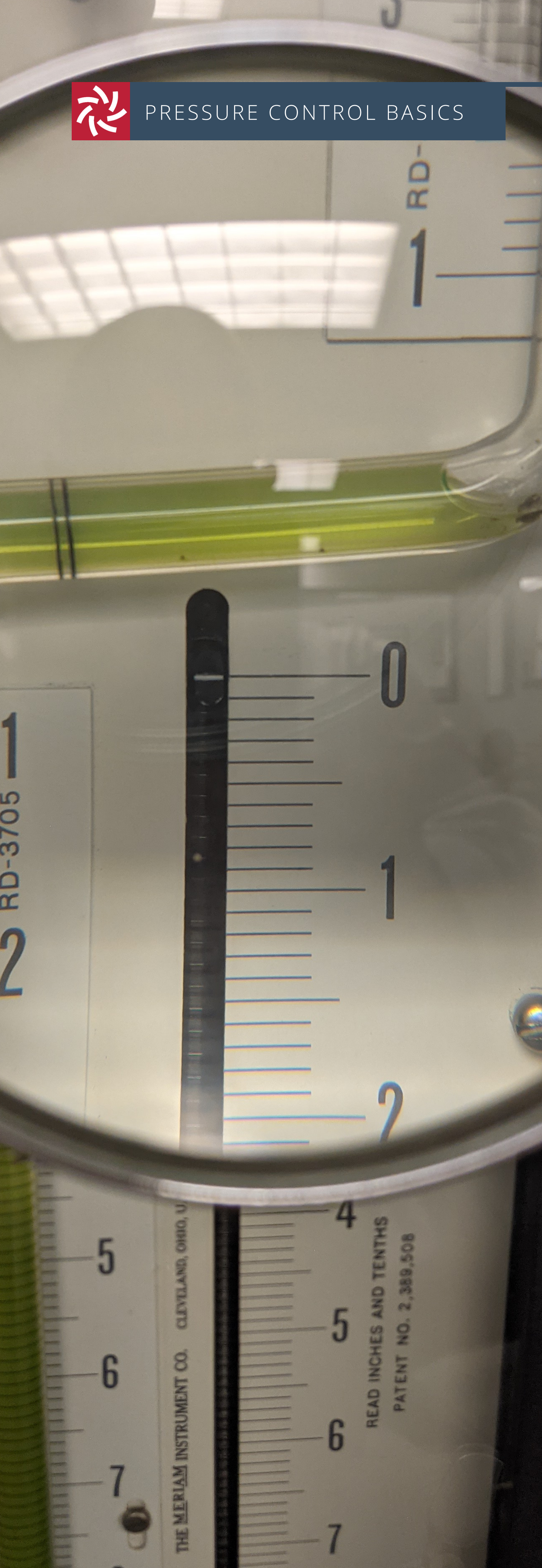
APPLICATION GUIDE

PRESSURE CONTROL BASICS

MAR 2021

COOK



OVERVIEW

Pressure control is utilized broadly in HVAC applications. A basic understanding of pressure control will allow this simple-but-powerful tool to be utilized a number of ways.

This guide will take a look at how pressure is measured, how pressure controllers work, and what information is needed to properly apply, install and operate pressure control systems.

Topics covered include:

- Measuring Pressure
- Positive Pressure vs. Negative Pressure: It's All About Perspective
- Pressure Controller Basics
- Direct Acting or Reverse Acting Control: How Do I Know?
- Pressure Control Applications

