Protecting Progressing Cavity Slurry Pumps

A progressing cavity pump consists of a single helix metal rotor that turns inside a double helix rubber stator. This forms a series of pockets that traverse the length of the pump, gently pushing fluid from the suction to the discharge in a smooth, pulseless stream.

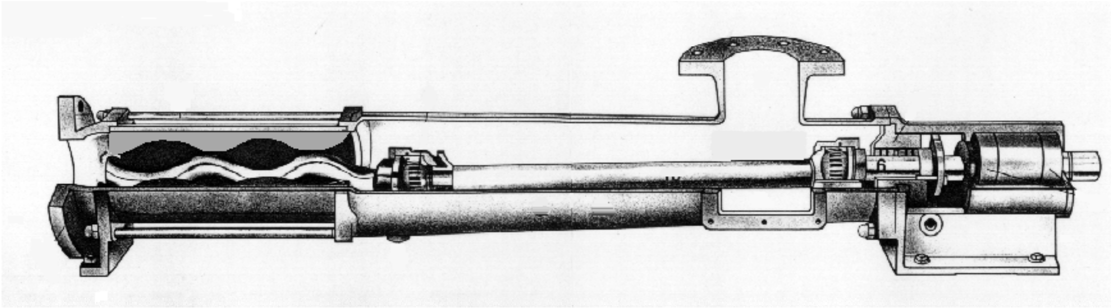


figure 1

Progressing cavity pump

Normal direction of flow through the pump is towards the left.

Picture courtesy Netzsch Inc, NEMO Pump Div

Progressing cavity pumps are unmatched in their ability to transport viscous, abrasive, and shear sensitive fluids. They can pump exotic solutions such as shrimp and brine without crushing or tearing the product. They routinely handle sewerage sludge, ceramic slurry, wax, chemicals, confectionery ingredients, grinding compound, sand, cement, grout, putty, pulp, ground meat, pigments, glue, paste, grease, paint, lime slurry, jelly, and soap.

Their precise internal geometry and minimal back flow make them accurate metering pumps, eliminating the need for a flow meter. You can deduce volumetric flow rate by adding a tachometer pickup to any rotating part of the pump and motor assembly.

To operate reliably, however, these pumps must stay within certain operating limits. Since they are a true positive displacement pump, discharge pressure theoretically spikes to infinity if the discharge is blocked. In reality, the motor stalls under these conditions, but usually not until after the flange bolts stretch or discharge piping bursts.

To minimize back flow, there is an interference fit between the metal rotor and the rubber stator, so these parts rub against each other during normal operation. The pump depends on the fluid stream to carry away the heat generated by friction. If the pump runs dry, the stator overheats until the rubber melts or scorches. At this point the ruined stator must be replaced.

These pumps handle difficult fluids that make it particularly challenging to monitor the process to prevent this.

Protecting against damage from over pressure requires the addition of a pressure switch. Pressure gauges and switches are prone to clogging or plugging when pumping the kinds of fluids usually handled by this type of pump. Protecting gauges and pressure switches with conventional diaphragm seals buys some time, but these devices become plugged themselves within a few days of operation.

The most successful approach to date has been to use an annular ring seal, usually referred to as an isolator ring.

