

## **The Onyx Smart Box - 2**

### **Instruction Manual**

This manual explains how to apply the Smart Box to pump control applications.

The Smart Box prevents lost production and down time by ensuring that pumps remain within proper operating limits. When combined with our Isolator Ring this system works with viscous fluids, suspended solids, abrasive, corrosive, and volatile liquids.

The Onyx Isolating Ring fits between standard pipe flanges allowing unobstructed fluid flow. No drilling, tapping, or special tools are required. Sensing pressure over the entire pipe circumference ensures that coating, settling or material bridging will not affect pressure readings. An optional mechanical gauge provides visual monitoring of pump conditions.

The Smart Box combines several features in one package. It monitors low pressure for run-dry protection; a built-in timer allows the pump a grace period for priming each cycle.

It also monitors high pressure to protect the pump against excessive pressure conditions. Over pressure can be gradual, as when a filter bed reaches saturation, or it can be sudden, caused by someone closing a valve in the discharge pipe.

The Smart Box includes a 'STOP' button. Installing the box near the pump meets electrical code requirements for a stop device within 50 feet and direct line of sight of active electrical machinery.

The 'Run' button provides a convenient way to manually operate the pump. Our box is very flexible and adapts easily to fixed speed or variable speed pumps, other PLC's, remote relay panels, and unlimited remote start and stop stations.

The Smart Box must be combined with the correct range pressure switch. The range must be high enough to withstand maximum normal operating pressure of the pump. Do not use a higher range than necessary or you will have difficulty setting the switch for the low pressure setting.

### **OPERATION**

After the Smart Box has been wired (see wiring instructions) and the high and low pressure switches have been set, the Smart Box is ready for operation.

No programming is required. The Smart Box comes pre-programmed and ready to run.

Turn on power to the pump and Smart Box. The red READY lamp should illuminate. This indicates that the pump is ready for operation.

- 1 To start the pump, twist the red STOP/RESET button. It will pop out.

Then press the green START button. The red light will go out, the green RUN light will come on, and the pump will start running.

- 2 To stop the pump, press the red STOP/RESET button. It will latch in. The green RUN light will go out, the red READY light will come on, and the pump will stop.
- 3 If the pump experiences an over pressure condition the Smart Box will immediately stop the pump and the yellow HI TRIP light will come on.

Find the problem with the pumping system. (Closed discharge valve? clogged line? etc.) The Smart Box will not allow a restart until the problem is fixed. When the problem is fixed and the pressure has been relieved, press the STOP/RESET button, then twist it to pop it back out. Now you can restart the pump.

- 4 If the pump experiences a run dry condition the Smart Box will stop the pump and the yellow RUN DRY light will come on. (The Smart Box allows a 90 second grace period for the pump to prime itself each cycle.)

Find the problem with the pumping system. (Closed suction valve? clogged suction line? empty feed tank? etc.) The Smart Box will not allow a restart until the problem is fixed. When the problem is fixed and the suction is flooded, press the STOP/RESET button, then twist it to pop it back out. Now you can restart the pump.

- 5 How come there's no LOCAL-OFF-REMOTE switch if I have remote controls?

Simple: You don't need one. The Smart Box can figure out what mode you want to be in. Don't complicate things by trying to add one of these selector switches to the circuit.

For example, assume that you have remote controls somewhere which can start the pump. If you press the STOP/RESET button on the Smart Box, the button latches in. The Smart Box figures you are in LOCAL mode, and automatically blocks any and all remote start commands.

To put the system into REMOTE control, simply twist the red STOP/RESET button so that it pops out. The Smart Box figures that it's OK to run now (the ready light comes on) so it automatically goes into REMOTE mode.

If you press the green START button on the Smart Box, it figures out that you want LOCAL RUN mode, so it automatically goes into LOCAL mode.

## **PRINCIPLE OF OPERATION**

In order for the Smart Box to protect pumps from over pressure and run dry conditions, a 2-stage pressure switch must be installed at the pump discharge.

Set the high pressure switch to the highest safe operating pressure for the process system.

If discharge pressure exceeds the high pressure setting, the Smart Box stops the pump and turns on the "High Trip" lamp on the front of the control box.

The pump remains stopped until the "Stop/Reset" button is pushed in and pulled out. After resetting, press the "Start" button to restart the pump. The Smart Box will not allow the pump to restart until excess discharge pressure has been relieved.