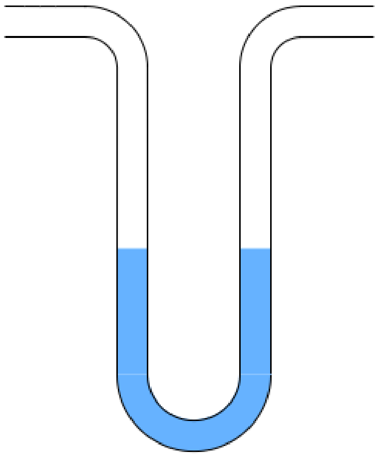
MEASURING PRESSURE

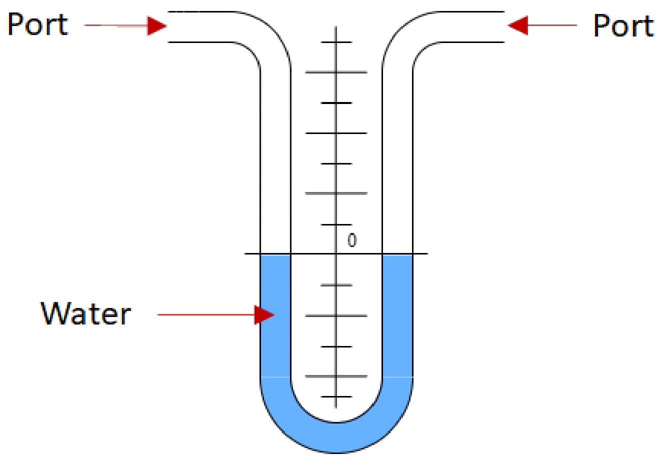
In this guide, when we say pressure, we mean differential pressure; the difference between pressure at one point and another. Duct static pressure, for instance, is the difference between the pressure inside the duct and outside the duct.

If we want to pressurize a building, it is relative to the atmospheric pressure outside the building, and if we want to pressurize a space it is relative to another space.

In HVAC applications, it is common to measure pressure in inches of water column or water gauge. Let's take a look at why.

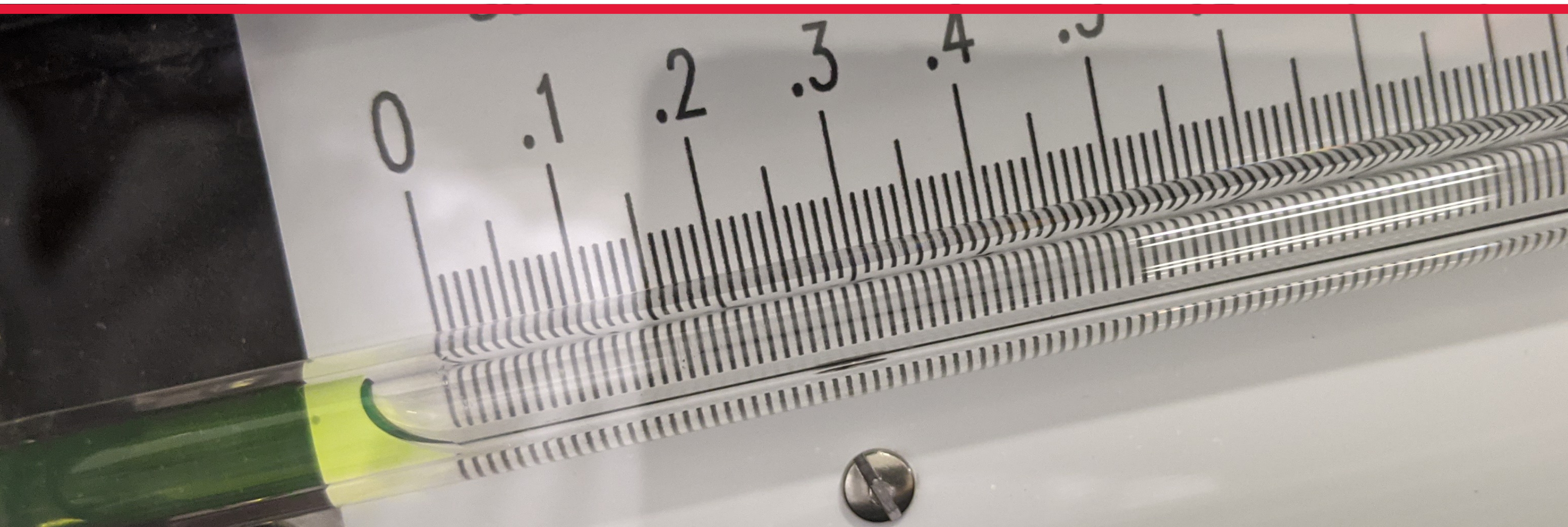
On the right is a tube with colored water in it to make the water level easier to see. It has two open ends that are open to atmosphere.

