White Paper: Liquid Filling Nozzles

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Filling nozzles, sometimes called filling needles or filling tubes, are the discharge point of the filler, where product enters the container. There are many designs but most are some variation on three basic types:

- Capillary
- Inward opening
- Outward opening

Some nozzles may combine features of the above such as an inward opening nozzle with a capillary extension.

In general nozzles should be as large a diameter as possible while still being small enough for the container opening. Larger diameter means lower product velocity for a given flow rate. This reduces foaming, splashing and agitation caused by high flow rates. On the other hand, the nozzle must be small enough that it allows air to escape from the container during filling. The annular opening between nozzle and container will impact the velocity of the escaping air. If filling above or just inside the container opening, this escaping air can sometimes have enough velocity to blow the product out as it tries to enter the container.

Nozzle diameter will also be affected by product viscosity and consistency. A more viscous product will require a larger diameter to achieve a satisfactory flow rate and avoid excessive pumping pressure.

Capillary nozzle

A capillary nozzle is essentially a plain section of tubing. It typically has no valving inside. The filling system will normally have shutoff valve upstream from it. Capillary nozzles get their name because they use a capillary action to prevent the product dripping from the end of the nozzle.

This principle can be illustrated by immersing a soda straw in water, holding a finger over the upper end and lifting it from the water. As long as the finger remains in place, no air can enter and the water will not drip. If air is permitted to leak in around the finger, dripping will occur. When the finger is removed, all the water will freely discharge.

This capillary action is a function of the surface tension of the liquid and the diameter of the nozzle. In general, though not always, the more viscous the product, the greater the surface tension. Some products have a very low surface tension and may not work at all with capillary nozzles.

In some instances the capillary action may normally be sufficient but vibration or a shock at the nozzle or tubing may break the tension. Once broken, product in the nozzle as well as the tubing leading up to the nozzle may run out. This causes either an overfill in the container under the nozzle, or a mess on the filling machine. Since the nozzle and tubing is now empty, it also causes the next bottle to be underfilled.

Nozzles should be protected as much as possible from shock and vibration.

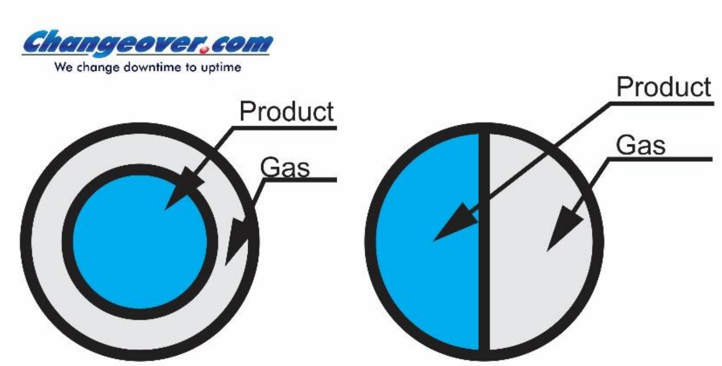
Special capillary nozzles

Ordinary capillary nozzles, discharging product vertically down, are suitable for most filling applications. There are some special nozzle designs for special needs.

If a particularly gentle fill is required, “side-shooting” nozzles may be used. Several designs are available but the main feature of all is that the end is closed and there are horizontal openings near the nozzle end. Since the total area of the several openings is greater than the single end opening, discharge velocity is reduced. Discharging the product against the container wall also helps reduce foaming, agitation and splashing.