This system protects pumps against run dry damage by monitoring the discharge pressure. It is important that the low pressure switch is properly set.

To set this switch, it is necessary to understand the differences between static pressure, friction pressure, and total pressure.

Static pressure results from the piping being filled with liquid and is present even when the pump is idle.

Static pressure is *not* influenced by pipe size, number of fittings, or viscosity. Static pressure is determined solely by fluid density and the difference in height between the pressure switch and the outlet of the pipe.

In the example in figure 1, the outlet of the discharge pipe is 12 feet higher than the gauge, so static head is 12 feet, which equals 5 psi.

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.

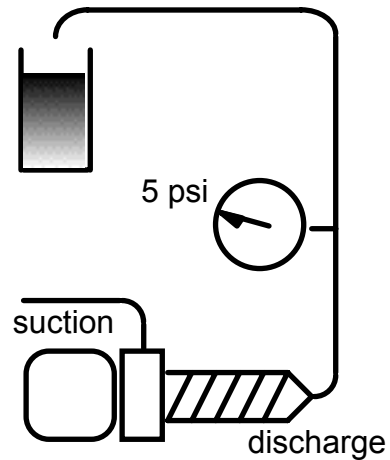


fig 1.

**Pump Off.**

**Static head is the pressure that results from the weight of the liquid in the pipe.**

Total pressure is the combination of static and friction pressure. This pressure can be 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 2, total pressure is 25 psi.

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

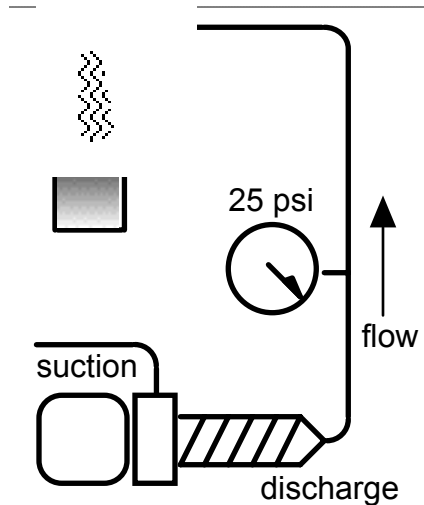


fig 2 Pump On.

**Total press = static press + friction head.**

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 signal that flow has stopped.

The Smart Box program allows the pump time to prime. Each time the pump starts, the Smart Box waits 90 seconds before checking for run dry conditions.

After this time-out period, if the pressure falls below the low pressure setting (which indicates the pump is running dry) the Smart Box stops the pump and the "Low Trip" lamp lights. The "Low Trip" state remains until the "Stop/Reset" button is pressed.

## Wiring

Wiring should be performed by a qualified electrician. All wiring should conform to national and local electrical codes. Disconnect all electric power to this box before wiring or servicing.

## Refer to wiring diagram # D-90037

When laying out the control circuit remember that the Smart Box needs 3 things:

- 1 It has to 'know' whether or not the pump is running.
- 2 It has to 'know' if the pressure is in the correct range.
- 3 It has to have the final authority to start and stop the pump.

Accordingly, the Smart Box must be the only device wired directly to the motor starter (or the 'Run' terminals if the pump is driven by a VFD).

**All Start and Stop commands must be routed to the Smart Box.**

## **Remove any other circuit that could start the pump motor!**

### **A Power Wiring:**

- Turn off the power source before making these connections. This is a safety warning designed to prevent possible of electric shock during this procedure.
- The Smart Box requires 120 VAC/60~ power. Power consumption is 0.2 amps.
- Connect a 120 VAC/60~ hot line to terminal #1.
- Connect a neutral line to terminal # 2.
- Connect a ground wire to the green and yellow earth terminal.

### **B. Pressure switch wiring:**

- Turn off power to the Smart Box before making these connections. If any signal wires touch any grounded surface while the Smart Box is energized, this short to ground could permanently damage to the PLC.
- Run (3) wires between the pressure switch and the Smart Box.

Power in this circuit is minimal and voltage is only 24 VDC, so these wires can be small gauge; 18 to 20 gauge is adequate for distances up to 100 feet.

