Auger Valve Dispensing

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Abstract

When tuned well, auger valves are capable of sub-milligram size deposits with less than 10% variability from deposit to deposit. When tuned poorly, a variety of problems can result, all of which can cause unacceptable deposit size variation.

In this paper, Nordson EFD guides you through the steps for development of a robust auger valve dispensing process. We will identify the most critical process parameters affecting auger valve use and explain how to manage those parameters to your advantage.

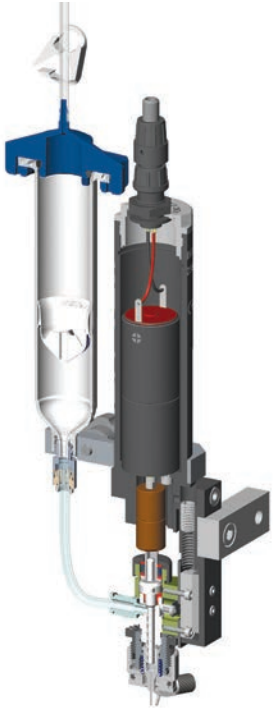
This whitepaper makes frequent references to dispensing solder paste but the concepts explained here apply to most materials dispensed with auger valves.

Introduction

Auger valves are the technology of choice for high accuracy dispensing of solder paste and other high viscosity materials. Auger valves are well suited for placing small to moderate sized solder deposits. As with many flexible systems, there is a list of key parameters to manage for optimal performance.

This paper is written in three parts:

- Defining auger dispensing system parameters
- Considering environmental and other parameters that can prevent success
- Symptom-cause identification for the most common auger dispense issues



Every auger application typically starts with a deposit size or sizes as a goal. Deposit size requirements are a constraint on what tips may be used, tip positioning requirements, and auger settings. After the mechanical system has been defined, there are then a number of parameters that may or may not require specific controls to meet deposit size goals.

While highly accurate and rapid to respond, most auger valves do not dispense material quickly. If cycle time is critical and deposit size is moderate to large, an auger valve may not be quick enough. Under these conditions, pulsed air dispensing or a spool valve may be a more effective option.

Defining Auger System Parameters

Deposit Size

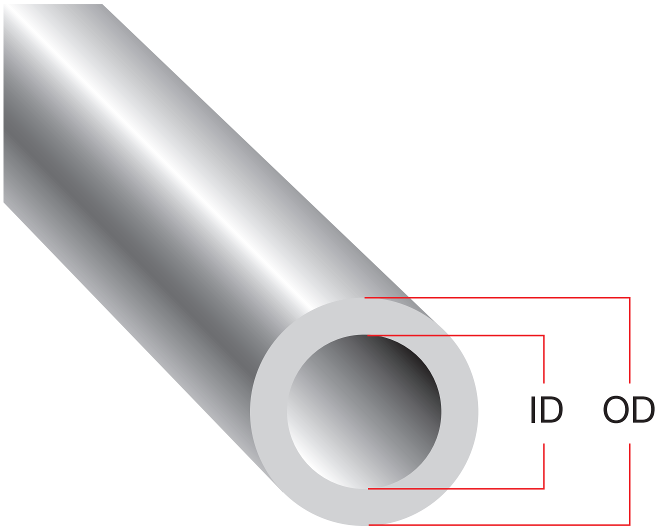
The first step in developing a dispensing process is identifying the size or sizes of deposits required. In some cases, the criteria for deposit size and shape may be purely visual but many cases require a repeatable measurement technique such as weight, 2D visual or 3D visual. In any case, the diameter is a valuable measurement, as it defines the sizes of an appropriate tip, the positional accuracy required for repeatable deposits, and the largest particle size you can use for a dispensable solder paste.

Tip Size

The determination of the correct tip size and type for each application is one of the most critical steps in the design of an optimized solder paste dispensing process.