Side shooting capillary nozzle

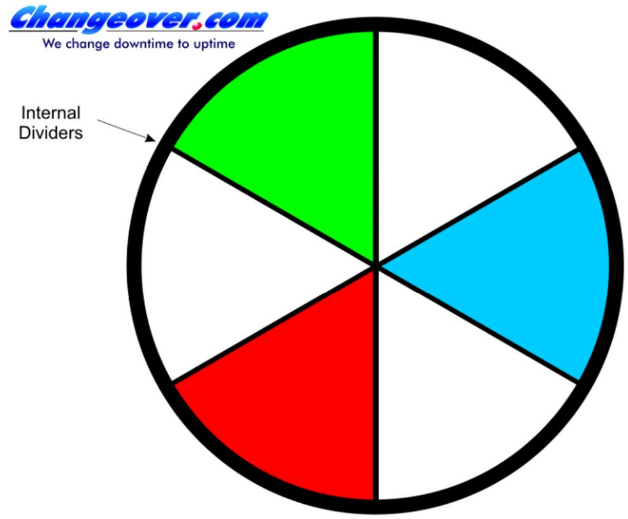
Multiple channel nozzles may also be used. These may be a concentric “tube-in-tube” or two, usually half-round, tubes mounted back to back. The most common use for this type of nozzle is injection of nitrogen, oxygen, argon or other gas.



Double Channel Capillary Nozzles

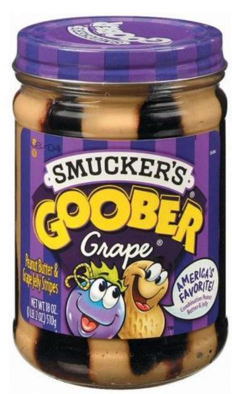
Overflow type fillers will use a channel for product and a second channel to vent the air from the bottle as it fills.

Another use for multi-channel nozzles is filling multi-part products. Several popular brands of toothpaste dispense from their tubes with a color ribbon. This sketch shows 3 channels of white base and 3 channels of flavor or color accent.



Multi-color Filling Nozzle
(Looking into discharge)

Another example is peanut butter and jelly combined in a jar.

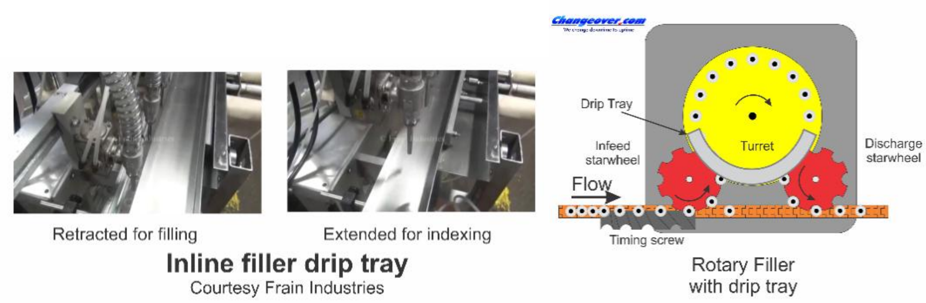


Dripping is a common issue with capillary nozzles. There are several possible causes:

If the end of the nozzle is lower than the reservoir level, as it should be, gravity will force product out of the nozzle. A valve located in the fluid path will prevent this flow but only if the valve does not leak. Particulates in a suspension, mechanical mis-adjustment or wear may cause the valve to seal improperly. When this happens, product leaks through and out the nozzle. If the reservoir is below the nozzle, this same leaky valve will allow air to infiltrate the fluid path as product leaks back towards the reservoir. Air leaking back into the nozzle will cause an underfill on the next cycle. It can also contaminate the interior of the nozzle and the product.

Another cause of dripping is leaking fittings between the nozzle and the valve. These can allow air to leak into the fluid path, breaking the vacuum and allowing dripping. Even very small leaks will cause this.

Dripping also occurs when the nozzle is submerged in the product. In this case the product is dripping from the outside of the nozzle rather than the inside. There is not much that can be done to prevent this. It can only be captured via a drip tray or via a suckback channel in the nozzle.



Stringing is another nozzle issue that is sometimes confused with dripping. Stringing has different causes and solutions. Stringing occurs at the end of the fill, when the valve is shut and product flow has ceased. Instead of breaking cleanly, a “string” of product remains.

