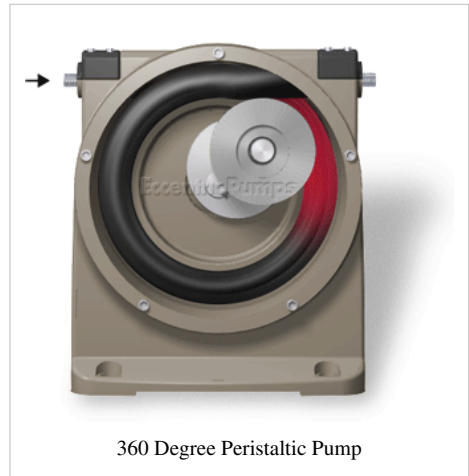


# Peristaltic pump

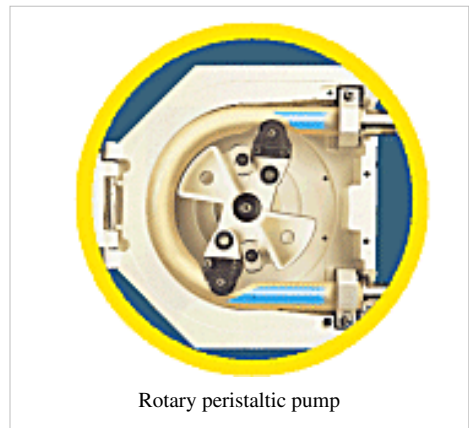
A **peristaltic pump**, or roller pump, is a type of positive displacement pump used for pumping a variety of fluids. The fluid is contained within a flexible tube fitted inside a circular pump casing (though linear peristaltic pumps have been made). A rotor with a number of "rollers", "shoes" or "wipers" attached to the external circumference compresses the flexible tube. As the rotor turns, 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" or "resilience") fluid flow is induced to the pump. This process is called peristalsis and used in many biological systems such as the gastrointestinal tract.



360 Degree Peristaltic Pump

## Applications

Peristaltic pumps are typically used to pump clean/sterile or aggressive fluids, because cross contamination cannot occur. Some common applications include pumping IV fluids through an infusion device, aggressive chemicals, high solids slurries and other materials where isolation of the product from the environment, and the environment from the product, are critical. The peristaltic pump is the standard method for introducing liquids into the nebulizer on an inductively coupled plasma mass spectrometry (ICP-MS) or Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-OES) unit.



Rotary peristaltic pump

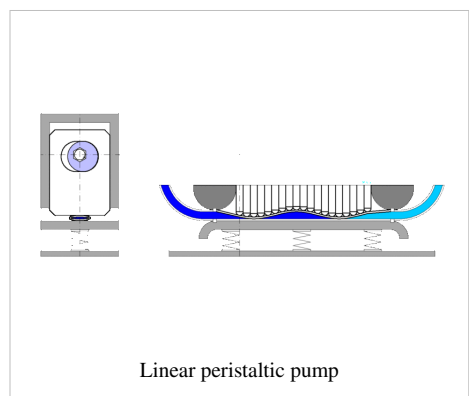
## Key Design Parameters

### Chemical Compatibility

The pumped fluid contacts only the inside surface of the tubing. There are no other valves, O-rings, seals or packings to worry about in a peristaltic pump. Therefore, the only compatibility to worry about in a peristaltic pump is the tubes for the fluid being pumped. Of all the design parameters, the compatibility is the first one that need to be considered.

The tubing need to be elastomeric to maintain the circular cross section after millions of cycles of squeezing in the pump. This requirement eliminates a variety of non-elastomeric polymers that have compatibility with a wide range of chemicals, such as PTFE, polyolefins, PVDF etc. from consideration as material for pump tubing. The popular elastomers for pump tubing are silicone, PVC, EPDM+polypropylene (as in Santoprene), polyurethane and Neoprene. Of these materials, the EPDM+polypropylene (-prenes) have the best fatigue resistance and a wide range of chemical compatibility. Silicone is popular with water-based fluids, such as in Bio-pharma industry, but have limited range of chemical compatibility in other industries.