Using too restrictive of a tip for the paste type will cause excessive backpressure and foster tip clogging. A useful guideline is that the tip ID should be at least seven times the solder paste powder size. Example: Type 3 powder is up to 75 µm in diameter in the 80% cut. 7 x 75 = 525 µm indicating that a 20 or 21 gauge tip is at the low end of what is feasible with Type 2 powder. Using too large a tip for the deposit size can interfere with deposit size control within established tolerances.

When choosing a tip, the rule of thumb is you may not expect to produce a deposit with a diameter smaller than 1½ times the tip ID. Example: if you need a 1.5mm deposit, the largest tip ID you should use is 1mm. It is technically possible to do so but is difficult and tends to be unreliable.



With very small dispense tips where the OD of the tip end is a significant fraction of the ID, the OD will start to define the minimum deposit size. Choosing the tip with the minimum OD will allow the smallest deposits.

Gauge	EFD Tip Color	Tip ID		Minimum Dot Diameter	
14	Olive	0.060"	1.54 mm	0.090"	2.29 mm
15	Amber	0.054"	1.36 mm	0.081"	2.06 mm
16	Grey	0.047"	1.19 mm	0.071"	1.80 mm
18	Green	0.033"	0.84 mm	0.050"	1.27 mm
20	Pink	0.023"	0.61 mm	0.035"	0.89 mm
21	Purple	0.020"	0.51 mm	0.030"	0.76 mm
22	Blue	0.016"	0.41 mm	0.024"	0.61 mm
23	Orange	0.013"	0.33 mm	0.020"	0.51 mm
25	Red	0.010"	0.25 mm	0.015”	0.38 mm
27	Clear	0.008"	0.20 mm	0.012"	0.30 mm
30	Lavender	0.006"	0.15 mm	0.010"	0.25 mm
32	Yellow	0.004"	0.10 mm	0.008"	0.20 mm

Tip Type

Under most circumstances, we recommend choosing the least restrictive type of dispense tip that will meet your deposit size requirements. Larger gauge tips allow for faster paste flow and produce less backpressure on the solder paste during the dispense cycle. They are also less resistant to paste drool under constant pressure. Shorter cannula tips have less flow resistance than longer ones. Tapered tips produce less backpressure than straight walled stainless steel tips but are vulnerable to process variation, as they are more flexible and can expand and contract due to auger induced pressures. Rigid tapered tips, as opposed to “regular” tapered tips, deform much less and produce more consistent deposits.

¼" GP ½" GP TT

The best choice of tip size and type is dependent on the application. The trick is identifying which is the best for your application. Longer tips are useful for reaching out of the way deposit locations and can add resistance to keep paste from drooling from large gauge tips. Paste dispenses more slowly from a smaller tip, allowing for smaller increments in deposit size per unit time. When deposit size consistency is of primary importance, cycle time can be sacrificed for tolerance by using a smaller gauge tip. In any case, tip choice can make or break a dispense process.

Tip Position

Tip position is the relative placement of the dispense tip to the work piece during a dispense cycle. The goals of tip positioning are to achieve unrestricted paste flow out of the tip during the dispense cycle and a clean paste break-off when the tip separates from the part.

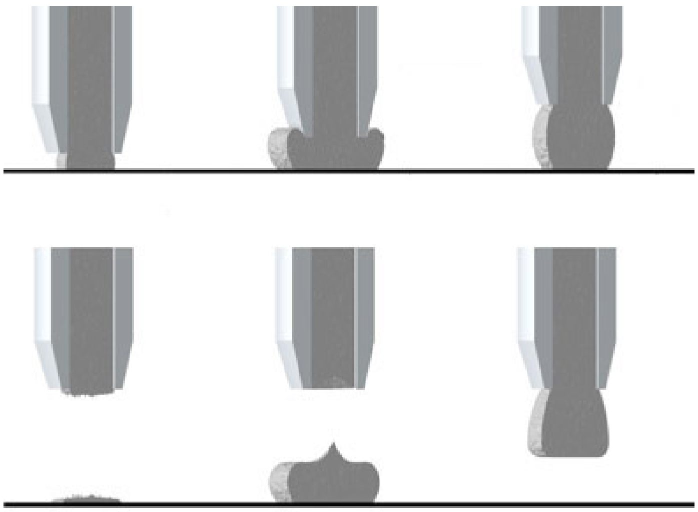
Orientation falls into two categories: perpendicular to the product surface and non-perpendicular. Only perpendicular orientation is addressed in this paper due to the almost infinite variety of outcomes possible with non-perpendicular tip positions. Non-perpendicular tip positions are often a great solution to a difficult dispensing problem but are not easily addressed with general guidelines.