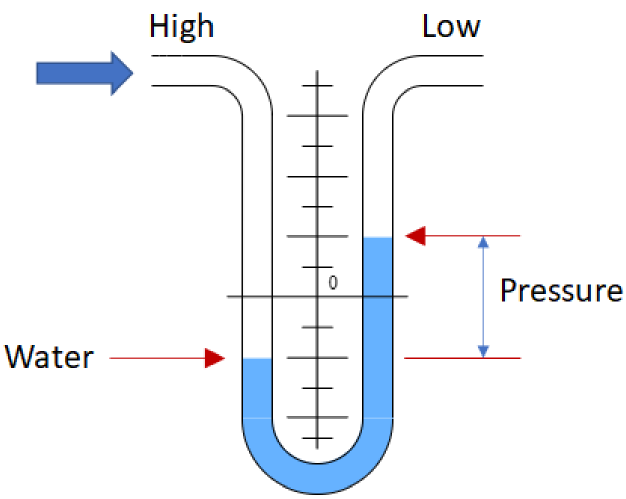




U-tube
Manometer

For convenience, we will add a 'ruler' to measure water level. In this case, the unit of measure is inches. We will refer to the open ends as ports. We now have what is known as a 'U-tube manometer'. The water level in our manometer is even on both sides of the tube, indicating there is no difference in pressure from one side to the other.