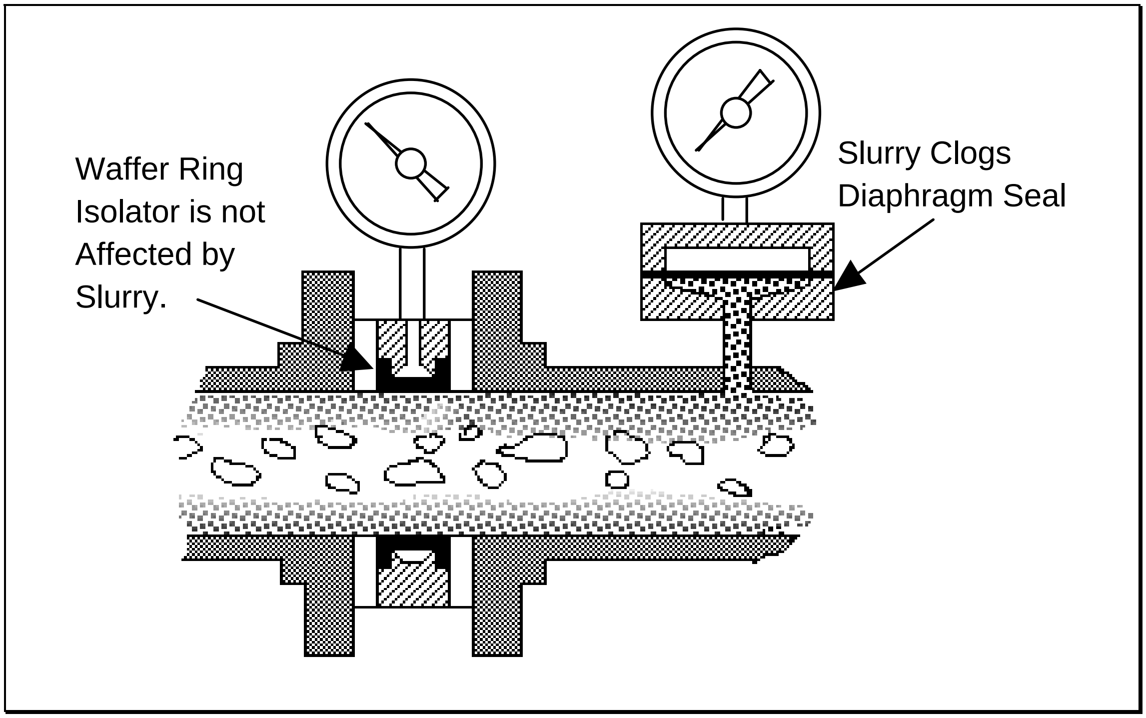


Figure 2

An Isolator Ring sandwiched between flanges transmits pressure to gauge or pressure switch without clogging

An isolator ring consists of a rubber 'inner tube' clamped in a steel ring. The assembly fits between flanges in the process pipe. Clear instrument oil behind the rubber membrane transmits pressure to the gauge or pressure switch. The motion of the process fluid continuously cleans the inside of the ring assembly.

Protecting the pump against damage from run dry conditions is trickier; several methods have are used, each with advantages and disadvantages.

FLOW METER: An obvious method is to install a flow meter coupled to a signal relay. If flow falls below a certain threshold, electrical contacts open, stopping the pump. This is straight foreword and reliable, albeit expensive. The only flow meters that can handle the fluids typically conveyed by progressing cavity pumps are magnetic or sonic meters, which cluster near the high end of the cost scale.

THERMAL MASS DISPERSION: This device monitors flow by measuring the rate of heat dissipation from a probe in the flow stream. Inside the probe are two thermocouples and a heating element. One thermocouple is next to the heating element, the other is some distance away.

An electronic circuit monitors the difference in the temperature of the two thermocouples. With no fluid motion around the probe, the thermocouple closest to the heating element registers a higher temperature than the reference thermocouple. When fluid flows past the probe assembly, it dissipates heat from the 'hot' thermocouple, so temperature at this thermocouple drops. By measuring the difference in temperature at these two points, the electronic circuit determines if there is sufficient flow present.

The thermal mass dispersion device is more cost effective than conventional flow meters, but is subject to certain limitations.

Fluids that build up a coating can insulate the probe, degrading sensitivity. Highly abrasive fluids can erode the probe to the point where it no longer functions.