There are two critical variables with regards to tip position: product surface and Z-height.

Dispensable product surfaces come in many variations: flat, bumpy, smooth, textured, wide, thin, pointy, recessed, and gapped just to name a few. In every case, the goal of tip positioning remains the same; achieve a consistent and clean paste break-off when the tip separates from the part. The surface shape dictates the techniques required for consistent dispense results. Your equipment and paste suppliers should be able to help in identifying a solder paste solution.

Z-height is the distance from the bottom of the dispense tip to the product surface. If the tip is too close to the surface, paste will exit the tip, hit the part, and backpressure will prevent further paste flow. Continued valve operation without paste flow causes flux separation and cold welding of solder alloy in the valve. If the tip is too far from the surface, paste will have greater adhesion to itself and the dispense tip than the product surface and fail to stay on the product. A “large dot small dot” pattern is likely to emerge and is a sure sign of too great a Z-height. A good starting point for Z-height is ½ to ⅙ the tip ID. As deposit size decreases, the gap proportion drops from ½ to ⅙ as there is a tendency to stick to the tip due to low mass of the deposit. Applications requiring deposits smaller than 0.3mm may require a footed tip to ensure consistent Z-height because robot and part tolerances can easily exceed allowable Z-height variation.

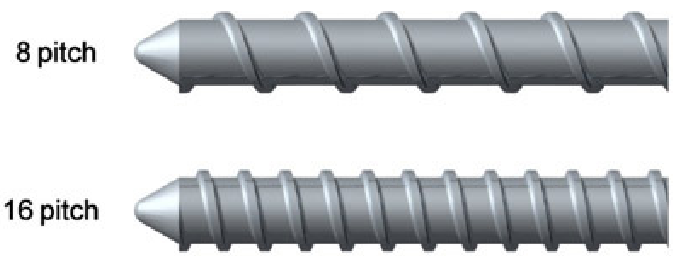
Example:



No Dot   Good Dot   Small dot/Big dot

Auger Screw Selection

Most auger valve manufacturers offer a selection of auger screws to choose from. Two of the most common styles are eight threads-per-inch (sometimes referred to as flights) and sixteen threads-per-inch. They also come in a variety of thread depths. As usual, there are tradeoffs associated with each of the available auger screw options.



The eight thread-per-inch auger screw is standard among valve manufacturers, and is appropriate for most applications. Inherent resistance and paste flow are moderate.

The sixteen thread-per-inch auger screw is used when either additional inherent resistance and/or finer deposit size control is required. With the distance between threads halved, the total distance paste must travel around the screw is doubled, while the amount of material exiting the screw per revolution is halved.

Various specialty screws can have much larger or smaller thread count, to either achieve faster flow or more precise deposits.

If the most appropriate screw type can be identified early in the process development cycle, time and effort can be saved.

Air Pressure

Auger valves are capable of being run with either constant pressure or pulsed pressure. In general, the most consistent deposition is achieved with constant pressure when dispensing solder paste. The system relies on the inherent resistance to flow provided by the auger screw and the dispense tip to prevent constant material flow out of the tip (tastefully called drool). The air pressure should only be high enough to maintain material flow, keeping the auger cavity supplied with materials so it does not run dry. Pressure typically ranges from 4psi to 10psi but both higher and lower values have been required for particular valve models and applications.

Even with a “correct” pressure setting that keeps the auger supplied with material, there may be an unacceptable quantity of drool during extended pauses between dispense cycles. Programmed removal of pressure from the solder paste reservoir during pauses is recommended in this situation.

