Time Pressure Dispensing

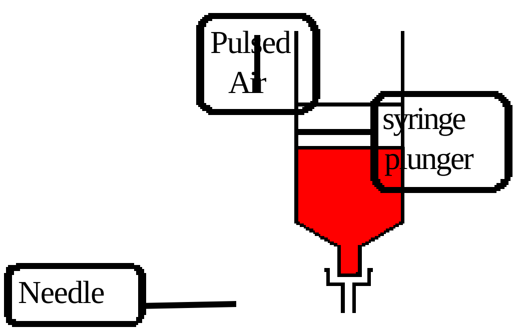
by Doug Dixon, GDM Product Manager

What is time pressure dispensing?

Time pressure is a method of dispensing liquid materials (surface mount adhesives and gasketing materials) that uses air pressure applied to the top of a syringe to force material through a needle. The amount of time the air pressure is applied is directly related to the amount of adhesive dispensed. Dispensing materials in this manner is also known as "air over" dispensing, referring to air pressure *over* time or air pressure applied *over* a syringe.

Air over or time pressure dispensing is used in both manual operations and automated equipment. In manual operations an operator holds the syringe by hand and controls the duration of air pressure with a foot pedal. Operators can apply air pressure as long as necessary to compensate for any variables that might cause inconsistencies, such as the level of material in the syringe or differences in ambient temperatures.

The evolution of time pressure dispensing into automated equipment was a logical next step. However, implementing a smart system to compensate for the numerous dispensing variables has proved to be a difficult task. Time pressure dispensing is the most widely used dispensing method, but an increasing number of automated dispensing systems now utilize more reliable methods such as Archimedes metering pumps or piston positive displacement pumps.



How do automated time pressure systems work?

By applying air pressure to a syringe for a specified length of time, material is forced down the syringe and out the needle. Automated time pressure systems cycle air pressure on and off with high frequencies, dispensing up to 40,000 dots per hour.

While several parameters affect the consistency of the dispensed material at high frequency cycle rates, those affecting dispensing the greatest are time, pressure, material rheology, and the level of material in the syringe. Automation equipment using time pressure technology controls air pressure and duration of air pressure applied to a syringe quite well. However, other variables such as material rheology and syringe level make automated time pressure difficult to understand and control. Automatic time pressure systems constantly monitor and evaluate dispensing consistency using a vision system that measures dot diameter. When the vision monitoring system finds that dot diameter has changed, it either attempts to increase the length of time the air pressure is applied, or alerts the operator that the machine needs attention.

The problem with time pressure systems is the number of interrelated variables requiring control. The vision monitoring system is one attempt to stabilize the dispensing variability by monitoring dot diameters, but it does not address the root causes of the inconsistencies. Time pressure systems are utilized because they are easy to implement, but at high frequencies consistency and quality are sacrificed.

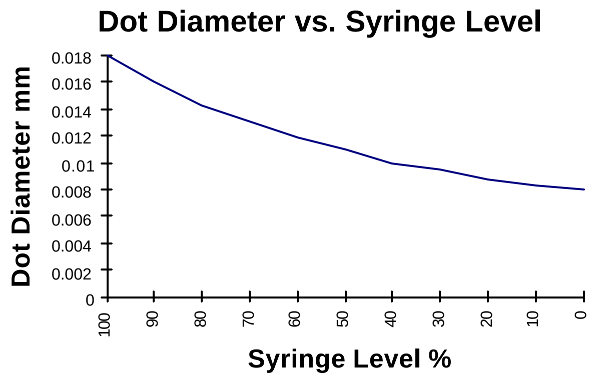
What are the effects of pulsing air pressure?

Air is a gas composed of minute elastic particles that are continually moving with high velocities, colliding with each other and with the walls of the containing vessel. The pressure exerted by a gas is due to the cumulative impact forces the moving molecules generate against the walls of the containing vessel. The magnitude of the pressure is a measure of the number of molecules and their energy. Pulsing the air pressure at high frequencies to repeatedly force material out a syringe continuously excites the air molecules in the syringe, creating heat. The heat is induced by the dynamic frictional effects of air compression and decompression. Heat is also induced by friction within the material being dispensed, as the molecules are forced to slide against each other and through the syringe. A measure of the internal frictional properties of a fluid is called viscosity. This defines the fluid’s resistance to flow.