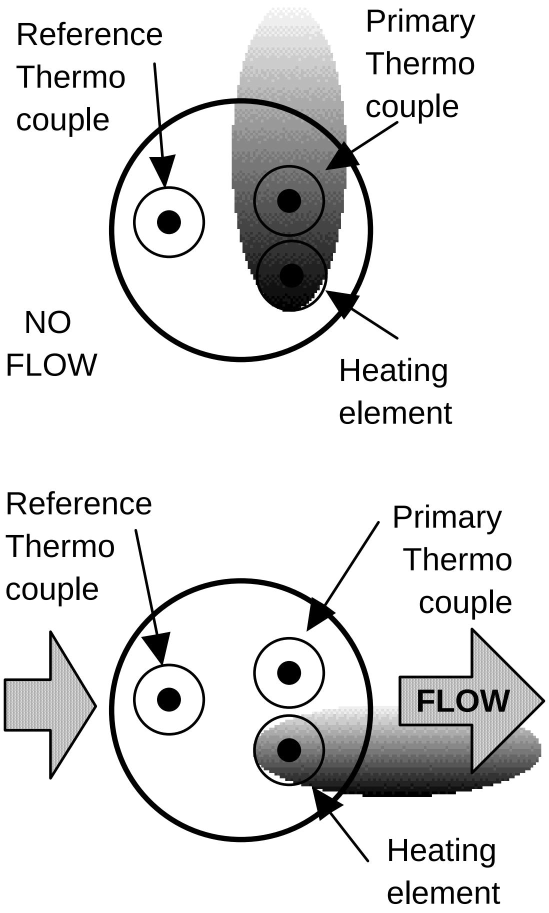


figure 4
The Thermal Mass Dispersion Device

These devices can be difficult to calibrate because when a progressing cavity pump runs out of liquid, it becomes an air compressor! Since thermal dispersion devices measure air flow as well as liquid flow, configuration and calibration can be difficult. For example, you can't test this device by simply turning the pump off; you have to force the pump to run dry to produce an air stream in the pipe to check if it is properly detecting fluid loss. This places the stator at risk.

CAPACITIVE DETECTORS: Depending on pipe size, cost is usually higher than a thermal mass dispersion device. These are installed on the suction side of the pump. They do not monitor flow; they monitor the presence or absence of fluid in the pipe.

The device consists of an insulated ring sandwiched between flanges on the pump inlet. The principle element in this device is a metal plate lining the inner circumference of the ring. A layer of electrical insulation separates this plate from the process fluid. The metal plate functions as one side of a capacitor circuit; the fluid in the pipe functions as the other plate.

With fluid in the suction pipe, capacitance of the circuit is high. If the pipe is empty, capacitance of the circuit is low. An oscillator applies a reversing polarity signal to the plate. The circuitry measures the dampening effect of the capacitive plate and infers the presence or absence of fluid within the boundaries of the ring.

A coating or build-up on the inner surface of the device affects the reading, but a simple re-calibration compensates fro a buildup to 0.250" or more without adverse effects. They are immune to false reading caused by air flow during run dry conditions because they do not detect flow, they detect the presence or absence of material within the boundary of the device.

THERMAL MONITOR: Another run-dry protection device is a thermocouple monitor buried in the stator. A small hole is drilled through the stator tube and a thermocouple is inserted. As the rotor turns inside the pump, it rubs across the thermocouple for a portion of each revolution, allowing the thermocouple to sense the temperature of the rotor. A signal relay amplifies and monitors the output from the thermocouple. If the pump runs dry, friction heats the rotor and stator. The thermocouple detects this temperature rise and triggers a signal to stop the pump.

The advantage to this approach is low cost. However, fluid temperature fluctuations can trigger false alarms. Conversely, cold ambient temperatures can delay response.

The hole involved prohibits the use of this device in sanitary, food, or high purity applications.

Different fluids will affect response time. Non-lubricating fluid such as lime slurry will elicit a fairly fast response, but fluids which exhibit higher lubricity such as polymer flocculent may take several hours to evaporate. The resulting gradual temperature rise may take several hours to reach the set point on the alarm relay. By that time the stator may have suffered substantial damage.

POWER MONITORS infer the presence or absence of flow by noting changes in electric power by the pump motor. However, the power dip caused by run dry conditions is short lived and difficult to capture. The reason is that running dry causes rapid heat build up. The fluid film lubricating the interface between the stator and rotor quickly evaporates, so friction increases within seconds after loss of fluid. Soon, he heat build up in the stator can causes the rubber to revert, making it gummy, and further increasing friction.

PRESSURE MONITORS

Pressure monitors use pressure to infer flow conditions. This method is simple and straight forward with the advantage that you can monitor high pressure with the same device.