When in need of using pulsed pressure, specialized paste formulations may be required to handle the aggressive processing conditions. Most often, pulsed pressure is thought of as a solution to a cycle time problem.

Example: “The valve does not dispense fast enough at the recommended pressure setting so a higher pressure is used to increase flow. The higher pressure results in unacceptable drool so the air feed is switched from constant to pulsed, eliminating the drool in between deposits. Pulsing the pressure adds energy to the paste accelerating flux decomposition, and causes paste separation. The eventual failure mode is deposit size reduction followed by flux rich deposits until the valve and/or tip becomes completely blocked. The paste manufacturer is then called in to fix the perceived paste problem."

If an application has a cycle time that seems to necessitate the use of pulsed pressure, then an auger valve may not be the best solution. Contact your paste and valve manufacturers before using pulsed pressure with an auger.

Auger Speed and Time

After defining the tip and pressure that gives the best performance, deposit size should be finetuned with auger speed and time. The pressure generated by the spinning auger is a product of rotational speed. Auger speed can be defined in a number of ways including (but not limited to) revolutions per minute (RPM), voltage, or % of maximum speed. To a point, the more revolutions per unit time, the more material the valve will dispense per unit time.

For any combination of valve, paste, and tip types, there are maximum and minimum achievable flow rates at the maximum practical pressure. This means that beyond a certain point, higher valve speed does nothing to change dispense rate. The amount of pressure required to overcome the inherent resistance in the dispense tip reaches the stress level at which two things happen. The alloy particles start to cold-weld together causing valve blockage, and paste temperature is elevated by the combination of friction and pressure. At the low end, either the auger motor fails to turn or the pressure generated by the spinning auger goes below the threshold required to overcome the inherent tip resistance, resulting in no flow.

To achieve the most precise control, combine slower speed with longer time. To maximize dispense rate, run the valve at the highest speed possible without damaging the paste.

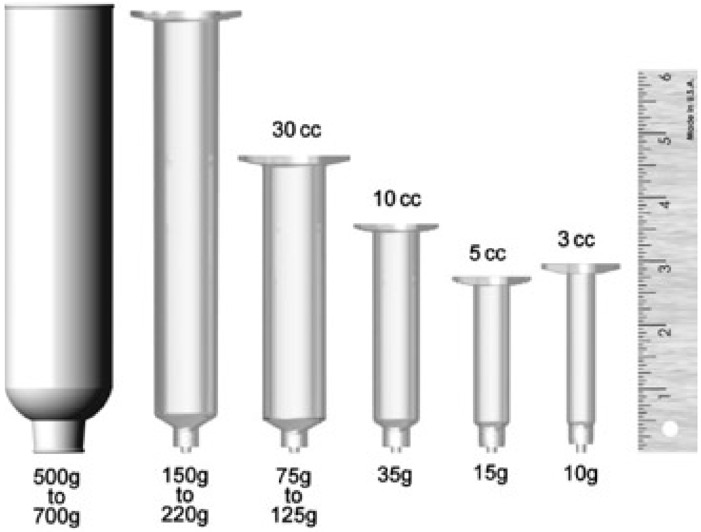
Other Process Parameters

Reservoir Size

Reservoir size is rarely a problem with auger valve dispensing applications. Typical deposit sizes allow for thousands of trouble-free deposits per reservoir using standard packaging for the paste type in question.

In vibration rich and high temperature environments, smaller reservoirs may be used to minimize paste waste due to accelerated paste damage.

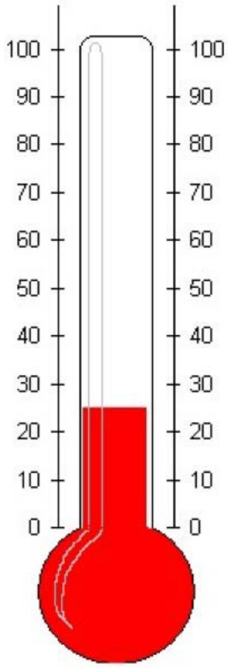
In vibration free applications where the temperature is within the recommended range, larger reservoirs may often be used without fear of paste yield loss; as long as the greater mass does not cause drool due to simple gravitational effects.