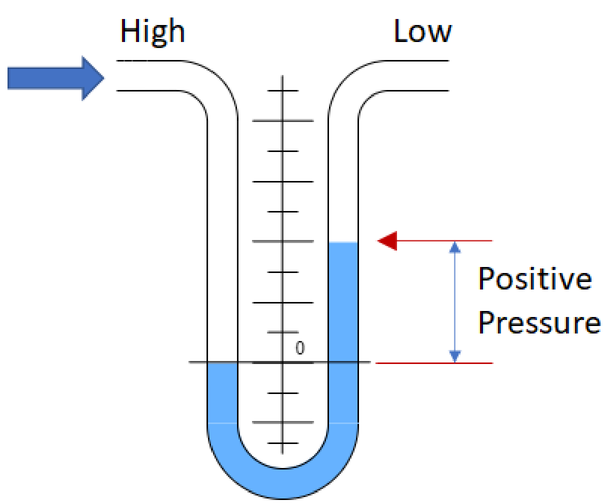


U-tube
Manometer

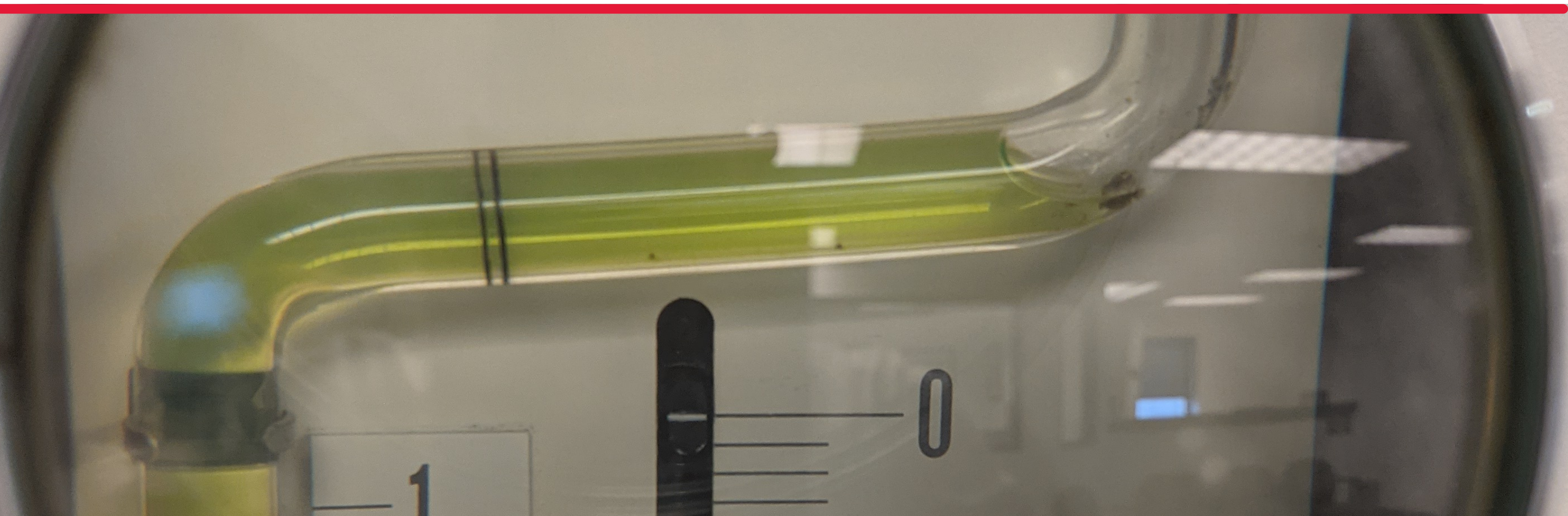
If positive air pressure (think blowing on a straw) is applied to one port, that pressure will push the water level down on that side and force it upward on the opposite side.

The difference in water level can be read as 'inches of water column' or 'inches -water gauge'.

If we move the '0' reference point to the lower water level, we read this as positive pressure.

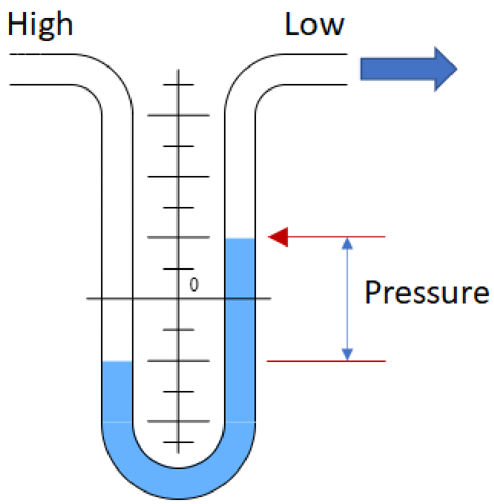


U-tube
Manometer

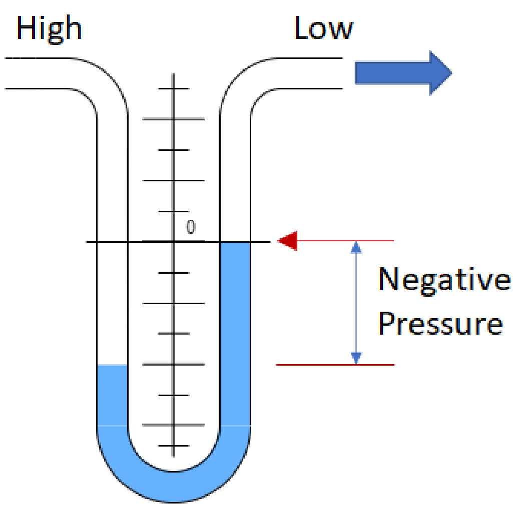


If an equal amount of negative pressure (similar to sucking on a straw) is applied to the port on the right, that pressure will pull the water level up on that side and lower it on the opposite side.

The difference in the water level is the same as it was in the prior example and therefore, so is the pressure difference.