- Inside the **pressure switch**, (NOT inside the Smart Box!) install a jumper across the two common terminals. Connect the common terminals in the pressure switch to terminal # 9 in the Smart Box.
- Connect the low switch N.O. contact to terminal #14 in the Smart Box.
- Connect the high switch N.C. contact to terminal #15 in the Smart Box.
- Tip: The Smart Box includes an internal wire checking feature. If there is a break in the circuit between the Smart Box and the pressure switch, the Smart box stops the pump and goes into an alarm condition.

### **C Wiring to a Fixed Speed Pump Motor:**

- The pump motor must have an independent starter. The contacts inside the Smart Box are **NOT** designed to handle the electrical load of a motor, even if the motor is single phase.

Run 2 wires between the Smart Box and the motor starter. These wires must be sufficient gauge to handle the load of the starter coil. This is usually a light load, so 16 to 18 gauge should be sufficient. Heavier gauge makes wiring inside the Smart Box difficult, as space is at a premium.

If: The coil in the motor starter is a 120 VAC/60~ coil,  
Then: Connect one wire from the coil to terminal # 3 on the terminal strip inside the Smart Box. Connect the other wire from the coil to terminal #8 inside the Smart Box.  
And: Leave the jumper between terminals # 4 & #5 in place

If: The starter coil is **not** 120 VAC,  
Then: Bring your coil power to terminal #5, and return to the coil from terminal #8.  
And: Remove jumper from between terminals #4 & 5 on the terminal strip. **This is important.** If you forget to do this, you will burn out the power supply, the PLC, and the indicator lamps on the printed wiring board.

Rating: The switching terminals in the Smart Box are rated for:

V max:	250 VAC
Carry current:	5 amps @ 250 VAC w/ p.f. = 0.4
Max switching cap:	1,250 VA 220 W

#### **D Wiring a Variable Speed Drive to the Smart Box:**

##### **Important:**

Remove the terminal strip jumper between terminals #4 & 5 inside the Smart Box. Failure to remove this jumper will cause the VFD to melt down. This could ruin your whole day.

The Smart Box works with all variable speed drives including three phase PWM and single phase DC type units, and digital controlled units.

Confusion often arises from the fact that VFD drives are frequently supplied with their own set of start and stop controls.

In this case, it is essential to disable the "START" push button on the VFD unit. All 'Start' commands must be directed to the Smart Box. Failure to do this makes it possible for an operator to force the pump to run without the protection of the Smart Box. This could damage the pump or cause personal injury by the pump operating outside its design pressure parameters.

In the case of digital programmable VFD units with membrane type switches, this simply entails going into the program and entering the appropriate code to disable the local start control. If you have this type of drive, do this now.

For drives with conventional push buttons wired to a terminal strip on the VFD, the wires from the 'START' button must be removed from the VFD and re-routed to the Smart Box. The following instructions will explain the correct procedure.

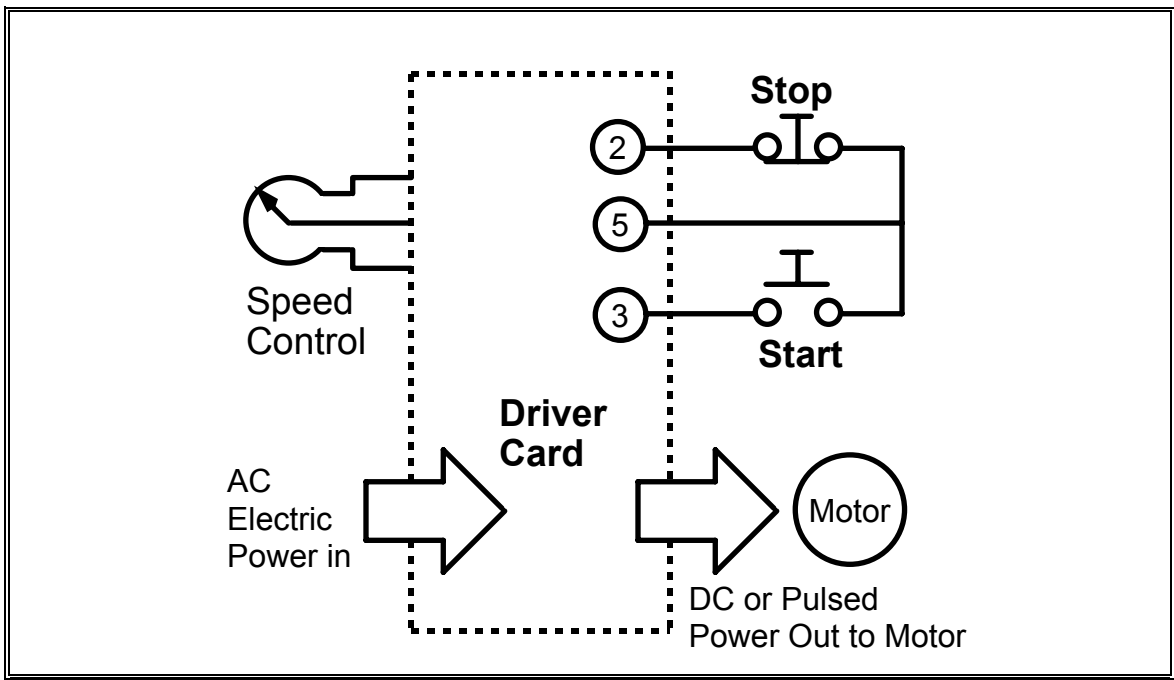
Follow these directions and the pump will operate in a logical sensible manner.