Temperature

The effects of temperature on solder paste dispensing are generic to most dispense methodologies. Auger valves are not an exception. As temperature changes, three things happen:

1) The paste changes viscosity.



I. Increases in temperature soften components in the paste, making it thinner; less viscous. Decreases in temperature have the inverse affect, thickening the paste. Note: Above 27˚C (80˚F), softening can reach the point at which the paste loses the ability to hold the solder alloy in suspension, resulting in paste separation.

2) Deposit size varies as the temperature varies.

I. Changes in viscosity affect flow rate and, therefore, deposit size produced with particular dispense settings. Keep temperature variation to a minimum as a safeguard against temperature related deposit size variation.

3) The flux chemistry reaction rate accelerates with increased temperature.

I. The flux is active to some extent even at low storage temperatures. At temperatures above 27˚C (80˚F) the reaction rate is noticeably faster.

Fixturing

Often overlooked as either a process design consideration or possible cause for problems, the valve fixture can play a critical role. The operating life of dispensable solder paste can be drastically reduced by poor fixture design practices.

The single most frequent fixture mistake is placement of dispense equipment relative to a heat source used for reflow. Close proximity to heating units can result in elevated solder paste temperatures with related affects. Shielding and improved airflow can both be used to minimize or eliminate such heating affects when close proximity is required.

Physical stress applied to solder paste in the forms of shaking, sharp impacts, and vibration all have degradation effects. The worst of the three is vibration. Equipment that generates strong vibrations, such as vibratory bowl feeders, should be isolated from dispense machinery to avoid rapid paste separation. If the dispense machinery cannot be isolated, smaller reservoirs can be used to match the volume used to the exposure limit imposed by the vibration source.

Sharp impacts and vigorous shaking of solder paste by slides and high-speed XYZ positioning systems can have cumulative separation effects over many dispense cycles. In some cases, smaller reservoirs of paste may be used to eliminate paste waste due to scrap, by matching the cycle count limit before paste failure to the paste volume dispensed over those cycles.

Care and Maintenance

Care and maintenance requirements for auger valves vary by manufacturer and model but some basic guidelines apply to most.

When idle for more than a few hours, the tip should be removed from the valve and an airtight cap put in place. This will protect paste in the valve from degeneration due to air exposure. Solder paste inside tips left on an inactive valve will harden over time. The smaller the tip, the faster it hardens.

The most frequently required maintenance activity is purging of the valve. For best performance, purge a valve after 48 run hours to flush out ageing paste and metal shards. If a valve will be left inactive for a day or more, purging the valve will prevent paste from hardening in the valve.

On a weekly basis, disassemble and clean the valve with a manufacturer recommended solvent. Regular cleaning keeps valves performing at their best.

Symptom – Cause Identification

Drool

If paste continues to extrude from the dispense tip after the dispense cycle is over, that behavior is called “drool”. The only way for drool to happen is for there to be sufficient force to move the paste out of the tip. There are a few possible sources for such force.

Air pressure too high: If using constant pressure and the pressure is high enough to overcome resistance to flow through the auger and the tip paste will move continuously. Options for managing this flow include a lower pressure if practicable, a more strictive flow tip, or changing to pulsed pressure.

Too much mass in reservoir: It is possible for the mass in the reservoir to have enough force due to gravity for the material to flow. The lower the material viscosity, the more vulnerable it will be to gravity effects. The only solutions for this are smaller reservoirs or changing the reservoir orientation and location to minimize the force vector effect from gravity. Other problems can also appear if a syringe is not vertical so this is not a first choice.