Extruded fluoropolymer tubes such as FKM (Viton, Fluorel, etc.) have good compatibility with acids, hydrocarbons, and petroleum fuels. But the material has insufficient fatigue resistance to get achieve an effective tube life.



Linear peristaltic pump

There are a couple of newer pump tubing developments that offer a broad chemical compatibility - a lined tubing approach and the use of fluoroelastomer approach.

Tubes like Chem-Durance<sup>[1]</sup>, Pharmed<sup>[2]</sup>, Pharma-Pure<sup>[3]</sup>, Solve-Flex<sup>[4]</sup> and Smart-Shield<sup>[5]</sup> take the lined tubing approach, whereas CHEM-SURE<sup>[6]</sup> and GORE High-Resilience Tubing Style 400<sup>[7]</sup> take the fluoroelastomer approach.

With the lined tubing, the thin inside liner is made of a chemically resistant material such as poly-olefin and PTFE that form a barrier for the rest of the tubing wall from coming in contact with the pumped fluid. These liners are materials that are not elastomeric, therefore the entire tube wall cannot be made with this material for peristaltic pump applications. These tubing provide adequate chemical compatibility and life to use them in chemically challenging applications. There are a few things to keep in mind when using these tubes - any pin holes in the liner during manufacturing could render the tubing vulnerable to chemical attack. In the case of stiff plastic liners like the polyolefins, with repeated flexing in the peristaltic pump they can develop cracks, rendering the bulk material again vulnerable to chemical attack. A common issue with all lined tubing is delamination of the liner with repeated flexing that signal the end of that tube life. For those with need for chemically compatible tubing, these lined tubing offer a good solution.

With the fluoroelastomer tubing, the elastomer itself has the chemical resistance. In the case of Chem-Sure, it is made of a perfluoroelastomer, that has the broadest chemical compatibility of all elastomers. The two fluoroelastomer tubes listed above combine the chemical compatibility with a very long tube life stemming from their reinforcement technology, but come at a pretty high initial cost. One has to justify the cost with the total value derived over the long tube life, and compare with other options such as other tubing or even other pump technologies.

There are many online sites for checking the chemical compatibility of the tubing material with the pumped fluid. Two of them are:

<http://www.coleparmer.com/techinfo/ChemComp.asp> [http://www.dupontelastomers.com/Tech\\_Info/chemical.asp](http://www.dupontelastomers.com/Tech_Info/chemical.asp)

The manufacturers of these tubing may also have compatibility charts specific to their tubing.

While these charts cover a list of commonly encountered fluids, they may not have all the fluids. If there is a fluid whose compatibility is not listed anywhere, then a common test of compatibility is the immersion testing. A 1 to 2 inch sample of the tubing is immersed in the fluid to be pumped for anywhere from 24 to 48 hours, and the amount of weight change from before and after the immersion is measured. If the weight change is greater than 10% of the initial weight, then that tube is not compatible with the fluid, and should not be used in that application. This test is still a one way test, in the sense that there is still a remote chance that the tubing that passes this test can still be incompatible for the application since the combination of borderline compatibility and mechanical flexing can push the tube over the edge, resulting in premature tube failure.

In general, recent tubing developments have brought broad chemical compatibility to the peristaltic pump option that many chemical dosing applications can benefit over other current pump technologies.

## Occlusion

The minimum gap between the roller and the housing determines the maximum squeeze applied on the tubing. The amount of squeeze applied to the tubing affects pumping performance and the tube life - more squeezing decreases the tubing life dramatically, while less squeezing decreases the pumping efficiency, especially in high pressure pumping. Therefore, this amount of squeeze becomes an important design parameter.