Heat affects the rheology of the material being dispensed. As the material temperature increases, its viscosity decreases. Dynamic changes in material viscosity result in inconsistent material flow. Surface mount adhesives are composite materials designed to react or cure, making them unstable at elevated temperatures and pressures. Once triggered, curing is an irreversible exothermic chain reaction that changes the material’s molecular structure and its ability to flow.

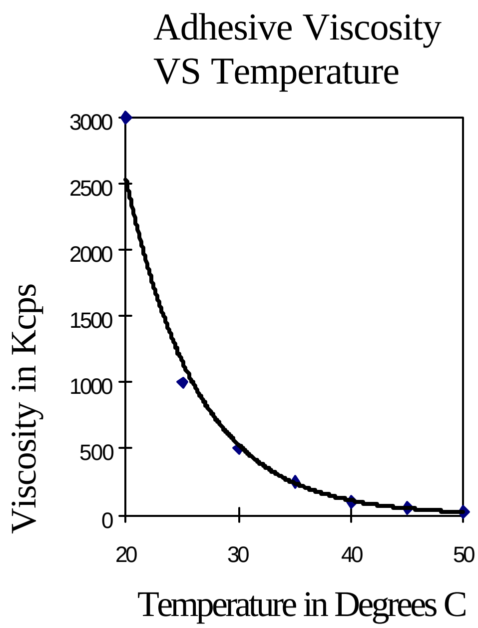
How does the level of material in the syringe affect time pressure systems?

As the level of material in the syringe decreases during dispensing, the volume of air in the syringe increases. As the syringe empties, it requires more time to compress the larger volumes of air above the material. These changes can be observed by plotting compression response curves showing the amount of time it takes to reach a specific air pressure for full and empty syringes. Because of these pressurization time differences, there are significant changes in dispensing volumes as the syringe empties. The graph below is an example of how differing syringe levels affect dot diameters in time pressure systems.



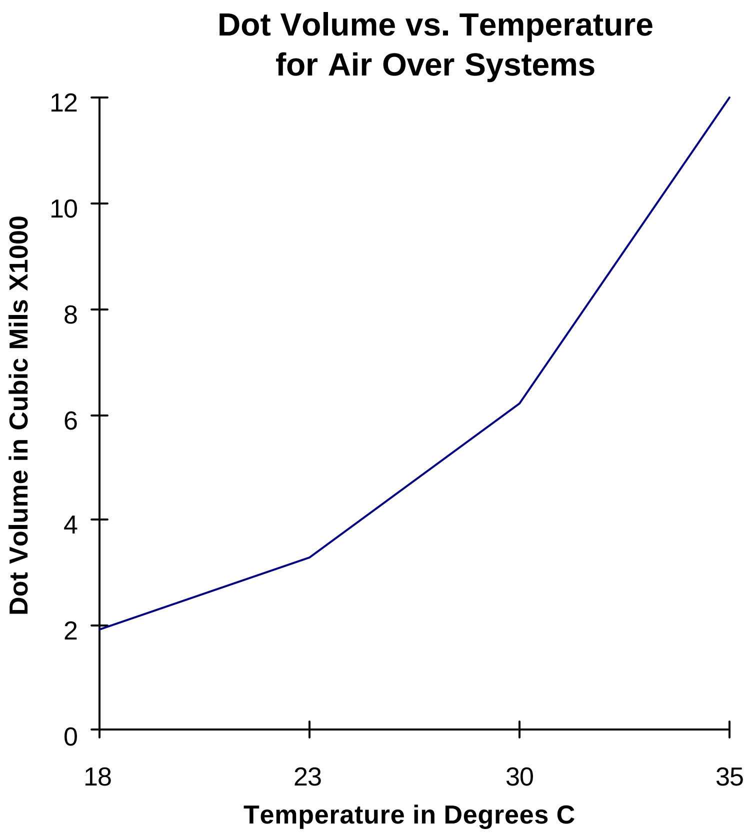
How does material viscosity affect dispensing consistency?