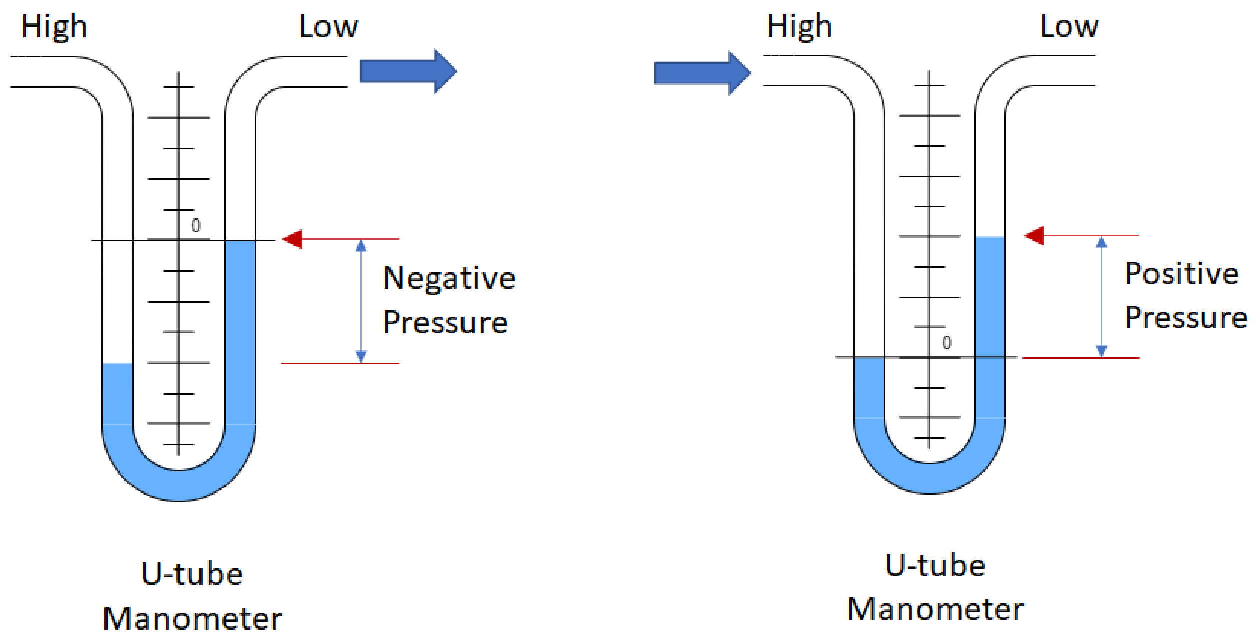


U-tube
Manometer



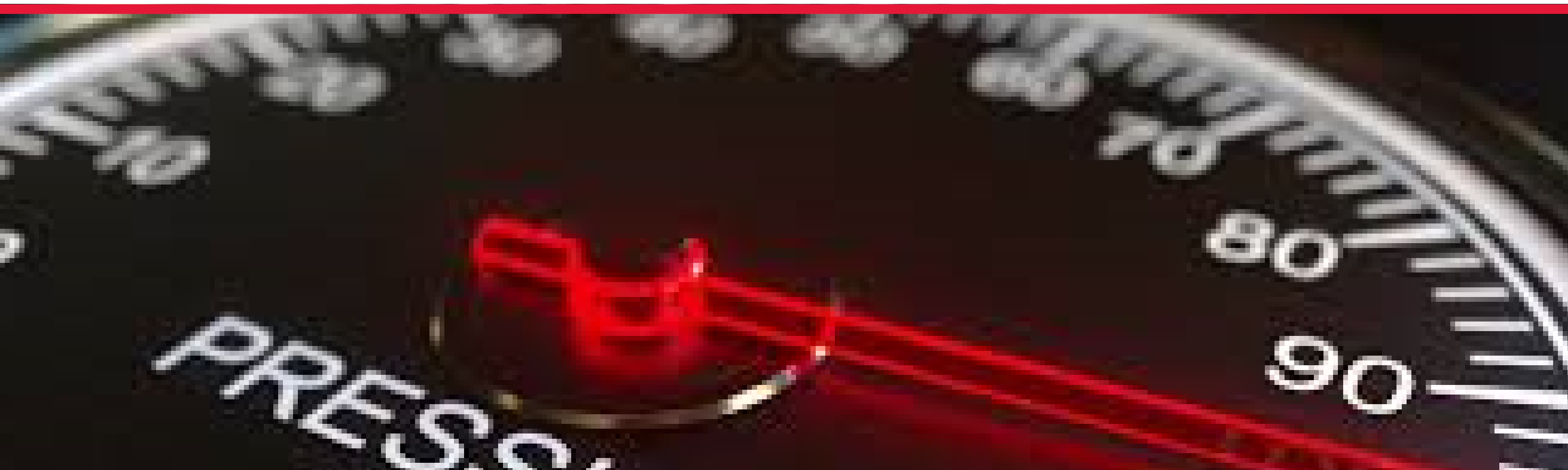
U-tube
Manometer

If, in this case, we move the '0' reference point to the upper water level, we read this as negative pressure.



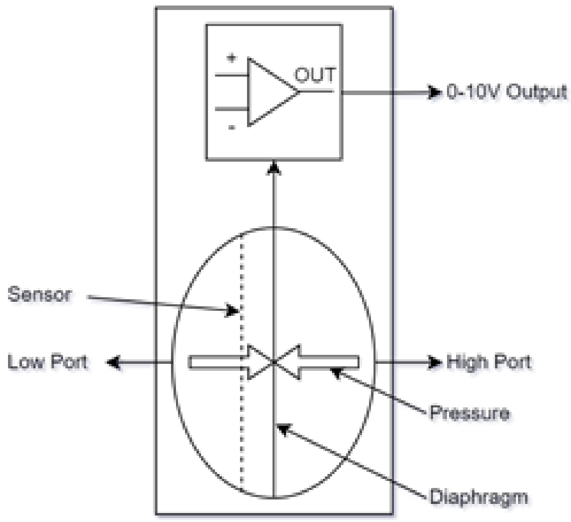
Both of these manometers are measuring the same pressure difference. Our interpretation differs based on where we decide the reference point is. Whenever we measure pressure and use it to control an air moving device such as a fan, our point of reference will determine whether we interpret the pressure as 'negative' or positive'.

