container. The volume of the filled product is controlled by adjusting the stroke of the piston. The steps of a piston filling machine are as follows:

- Suck back
- Rotary valve change position
- Nozzle open
- Piston forward to discharge solution
- Nozzle close
- Rotary valve change position.

Syringe filling machines typically are valve-less rotary piston fillers, although peristaltic and time pressure syringe fillers do exist. Instead of the existence of a solid piston, a portion of the piston body is removed. On the infeed stroke, the side of the piston with the cavity is rotated to the inlet. The down stroke creates a vacuum and product enters the pump body. The piston rotates 180°, and the liquid-filled cavity faces the outlet. The pump upstroke occurs and the product is forced out of the pump. The rotation continues another 180° and the cycle repeated.

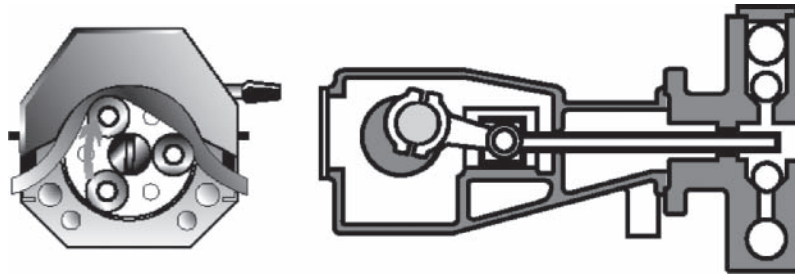
Peristaltic Filling

Peristalsis describes movement of ingested food in the gastrointestinal tract. The same principle is used for filling machines. Peristaltic filling involves positive displacement where the solution contained within a flexible tube that is fitted inside a circular (rotary) or elongated (linear) (Fig. 19-1) pump casing. A rotor with a number of "rollers," "shoes," or "wipers" attached to the external circumference compresses the flexible tube. As the rotor turns or moves, the part of tube under compression closes (or "occludes") thus forcing the fluid to be pumped to move through the tube. Additionally, as the tube opens to its natural state after the passing of the cam ("restitution") fluid flow is induced to the pump.

Since there are no moving parts in contact with the fluid, peristaltic pumps are inexpensive to manufacture. Their lack of valves, seals, and glands makes them comparatively inexpensive to maintain, and the use of a hose or tube makes for a relatively low-cost maintenance item compared with other pump types. Peristaltic pumps also minimize shear forces experienced by the product solution, good for shear-sensitive protein products. However, they are not as good for high viscosity liquids and cannot match rotary piston machines for small-volume filling precision.

Typical tubing systems used for filling machines, regardless of mechanism, are silicone rubber, polyvinyl chloride, and fluoropolymer.

Advantages and disadvantages of each filling mechanism are summarized in Table 19-1 (1).



Peristaltic Pump Schematic
Rollers of pump head push the fluid along the tubing as they rotate

Piston Pump Schematic
Piston pumps fluid via adjustable strokes through check valves

Figure 19-1 Peristaltic and piston pumps. *Source*: Courtesy of Cole-Parmer (coleparmer.com).