Positive Displacement Piston Pump

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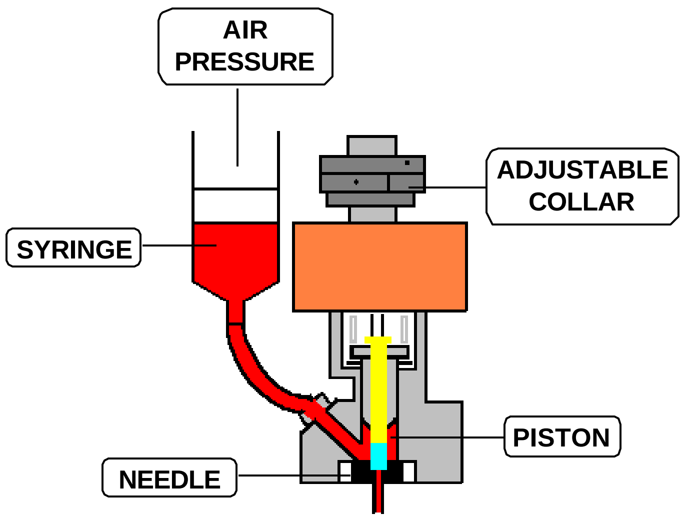
What is a positive displacement piston pump?

Positive displacement piston pumps use a piston to force material through a needle. With these pumps, constant air pressure is applied to a syringe of material. The syringe feeds material to the piston chamber while the piston is in the up stroke position. When the chamber is full, the piston is driven into the needle hub, forcing material out the needle. This piston technology is similar to that used in the automotive industry. An example of a piston pump assembly is shown below.



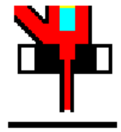
How do piston pumps work?

Constant air pressure is applied to a syringe of material, forcing the material down a material feed tube. The feed tube is mounted to the piston chamber. The chamber is filled with material when the piston is in its up stroke. When the piston is driven into the hub of the needle, the material is forced out the needle. The timing of the piston's up stroke is programmed into the software controlling the equipment and allows just enough time to let the chamber fill. When the piston is in the down stroke, the material feed path is closed so no additional material can escape from the needle.

Because material is forced out of the needle mechanically with piston pumps, the deposition time is extremely fast and is solely dependent on the piston's stroke cycle time. The volume of the material dispensed is determined by two easily controlled parameters—diameter and piston stroke. Thus, the viscosity of the material plays a minimal role in the volume of material dispensed with piston pumps.

The diagrams below show the sequence of steps involved in piston pump dispensing.

Step 1 – The piston is in the up stroke position and material is allowed to fill the piston chamber. As the piston moves up, it creates a vacuum which helps suck the material down the material feed tube and into the piston chamber.



Step 2 – The material has filled the piston chamber and the piston is ready to start its down stroke.

Step 3 – The piston begins to seat in the needle hub. The actual volume of material dispensed is determined by the piston displacement from this stage.

Step 4 – The piston has completely seated inside the needle hub and material has been dispensed onto the printed circuit board.

What is drool?

If the piston is not seated properly inside the needle hub at the end of its down stroke, then low viscosity materials can ooze past the piston, resulting in unwanted material dripping or drooling out of the needle. Drooling can occur if the piston is not seated far enough into the needle hub or if the fit of the piston in the needle hub is not tight enough. Drooling will also occur if the air pressure supply is too high on the syringe.

Why is constant air pressure important for piston pumps?

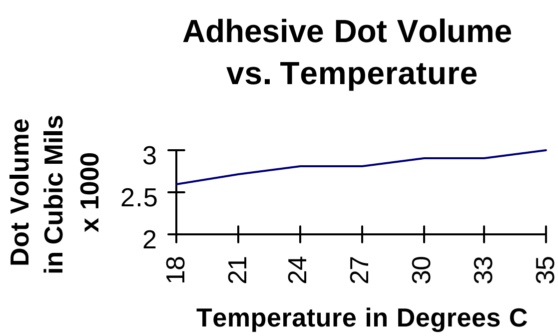
Constant air pressure maintains a constant force on the syringe plunger so the piston's up stroke timing doesn't have to compensate for the time it would take to compress the air volume between the air inlet and the plunger. There are other benefits to maintaining constant air pressure besides maintaining a ready supply of material. It also reduces the number of parts needed to supply and regulate the air pressure to the syringe.

Low air pressure – If the air pressure on the syringe is set too low there will not be enough force on the plunger to move material into the piston chamber. The length of time the piston is in the up stroke position is directly related to the time it takes to fill the piston chamber. This time is adjustable in software parameters. If the piston fires before the material has filled the piston chamber, the piston will displace an inconsistent volume of material, resulting in insufficient or missing dots.