Air in Paste: If the solder paste contains too much air from the mixing process, it acts like a foam; it compresses and decompresses with the application and removal of pressure. In the auger screw and tip area, paste is pressurized when the auger turns, compressing the paste. When rotation stops the stored compression has a large resistance for paste to flow backwards, towards the syringe due to pressure (if using constant pressure), restrictive geometry and mass. That means it most often decompresses through the dispense tip. This type of drool can be reduced but not always eliminated through a combination of a more restrictive tip, lower pressure/mass, and running the auger in reverse.

Big Dot – Small Dot – No Dot

Every dispense process has variability in deposit size. However, sometimes there is dot size variation beyond natural variation. Oversize, undersize and absent dots can be the symptoms of a few root causes.

Tip is too big: Sometimes a tip is too big for an application, even if it follows the 1 ½ times the tip ID guideline. Possible does not mean optimal. Try a smaller gauge tip so there is less opportunity for paste to either stick to the tip or be pulled out of the ID.

Tip to Substrate Gap Problem: If the gap from tip to substrate is too small, too large, or varies by too much, deposit size can change drastically from deposit to deposit. This problem can be a function of choosing the wrong gap, positional accuracy of your equipment, part to part variation, or fixturing tolerances. This can be the most challenging problem to solve for small deposits. If practicable, a footed tip should be used because this compensates for most sources of gap variation.

Air in Paste: If the solder paste contains air that does not uniformly distribute and/or shows visible bubbles, this non-uniform air causes drool, as noted above, that is observable as varying and missing deposits. As an air bubble works its way to the dispense tip, it acts as a bigger spring and will exert increasing force towards the tip until it escapes. When it is near the tip end, deposits will get larger and larger until one or more either reduce in size or are missing due to the air void where paste should have been. If your paste has air issues, the only solution is to work with your supplier to solve them. The auger cannot compensate for this material problem.

Dispensing Stops

Of equal concern to deposit size, being out of control is the sudden stop to dispensing. It is possible for such a stop to be an error in auger function, a tip blockage, or a major air event.

Auger Error: Some auger controllers are designed to protect the electric motor from dangerous amounts of current; enough to damage the motor. This is called over current protection. When there is sufficient resistant to rotation this protection will occur. Resistance to rotation is caused by friction in some part of the auger assembly and is most commonly caused by particles getting past a seal into a bearing surface or the tip and auger path filling with high density, compacted material.

Gap from Tip to Substrate too Small: If the gap is too small, back pressure will prevent even movement of solder paste. Flux rich paste will be forced out by the auger created pressure and the metal rich paste left in the tip, the tip will block. The solution is to increase the tip to substrate gap to prevent this kind of tip block.

Tip Size too Small for the Paste Type: If the tip chosen is not large enough to allow passage of the large particles in the solder paste, eventually it will experience a block. The solution is either a larger ID tip or a smaller particle size solder paste.

Paste Damaged by Auger Pressure: If the solder paste is under more force than can be relieved by exiting the dispense tip, that paste under pressure will be damaged. Solder alloys are relatively soft and those soft particles can weld together under auger pressures. These welded together objects can become large enough to block the dispense tip. Try decreasing auger speed to see if that is the root cause.

Major Air Event: Sometimes dispensing stops due to either a large air bubble or what is called “tunneling”. Tunneling is the situation where the paste has a sink hole in the middle and a column of air works its way down into the auger fluid path. This uninterrupted air path allows a constant flow of air out of the tip. A piston that has stopped moving with a pocket of air underneath is a visual symptom of possible tunneling, although tunneling is a rare root cause.

Conclusion

Nobody becomes an expert in auger dispensing overnight. It takes a basic education followed by plenty of experimental practice to develop an intuitive understanding of the relationships between the many process parameters.

The same is true of every other soldering process so there are no real shortcuts on the learning curve. Manual methods require the development of control and technique. Automatic and semi-automatic systems have their own sets of process parameters to control.

A good understanding of symptom – cause relationships will greatly simplify and accelerate the problem solving process. If you have trouble with auger dispensing and self help is not working fast enough, contact your equipment and material suppliers for expert assistance.

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