Viscosity is a measure of a material's ability to flow. Lower viscosity materials require less air pressure to make them flow than higher viscosity materials do. A small change in material viscosity dramatically affects the amount of pressure needed to force a set volume of material to flow through a needle. It is difficult to control the volume of material dispensed if the material viscosity is changing. The relationship between viscosity and temperature is shown below for a typical surface mount adhesive.



How do time pressure systems try to compensate for viscosity changes?

Manufacturers of time pressure equipment sell atmosphere heaters as an attempt to stabilize material viscosity by decreasing temperature changes that result from pulsing the syringe at high frequency and pressure. Raising the epoxy temperature above ambient temperatures between 30º to 35º C (86º to 95º F) minimizes the realized temperature changes due to the high frequency pulsing. The graph below shows the effect of temperature changes on dispensing volumes in time pressure systems. Note that the recommended dispensing temperatures for time pressure systems of 30º to 35º C (86º to 95º F) has the steepest slope on the graph and indicates that even a one degree change in the dispensing cabinet temperature results in a significant change in volume of material dispensed. Increases in volumes with temperature increases is directly related to decreases in viscosity of the surface mount epoxies.



Raising the temperature of the epoxy has two major advantages for time pressure systems. The first advantage is that the temperature changes on the material are reduced over the usage of the syringe, helping stabilize material viscosity. With the material viscosity somewhat stable, the time pressure systems can concentrate on syringe level effects which are controlled through pressure and time. The second advantage of heating epoxies for dispensing is it reduces the material viscosity which reduces the tendency for the material to string. Lower viscosity materials tend to have less tailing and stringing than higher viscosity materials. Preheating the syringe with cabinet heaters prior to using also helps reduce temperature and viscosity changes which would otherwise be dramatic where the epoxies are refrigerated.

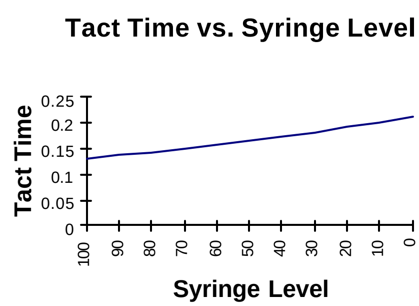
A disadvantage of heating surface mount epoxies is that the material trigger point at which exothermic curing reactions occur are as low as 40º C (104º F). Once the epoxy reaches this temperature it starts its curing cycle (which cannot be reversed).

How do time pressure systems try to compensate for consistency?

Manufacturers of time pressure systems have gone to elaborate lengths to compensate for the numerous dispensing variables. The most common method of maintaining consistent depositions is to utilize a vision system to monitor the material diameters of the depositions. These vision systems recognize two-dimensional representations of the actual volumes dispensed. The volumes may increase or decrease without changing the effective two-dimensional characteristics of the dot diameter as seen by the camera.

The interaction of vision systems and dispensing equipment and how they deal with the vision data generated differs with vendor and equipment. High end time pressure systems offer a semiautomated method of monitoring dot diameters in which the length of time the syringe is pressurized can be adjusted (increased) as the diameter of the material dot changes. Monitoring the diameters of the dispensed dots allows the operator to set software limits for dot diameters. Any dot diameter that falls outside set limits results in either stopping the dispensing equipment or alerting the operator of necessary adjustments. Once depositions fall under a set diameter, either the time constant or the pressure must be increased. Increasing the time constant increases the length of time pressure is applied to the syringe.

Changing the time constant or air pressure can have adverse effects on throughput and dot quality. The graph below is an example of how throughput is affected by syringe level due to needed increases in the time constant to compensate for syringe level. Tact time, a measure of throughput, is the length of time it takes for one complete cycle which includes all X, Y, and Z movements, and shot times.