The term "occlusion" is used to measure the amount of squeeze. It is either expressed as a percentage of twice the wall thickness, or as an absolute amount of the wall that is squeezed.

Let

```
y = occlusion
g = minimum gap between the roller and the housing
t = wall thickness of the tubing
```

Then

```
y = 2 x t - g (when expressed as the absolute amount
of squeeze)
y = (2 x t - g) / (2 x t) x 100 (when expressed as a percentage of
twice the wall thickness)
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The occlusion is typically 10 to 20%, with a higher occlusion for a softer tube material and a lower occlusion for a harder tube material.

Thus for a given pump, the most critical tubing dimension becomes the wall thickness. An interesting point here is that the inside diameter of the tubing is not an important design parameter for the suitability of the tubing for the pump. Therefore, it is common for more than one ID be used with a pump, as long as the wall thickness remains the same.

## Inside Diameter

For a given rpm of the pump, a tube with larger inside diameter (ID) will give higher flow rate than one with a smaller inside diameter. Intuitively the flow rate is a function of the cross section area of the tube bore.

## Flow Rate

Flow rate is an important customer requirement. The flow rate in a peristaltic pump is determined by many factors, such as: 1. Tube ID - higher flow rate with larger ID 2. Length of tube in the pump measured from initial pinch point near the inlet to the final release point near the outlet - higher flow rate with longer length 3. Roller RPM - higher flow rate with higher RPM

Interestingly enough, increasing the number of rollers doesn't increase the flow rate, instead it may decrease the flow rate somewhat by reducing the volume of fluid between the initial pinch point and the final release point. Increasing rollers do tend to decrease the amplitude of the fluid pulsing at the outlet by increasing the frequency.

## Variations

### Hose pumps

Higher pressure peristaltic hose pumps which can typically operate against up to 16 bar, typically use shoes and have casings filled with lubricant to prevent abrasion of the exterior of the pump tube and to aid in the dissipation of heat, and use reinforced tubes, often called "hoses". This class of pump is often called a "hose pump".

The hoses in a hose pump are typically reinforced, resulting in a very thick wall. For a given ID the hoses have much bigger OD than a tubing for the roller pump. This thicker wall, combined with a stiffer material typically used in the hoses make the forces necessary to occlude the hose much greater than for the tubing. This results in a bigger pump and motor for a given flow rate with the hose pump than the roller pump, consuming more energy to run.

The biggest advantage with the hose pumps over the roller pumps is the high operating pressure of up to 16 bar. If the high operating pressure is not required, a tubing pump is a better option than a hose pump. With recent advances made in the tubing technology for pressure, life and chemical compatibility, as well as the higher flow rate ranges, the advantages that hose pumps had over roller pumps continues to erode.

### Tube pumps

Lower pressure peristaltic pumps, typically have dry casings and use rollers, use non-reinforced, extruded tubing. This class of pump is sometimes called a "tube pump" or "tubing pump". These pumps employ rollers to squeeze the tube. Except for the 360 degree eccentric pump design as described below, these pumps have a minimum of 2 rollers 180 degrees apart, and may have as many as 8, or even 12 rollers. Increasing the number of rollers increase the frequency of the pumped fluid at the outlet, thereby decreasing the amplitude of pulsing. The downside to increasing number of rollers is that it proportionately increases number of squeezes, or occlusions, on the tubing for a given cumulative flow through that tube, thereby reducing the tubing life.

There are two kinds of roller design in peristaltic pumps:

1. Fixed occlusion - the rollers have a fixed locus as it turns, keeping the occlusion constant as it squeezes the tube. This is a simple, yet effective design. The only downside to this design is that the occlusion as a percent on the tube varies with the variation of the tube wall thickness. Typically the wall thickness of the extruded tubes vary enough that the % occlusion can vary with the wall thickness (see above). Therefore, a tubing at the high end of the wall thickness, but within the accepted tolerance, will have higher % occlusion, increasing the wear on it, thereby decreasing the tube life. The tube wall thickness tolerances today are kept pretty tight that this is not much of a practical issue. For those mechanically inclined, this may be the constant strain operation.