Do not modify the following approach by tapping into "permissive" VFD circuits such as motor thermal overload terminals. That trick will enable the Smart Box to stop the pump, but you will have no way of starting the pump, which isn't very practical.

Inside the VFD there are usually 3 terminals for Stop / Start control. Figure 3 shows a typical variable speed drive layout. Locate these three terminals.

Install a jumper wire across the Start terminals in the VFD. In the example shown in figure 3, this jumper wire goes across terminals #3 and #5. The idea here is that you want to force a constant START command into the VFD.

Run a pair of wires between the VFD and the Smart box. Attach one end of the pair to the "STOP" terminals in the VFD; in this example terminals #2 and #5 in the VFD. Connect the other end of the wire pair in the Smart Box to terminals #5 and #8 on the terminal strip.



**fig 3 Typical VFD Arrangement**

**E. Remote Controls Using a 3-wire Start / Stop System:**

- The simplest accessory to the Smart Box is a remote Start / Stop station. Connect remote stations to the Smart Box, **NOT** the motor starter.
- The Smart Box can accommodate an infinite number of remote 'Stop' buttons.

Likewise, the Smart Box can accommodate an infinite number of remote 'Start' buttons.

- Remote start buttons must be **momentary** N.O. configuration.
- There is a Red Jumper wire running from terminal #10 to #11. Remove this jumper wire whenever a remote 'Stop' button is used.
- Connect as many 'Stop' buttons as needed in series between terminals #10 and #11.
- Connect as many 'Start' buttons as needed in parallel between terminals #10 and #12.

#### **F. Remote controls with a 2-wire Remote Start / Stop system:**

- Some systems are designed for remote operation using a single-pole relay or a remote 2-wire 'on/off' switch. The Smart Box can accommodate this input.
- A typical example is the control supplied with a belt filter press. In this system, a relay with a set of N.O. contacts closes when the pump is supposed to run, and the contacts open when the pump is supposed to stop.
- Connect any 2-wire device to the Smart Box at terminals #10 and #13.

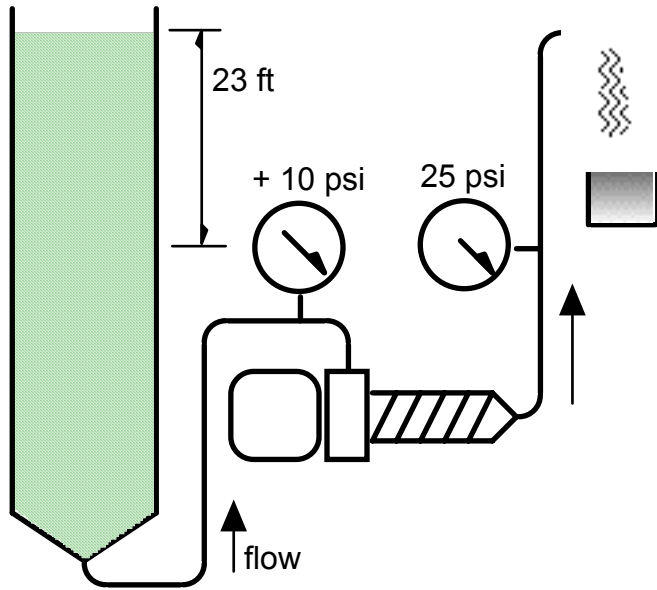
#### **G. Fault signal:**

- In addition to the indicator lamp on the front of the box, the Smart Box includes a set of N.O. contacts which can communicate a fault condition to any remote device.