Positive displacement pumps should always be fitted with over pressure protection. If operated against a closed discharge (dead-headed) a positive displacement pump builds up pressure until a system component fails. The motor fuses may blow, but it is equally probable that a pipe fitting will burst.

Pressure switches are more reliable on slurries than pressure relief valves and easier to reset than rupture disks.

Several manufacturers offer control boxes to interface with the pressure switch and isolator ring assembly.

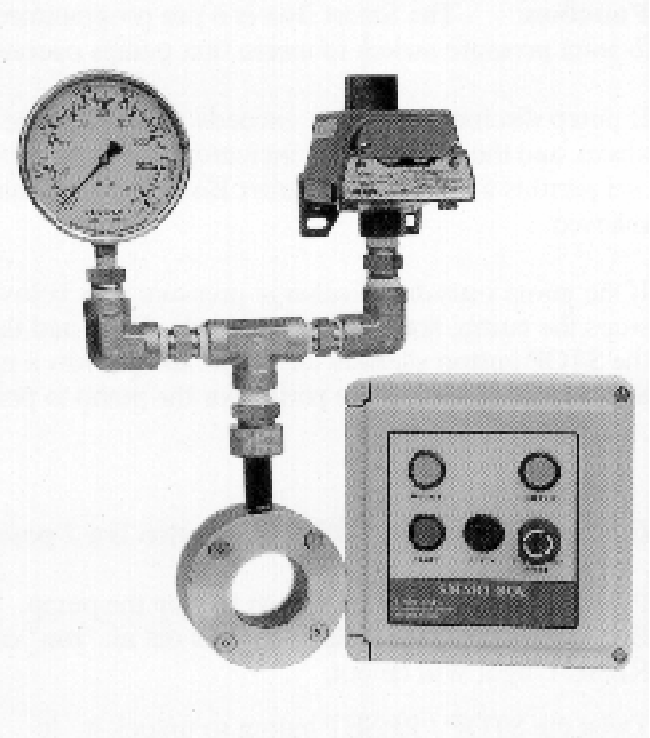


figure 5
Typical isolator ring with control box.
Photo courtesy Onyx Valve Co

These boxes incorporate local push button control stations and include a timer to allow the pump time to prime itself each operating cycle. Some of these boxes incorporate seal flush controls as well. To use this approach, it is necessary to understand the difference between static pressure, friction pressure, and total pressure.

Static pressure results from the pipe being filled with liquid and is present even when the pump is idle. It is *not* influenced by pipe size, number of fittings, or viscosity. Static pressure is determined solely by fluid density and difference in height between the pressure switch and the outlet of the pipe.

In the example in figure 6, the outlet of the discharge pipe is 12 feet above the gauge, so static head is 12 feet, which exerts 5 psi of pressure.

Friction pressure results from the flow of liquid through a pipe and is present only when the pump is running. It depends on flow rate, size and length of pipe, number of fittings, and fluid viscosity.

Total pressure is the combination of static and friction pressure. This pressure is observed directly by reading the gauge on the pump discharge.

When the pump is idle, the gauge shows static pressure. When the pump is operating with flow present the gauge shows total pressure.

In the example in figure 7, total pressure is 25 psi.

For run dry protection, set the low pressure switch midway between the static and total pressure. In our example the correct setting for the low pressure switch is 15 psi.

When the pump is running correctly the low pressure switch signals that flow is present. If the pump runs dry and flow stops, the pressure falls back to the static pressure. This causes the low pressure switch to trip.

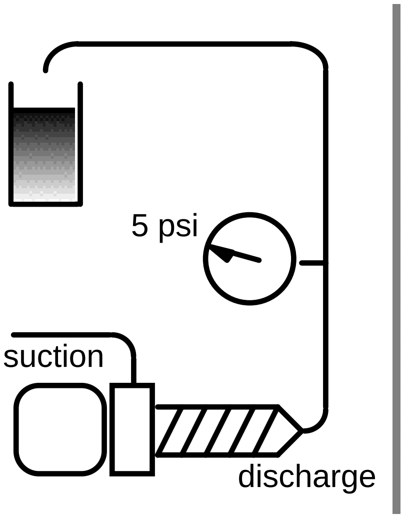


fig 6.
Pump Off.