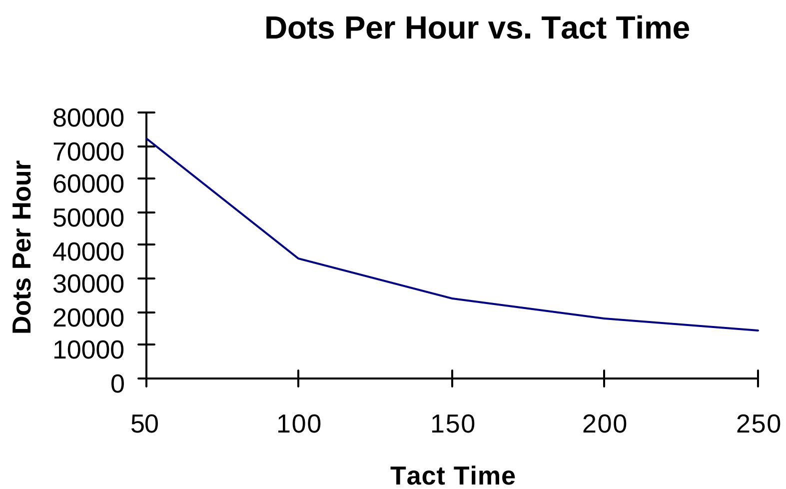


Speed limitations

The complete cycle time for a dot of material to be dispensed includes the X, Y, and Z travel times and the cycling time for the material to be forced through the needle. This is commonly known as shot time, and it is clocked in milliseconds (ms).

As the equipment industry reaches its maximum throughput capabilities in equipment motion control, it is forced to optimize cycle times by decreasing shot size. In time pressure systems, the only methods of reducing shot time are to either decrease the material viscosity or increase the air pressure. Suppliers of time pressure dispensing equipment are recommending the highest possible operating temperatures the material industry can support. Therefore, the only possible method of decreasing shot time is to increase the air pressure. Higher air pressures and shorter shot times result in faster cycle times, but they also have serious effects on dot volume variability. Current shot times used in time pressure systems range from 50 to 500 ms. Even a best case shot time of 50 ms leaves only 40 ms to complete X, Y, and Z movements in order to achieve the 40,000 dots per hour cycle time. Some flexibility in these times exists because the syringe can be pressurized as the Z travel begins. This is commonly called “predispense.”

The graph below shows the relationship of cycle time in dots per hour to tact time. Tact time is the length of time it takes for one complete cycle, which includes all X, Y, and Z movements, and shot times.



Summary

Changes in temperature affect the viscosity of surface mount epoxy materials. In time pressure systems a small increase in dispensing cabinet temperature during dispensing results in a significant increase in the dot volume of material dispensed. Small changes in the level of material in the syringe affect the response curve due to the additional air volume being compressed. Changes in the response curve must be compensated for by either increasing the air pressure or the time constant. Increasing the time constant (shot time) affects equipment cycle time, reducing the equipment’s throughput.

Although time pressure systems may be easy to implement into automation equipment, it is extremely difficult to control all the necessary parameters needed to maintain consistent dispensing. There is an increasing demand from dispensing users to move away from time pressure technology due to the variability of depositions over time. The only current dispensing methods capable of minimizing these variables are Archimedes metering pumps and positive displacement piston pumps.

Glossary

Coefficient of thermal expansion (CTE) – linear dimensional change of a material per unit change in temperature

Compression – pressed together; reduced in size by pressure

Exothermic – characterized by or formed with the evolution of heat

Green strength – the strength of a joint or assembly with an unset adhesive

ID – inside diameter

ms – time duration in milliseconds; 1000 ms is equal to 1 second

OD – outside diameter

Response curves – the time it takes to realize the full applied force or pressure when compressing air

Rheology – a science dealing with the deformation and flow of material; the ability to flow or be deformed

Shot size – the length of time dispensing equipment needs to force material through a needle

Slump – the distance adhesive material moves after application during curing

Spread – the distance adhesive moves after application at ambient temperature

Stringing – material connected to, but outside the main body of deposition; defective or nonconforming deposition

Surface insulation resistance (SIR) – The electrical resistance of adhesive determined under specified environmental conditions; see IPC–SM–817

Tailing – material connected to, but outside the main body of deposition; defective or nonconforming deposition with tail-like appearance

Thixotropic ratio – a ratio of viscosities taken at two different shear rates, indicating thixotropy properties

Thixotropy – a property of adhesive systems that allows thinning upon agitation and thickening upon subsequent rest

Trigger point – thermal temperature at which exothermic reactions start

Viscosity – the property of an adhesive to frictionally resist internal flow that is directly proportional to the applied force; a ratio of shear stress/shear rate

Wetting – the ability of a material to adhere to surfaces in uncured state