2. Spring loaded rollers - As the name indicates, the rollers are mounted on a spring. This design is a bit more elaborate than the fixed occlusion, but helps overcome the variations in the tube wall thickness over a broader range. Irrespective of the variations, the roller imparts the same amount of stress on the tubing that is proportional to the spring constant, making this a constant stress operation. The spring is selected to overcome not only the hoop strength of the tubing, but also the pressure of the pumped fluid.

The operating pressure of these pumps is determined by the tubing, and the motor's ability to overcome the hoop strength of the tubing and the pressure.

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### 360 Degree eccentric design

A unique approach to peristaltic hose pump design employs a single oversized roller on an eccentric shaft that compresses an engineered, low friction hose through 360 degrees of rotation. The benefits of this design include more flow per revolution and only one compression and expansion per cycle. At equal performance points this pump runs more slowly, with consequent longer hose lifetime, than pumps with multiple shoes or rollers.

Many older hose pumps use shoes to compress the hose. When the shoe slides over the outside of the hose, it creates friction and heat, which shortens hose life. A single roller pump uses a large diameter lubricated roller on an eccentric shaft that rolls over the hose. This means that it produces less friction, and therefore less heat, than a pump with shoes.

In addition to less heat, an eccentric shaft hose pump functions with only a single compression of the hose per revolution. For every one rotation, the pump has one compression of the hose, while pumps with multiple shoes or rollers have at least two compressions per revolution, and in some cases three or four. Since the hose is the heart of a peristaltic hose pump, and hose life is inversely proportional to the number of squeezes, this design will outperform a pump with shoes at the same speed.

The hose in this type of pump takes up the full 360 degrees of the pump housing. This is important, because at an equal size, this design will produce 55% more flow at the same speed. This means that one can get more flow at the same pump speed, or run the pump more slowly to generate the same flow.

### Advantages

Because the only part of the pump in contact with the fluid being pumped is the interior of the tube, it is easy to sterilize and clean the inside surfaces of the pump. Furthermore, 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 to other pump types. Peristaltic pumps also minimize shear forces experienced by the fluid, which may help to keep colloids and slurry fluids from separating.<sup>[8]</sup>

### Tubing

It is important to select tubing with appropriate chemical resistance towards the liquid being pumped. Types of tubing commonly used in peristaltic pumps include:

- Polyvinyl chloride (PVC)
- Silicone rubber
- Fluoropolymer

Trade names include Tygon, Viton, Pharmed<sup>[9]</sup>, Norprene<sup>[10]</sup>, Marprene<sup>[11]</sup>, Bioprene<sup>[12]</sup>, STA-PURE<sup>[13]</sup>, CHEM-SURE<sup>[6]</sup>, GORE High-Resilience Tubing<sup>[14]</sup>, Neoprene, Fluorel<sup>[15]</sup>, Pumpsil-D<sup>[16]</sup> and Pumpsil<sup>[17]</sup>.

Example of tube being changed on a peristaltic pump.<sup>[18]</sup>

## Typical applications

- Dialysis machines
- Open-heart bypass pump machines
- Infusion pump
- AutoAnalyzer
- Sewage sludge
- Aquariums, particularly calcium reactors
- Analytical chemistry experiments
- Carbon monoxide monitors (e.g., at Longannet power station)
- Agriculture
- Food manufacturing
- Beverage dispensing
- Chemical
- Engineering
- Construction - pumping cement
- Pharmaceutical production
- OEM applications
- Print and packaging
- Paint and pigments
- Pulp and paper
- Science and research
- Water and Waste
- 'Sapsucker' pumps to apply vacuum to maple trees to enhance sap extraction and pump the sap to the evaporator
- Liquid food fountains

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