Static head is the pressure resulting from the weight of the liquid in the pipe.

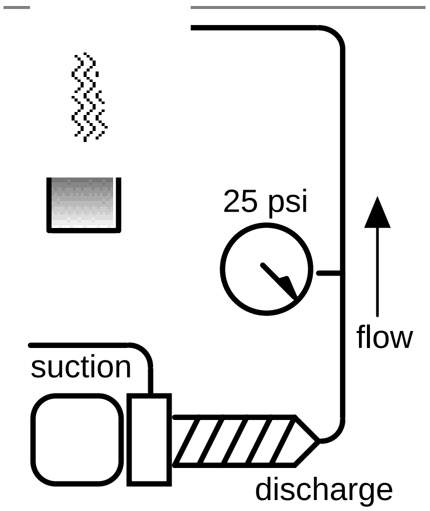
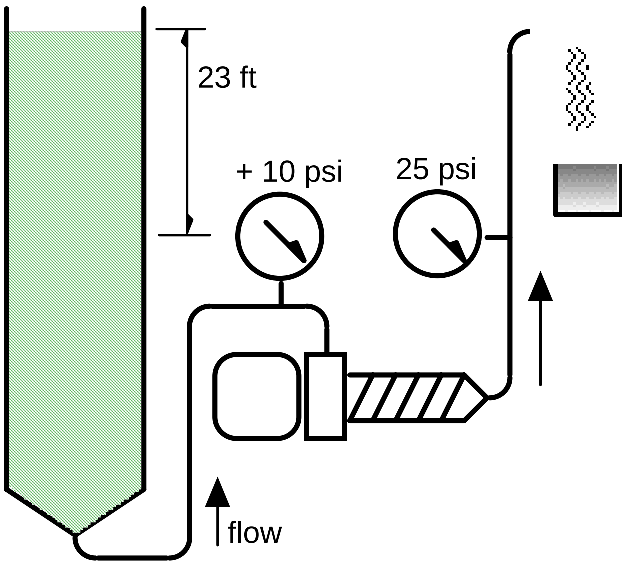


fig 7

Pump On.

Total press = static press + friction head.

Flow Detection with Pressure Switches.
Suction or Discharge?



Is it better to monitor pressure at the inlet or the outlet of the pump?

Let's use an example to study pressure changes at both points in the system.

Figure 8 shows a typical flooded suction and pump arrangement.

At the beginning of the cycle, the feed tank is full so the **suction** gauge reads positive 10 psi. As the pump lowers level in the feed tank, the reading on the suction gauge gradually drops.

figure 8

Progressing Cavity pump with pressure monitor on Suction side

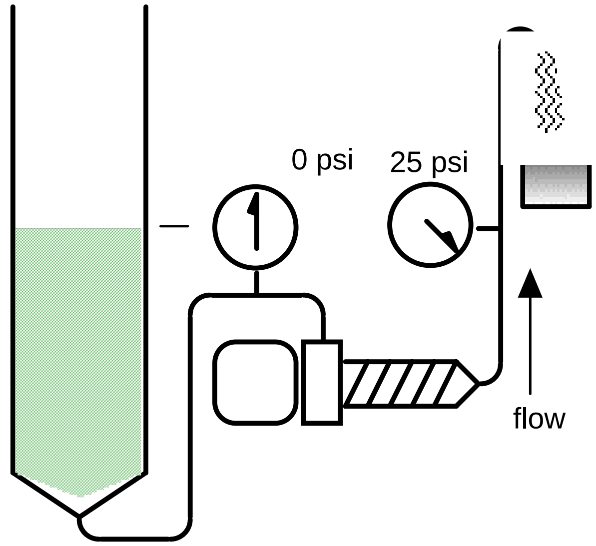


figure 9

Same tank half full.