This set of contacts are across terminals # 6 & 7 on the terminal strip in the Smart Box. They are rated for 1 amp @ 125 VAC or 1 amp @ 24 VDC.

## Flow Detection with Pressure Switches Suction or Discharge?

Most positive displacement pumps depend on the transport fluid to carry away the heat of friction. Run-dry conditions overheat and damage internal components in short time. Pressure switches provide a simple cost effective way to infer flow.



*figure 4*

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 4 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.

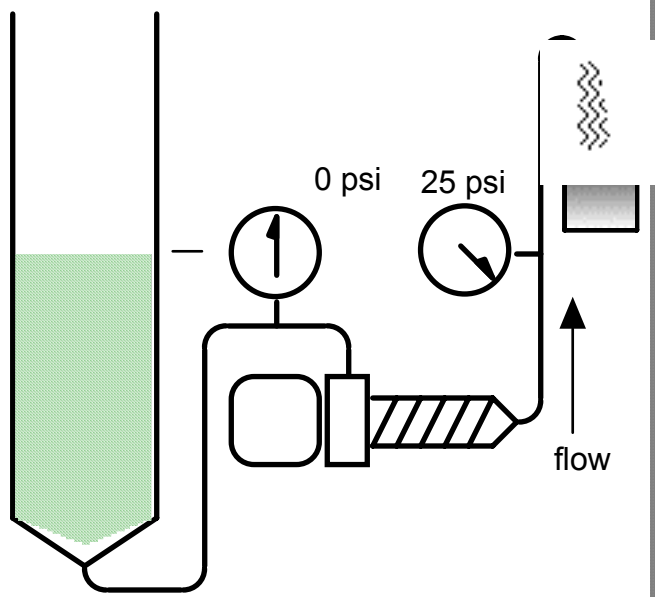


figure 5

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

Now the suction gauge reads zero pressure.

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

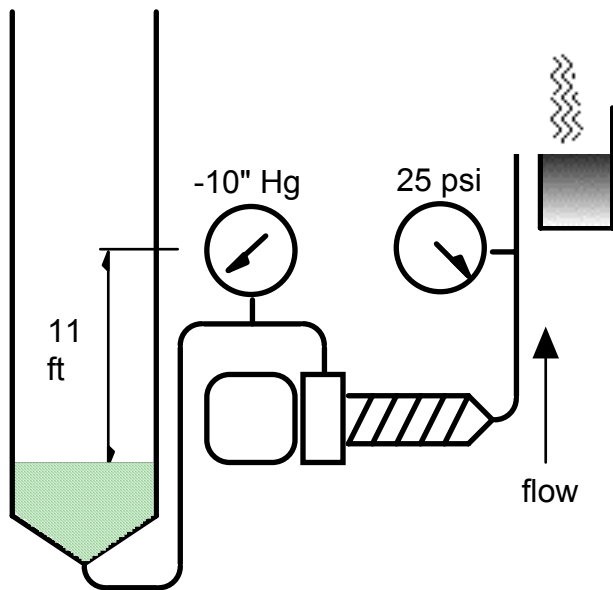


figure 6

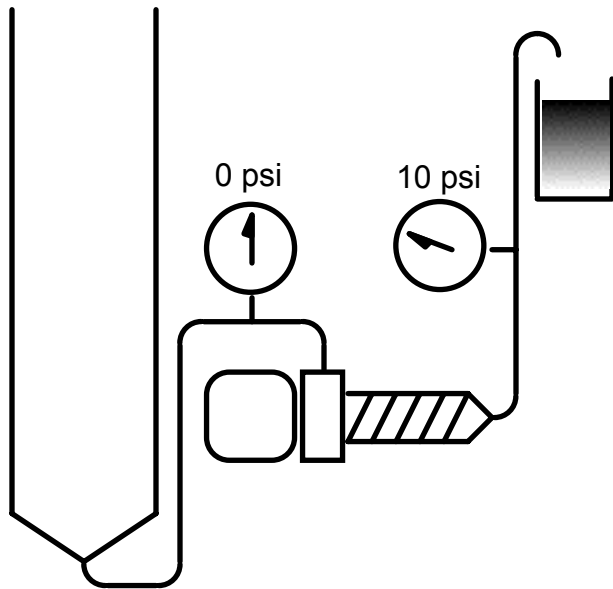
Figure 6 shows the situation when the feed tank level is almost to the bottom of the feed tank. Suction pressure drops into the vacuum range, but the pump is still operating perfectly, lifting fluid into the suction port.