Stringing is more of a product than a nozzle issue, though care in nozzle selection can help control it. Honey is one example of a stringy product. When a spoonful of honey is poured into a cup of tea, a string of honey will remain for some time between the spoon and the tea. This picture shows a string remaining between bottle and nozzle.

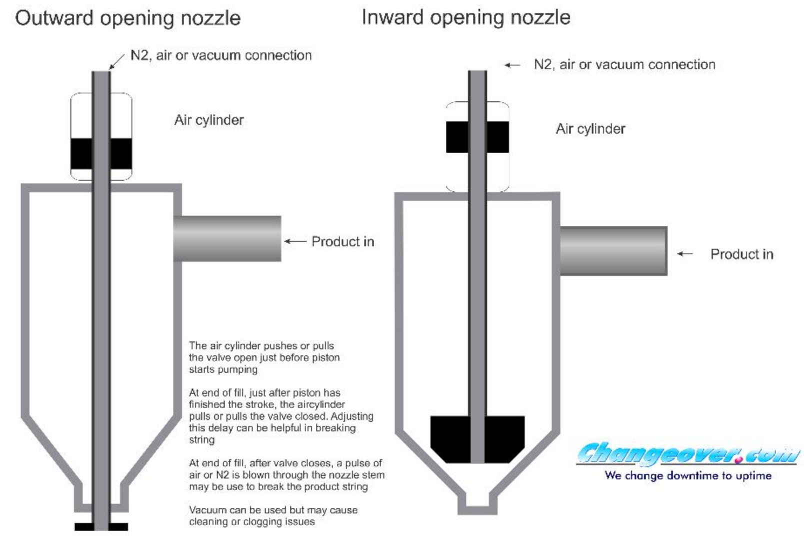
If the bottle is indexed before the string collapses, as in the picture, it will be pulled over the neck and onto the outside of the bottle and the conveyor.

Stringing can be difficult to control. It generally can’t be caught with a pan, like dripping. The edge of the pan will catch the string and some will run down the bottom of the pan and onto the filler. One way to control dripping is to provide a small physical shock at the end of filling to break it loose.

This may be done by adding a time delay after dispensing then closing the filler discharge valve forcefully. A pinch valve may be used on the tubing to the nozzle to provide a sudden sharp pulse. A small injection of compressed gas into the nozzle will work in some cases. Reversing the product flow momentarily through pump valve timing or pump rotation may also help. It may also be possible to fill the product at a slightly higher temperature to reduce the stringing effect.

Positive shutoff nozzles

Positive Shutoff Nozzles (PSNs) have valves inside the nozzle near the tip. These can be classified as inward and outward opening.



Both are similar in construction. The main difference is that the valve stem opens downward and outward on one and upward and inward on the other. As long as a positive seal is made between valve and seat, these valves cannot leak.

The filling cycle begins with an air cylinder opening the nozzle tip. Only then, can the pump start. When filling is complete and after the pump stops, the valve closes. Opening and closing is normally nearly simultaneous with pumping though delays to either or both can be used as needed for proper product handling. A slight delay (100-200ms) in closing may be useful to break a string.

It is strongly recommended to use a sensor to positively determine the position of the valve and inhibit filling if the valve is not open. If the valve is closed when the pump begins or closes before the end of filling, excessive pressure can rupture the product tubing.

Some of these valves have a hollow operating rod. This allows connection of vacuum, nitrogen or other gas to aid in controlling dripping and stringing.

At the end of the filling cycle, vacuum may be enabled to suck product out/off of the end of the nozzle. The outward opening nozzle often has a pointed tip so that any product remaining on the outside of the nozzle flows naturally toward the center vacuum hole.

Alternately, a puff of nitrogen or air may be used to blast any residual product string loose at the end of the cycle.

Conclusion

Nozzle are a key component in any filling system. Care must be taken to select the proper nozzle for optimum performance with the filler, product and container. There is no “one size fits all” and failure to pay attention to nozzles can result in operational headaches. The right nozzle will be even better than aspirin.