispense the same volume of solder paste in a production run. Since the cost of adding solder paste to syringes is minimal compared with the price of additional syringes, significant cost savings can result.

The System Approach to Linear Drive Dispensing

Importantly, the NoFlex™ Linear Drive System is just that: a *system*. (See Figure 5.) The dispenser itself is but one component. Complementing the gun is an “intelligent dispensing”

control unit (Figure 6). As such, key data are programmed and stored in: the exact syringe dimensions (inner diameter and length), dispense volume, dispense rate, drawback, and drawback delay. With these parameters entered, the software calculates the “steps” forward and backward to produce the desired dispense amount, each step being either 3.5 degrees or 7.5 degrees in rotation, depending on the selected dispensing gun. In other words, the software determines the exact movement of the piston in the barrel to dispense the required amount. Neither the viscosity of the material nor the amount left in the syringe has any impact on dot volume; and simply activating the control, either manually or automatically, ensures high repeatability in delivering the desired amount.



Figure 5. NoFlex™ Linear Drive System

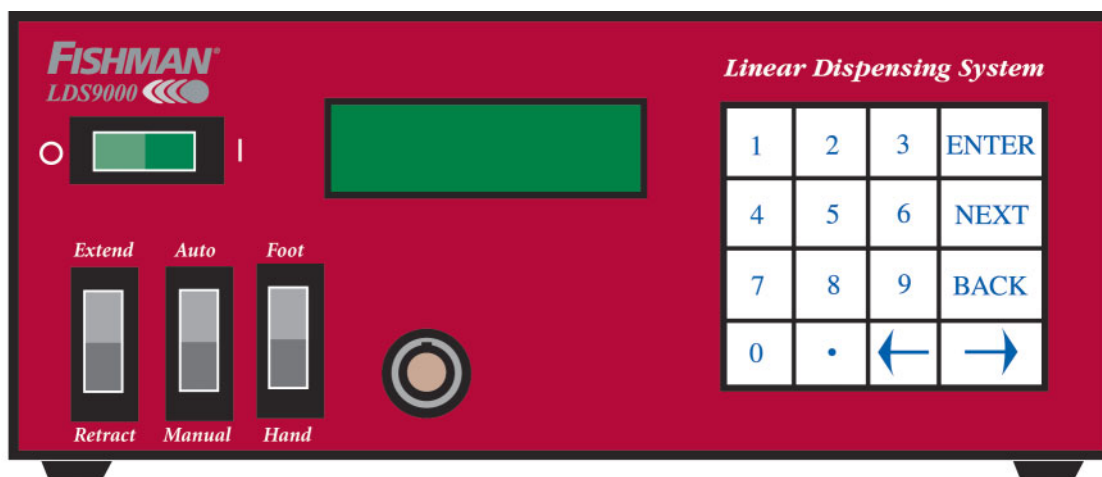


Figure 6. Control unit for NoFlex™ Linear Drive System

Conclusion

Selecting a type of dispenser for solder paste depends on certain fundamental considerations, beginning with the dot volume (or size) and repeatability. Once these requirements have been determined, classes of dispensers are either included in or out. Time/pressure pumps, for

instance, simply cannot meet the requirements for many semiconductor components, especially given the high density substrates of today.

For most applications in terms of small dot volume and high repeatability, the auger valve is often the dispenser of choice, and it has been for a number of years. Dispensing with an auger-based gun, however, has limitations, not the least of which include: stressing of the material with possible separation of the flux and metal particles, cavitation, inconsistent deposits as the volume falls in the syringe, variations in the amount dispensed due to changes in viscosity, and the inability to completely fill a syringe with solder paste.

The NoFlex™ Linear Drive System is a positive displacement pump that obviates such problems. Moreover, as a complete system, the dispenser is complemented with a control unit and software that provide a programmed signal to the linear actuator, dictating the exact linear movement of the piston in the syringe barrel to achieve the volume of solder paste required, dot after dot after dot, regardless of viscosity or the volume of solder paste remaining in the syringe. Such dispensers are finding increasing application in industry, from hand-held and bench-top systems to fully-automated robotic work stations.

Further information on NoFlex™ Linear Drive Systems can be found at www.fishmancorp.com.