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

Figure 7 shows the end of the cycle.

The pump emptied the feed tank, so now suction pressure is atmospheric.

**The suction gauge changed direction and went back up to zero.**



*figure 7*

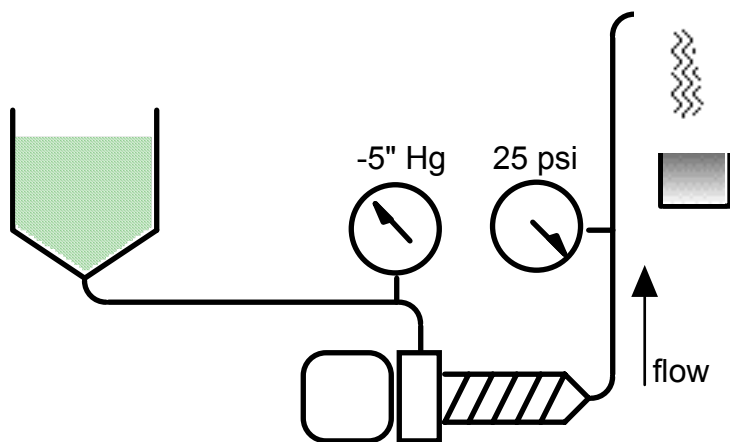
There is still liquid in the discharge pipe, but no flow through the pump, so discharge pressure drops to the static head of the discharge pipe, + 10 psi.

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 do 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 8*

Figure 8 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 an ideal set up, monitoring suction pressure is tricky. Figure 9 shows a 'perfect' pumping system. The pump suction is flooded and suction pressure never falls below atmospheric. The problem is tuning the system.

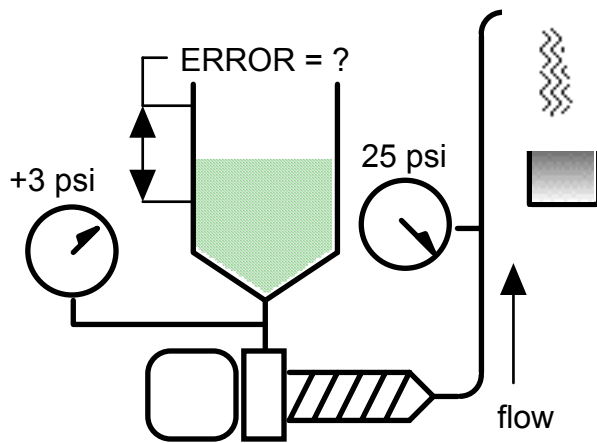


figure 9

Pressure switches have what is known as "deadband".

Deadband is the change in pressure required to operate the switch and make the contacts transfer. In most switches, this deadband is about 1.5 psi. That translates into  $\approx 4$  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 300 psi, a generous swing. Setting a discharge pressure switch in the middle of this range provides simple clear cut indication of flow.

Of course there is always the odd system with low flow rates and low pipe friction, so 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.

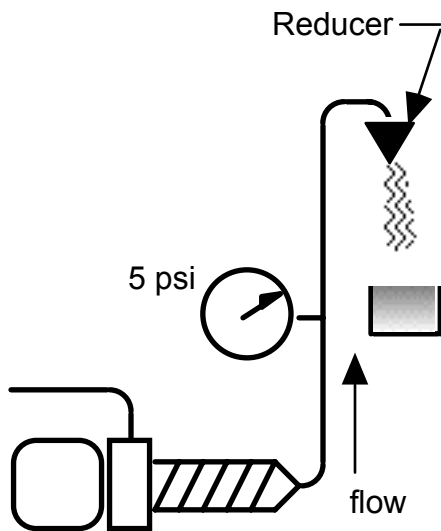


figure 10

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 10 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.



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