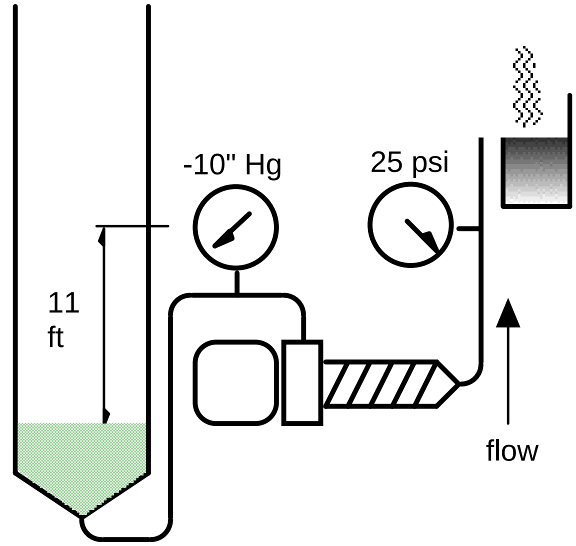


figure 10

Feed tank is almost empty.

As long as the pump sustains flow the **discharge** gauge reads the total of static and dynamic friction head, which is +25 psi.

This pressure represents 10 psi of elevation head combined with 15 psi dynamic friction head.

Figure 9 shows the same pump after the level falls to the middle of the feed tank.

Now the suction gauge reads zero pressure, because feed tank level is at the same elevation as the suction gauge.

Lift to the outlet tank and pipe friction hasn't changed, so the discharge gauge still reads +25 psi.

Figure 10 shows the situation when the feed tank level is almost to the bottom of the feed tank. Suction pressure drops into the vacuum range, but the pump is still operating perfectly, lifting fluid into the suction port.

Notice that the discharge pressure holds steady at +25 psi.

Figure 11 shows the end of the cycle.

The feed tank is empty, so now suction pressure is atmospheric.

The suction gauge changed direction and went back up to zero!

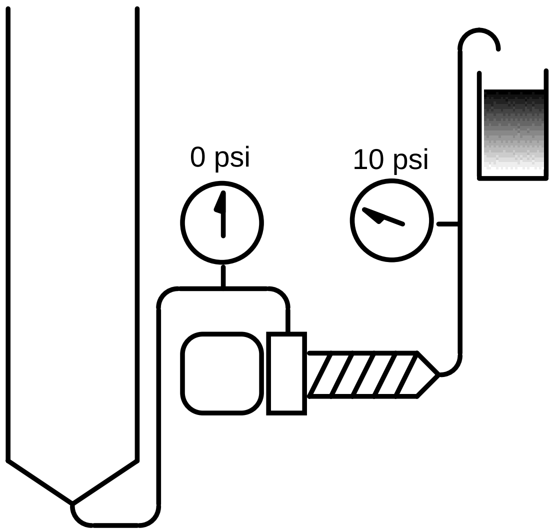


figure 11

Tank empty

There is still liquid in the discharge pipe, but no flow through the pump, so discharge pressure drops to the static head of the discharge pipe, + 10 psi.

Notice that the suction gauge shows the same pressure at tank empty as it did at tank half full.

There is no way to discriminate between these two conditions by reading the suction gauge.

Where would you set a pressure switch on the suction side of the pump?

Even if the feed tank is higher than the pump, it is difficult to monitor flow on the suction side.

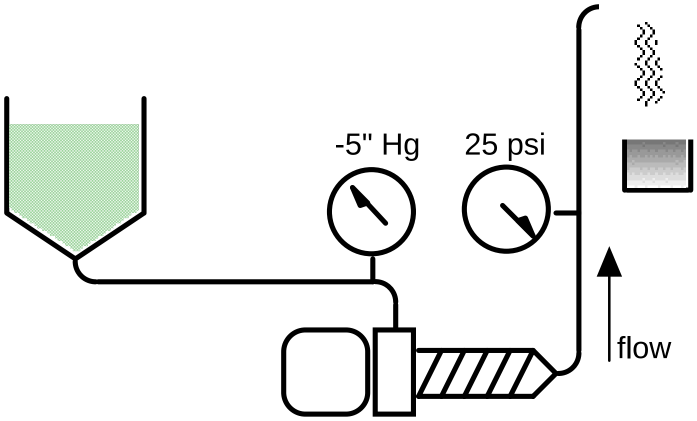


figure 12

Elevated feed tank

Figure 12 shows a system with an elevated feed tank.