High air pressure – If the air pressure on the syringe is set too high it will force material between the piston and the needle hub, causing material to drool from the needle. Excessive air pressure can also cause the chamber to fill too quickly . The piston up stroke timing would then need adjustment to prevent material from flowing out the needle prior to seating the piston.

How does material viscosity affect dispensing consistency?

Material viscosity has very little effect on the dispensing consistency of positive displacement piston pumps. The only effect material viscosity has in piston pumps is on the length of time needed for the piston's up stroke. This is because lower viscosity materials tend to flow quicker than higher viscosity materials, allowing the piston chamber to fill faster. The graph below shows how resilient the piston positive displacement pump is to viscosity changes. It shows volumes of material dispensed over a wide range of temperatures or viscosities, since viscosity is directly proportional to temperature.



How does syringe level affect piston pumps?

Changes in the level of material in the syringe affect the rate of material flow into the piston chamber. The syringe level effect on material flow rate is caused by the changing surface area friction of material wetting the syringe's side wall. This change in surface friction affects the amount of pressure required to move a consistent volume of material out of the syringe. As the syringe empties, it requires less pressure to obtain the same flow rate as when it was full, so the piston chamber fills faster. Syringe level differences in piston pump dispensing systems ultimately have very little effect on dispensing consistency since the air pressure is used only to fill the piston chamber and not to force material out of the needle. The actual change in deposition volumes is less than one percent over the entire syringe. This is because the piston is only in the up stroke position long enough for the material to fill the piston chamber and the volume dispensed is metered mechanically through piston stroke length and piston diameter.

How do the piston stroke and diameter affect volume?

As the piston enters the needle hub, the material inside the needle hub is displaced. Therefore, the distance the piston travels inside the needle hub along with its diameter determines the actual volume of material that is dispensed.

The piston stroke can be adjusted by moving the collar on the piston cylinder. The collar limits the down stroke of the piston into the needle hub which determines the distance the piston travels inside the needle hub. Improper adjustment of the piston stroke can cause drooling or cavitation. It is important to use the correct piston diameter and stroke so the optimal volume of material is dispensed with each piston stroke.

The piston stroke length can be set up using feeler gauges or by experimentation. Adjusting the piston collar up or down changes the volume of material dispensed. The selection of piston diameters is limited because the needle and the piston must be matched and the number of resulting combinations would be difficult to control. It is common to control the specific volume needed by using one of the standard piston diameters and setting the piston stroke accordingly. Specific material volume needs can be designed into the piston and needle combinations and be specially designed, ordered, and manufactured.

How often do piston pumps need to be cleaned?

Materials left in the piston pump tend to dry and cure, eventually blocking the material flow path. Dry materials can flake off and become lodged in the needle hub, blocking flow to the needle. Regular maintenance is needed to ensure proper performance and best results. Manufacturers of positive piston displacement pumps recommend daily needle cleaning and weekly pump cleaning.

Summary

Positive displacement implies that a volumetric amount of material will be displaced with a mechanical actuation that is not material or temperature sensitive. The piston positive displacement pump determines the volume displaced by the diameter and the stroke length of the piston. The actual volume dispensed can be calculated mathematically using piston diameter and piston stroke length.

There are some very distinct advantages in using mechanical actuation to meter and maintain the volume of material dispensed. Mechanical actuation dispensing is very consistent and is insensitive to changes in material viscosity and syringe level.

The two types of mechanical pumps on the market for high speed dispensing of surface mount epoxies are Archimedes metering pumps and piston positive displacement pumps. Both types of pumps have demonstrated increased dispensing throughput and increased dot quality. The piston positive displacement pump is less sensitive to changes in material viscosity and syringe material level than Archimedes metering pumps. The major disadvantage of piston positive displacement pumps is that material volumes are determined by the piston stroke which is manually set with an adjustable collar.

An alternative to piston and Archimedes pumps is time pressure dispensing. The time pressure method of dispensing requires less maintenance than the mechanical methods. However, this type of dispensing cannot maintain volumetric repeatability and generally slows down the equipment's throughput capability.

Glossary of terms

Archimedes metering pumps – Archimedes pumps use an auger screw to turn the material down a cylinder; the rotation of the screw creates a shearing force on the material which forces the material down the threads of the screw

Drool – material that oozes out of the needle unintentionally between dispensing cycles

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

Piston stroke – the piston stroke is the distance the piston enters the needle hub, displacing material; the piston stroke can be changed by moving the adjustable collar up or down

Positive displacement pumps (PDP) – implies a volume of material will be dispensed with a mechanical actuation which is not dependent upon material viscosity or temperature changes

Time pressure (air over) dispensing – time pressure dispensing uses pressurized pulses of air applied to a syringe to force material down a needle

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