The suction gauge shows positive pressure when the feed tank is full and the pump is not running.

When the pump starts, friction in the feed pipe pulls the suction pressure at the pump inlet slightly into the vacuum range.

In this situation the suction gauge reading goes up to zero when the tank is empty; but

The pressure also goes up past zero when the pump turns off, so where would you set a pressure switch on the inlet manifold?

Even with a perfect set up, monitoring suction pressure is tricky. Figure 13 shows an 'ideal' pumping system. Pump suction is flooded and suction pressure never falls below atmospheric. However, pressure switches are subject to "dead band".

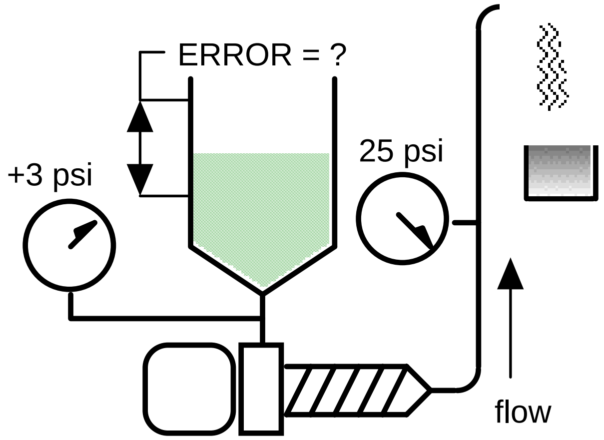


figure 13

"Perfect" feed tank

Dead band is the change in pressure required to operate the switch and make the contacts transfer. In most switches, this dead band is about 1.5 psi. That translates into ≈4 feet of head.

In other words the best accuracy you can expect for a switch on the suction side of a pump is an error range of about 4 feet elevation under ideal conditions.

It's difficult to make generalizations, but dynamic friction head on the discharge side usually ranges anywhere from 5 to 150 psi.

Setting a discharge pressure switch in the middle of this range provides simple clear cut indication of flow.

There are systems with low flow rates and low pipe friction, where there is insufficient friction head to trip a pressure switch. Your options are to find or create some pipe friction. If there is a check valve on the pump discharge, there is usually enough friction pressure upstream of the check valve to operate a pressure switch.

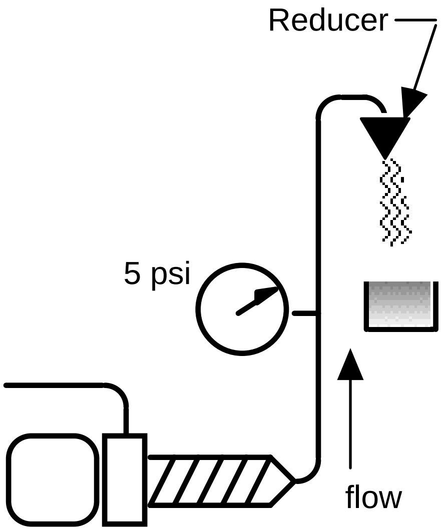


figure 14

In a system with minimal pipe friction, it is easy to create some.

Adding a reducer nozzle at the terminus of the system as shown in figure 14 usually creates at least 5 to 10 psi pressure differential between flow and no-flow conditions.

A minimum differential of 5 psi is sufficient to dependably trip a pressure switch designed to monitor flow.

Protecting progressing cavity pumps from over pressure and run-dry conditions makes economic sense. A pump protection device usually costs less than the replacement cost of one stator, and avoids the cost of an unscheduled shut down to service the pump.

For safety reasons, a pressure switch or similar device should always be used with any positive displacement pump.

The different methods of protecting progressing cavity pumps include:

- Flow Meter
- Thermal Mass Dispersion Device
- Capacitive Detector
- Thermo-couple Monitor
- Electric Power Monitor
- Pressure Switch

A pressure switch is a simple economical solution to monitoring progressing cavity pumps. Applying a pressure switch to monitor pump conditions requires an understanding of some basic fundamentals of hydraulic behavior.

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Onyx Valve Company manufacturers a complete line of pinch valves, valve actuators, controls, and pressure isolators.

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