Now let's take a look at a basic pressure controller and see how it works.

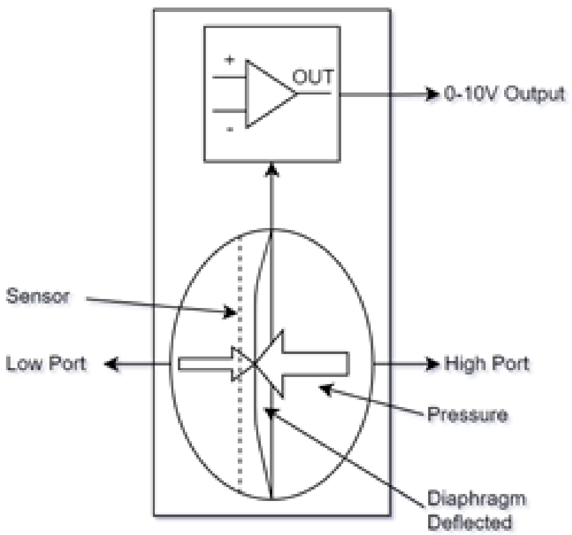


On the right is a schematic diagram of a pressure controller. Two of its primary components are a pressure transducer (shown on the bottom) and a signal output device (shown at the top).

Let's take a look at the pressure transducer. Similar to our u-tube manometer, we have two ports. Instead of water in a tube, we have a diaphragm that moves with a difference in pressure and a sensor that measures the amount of diaphragm movement



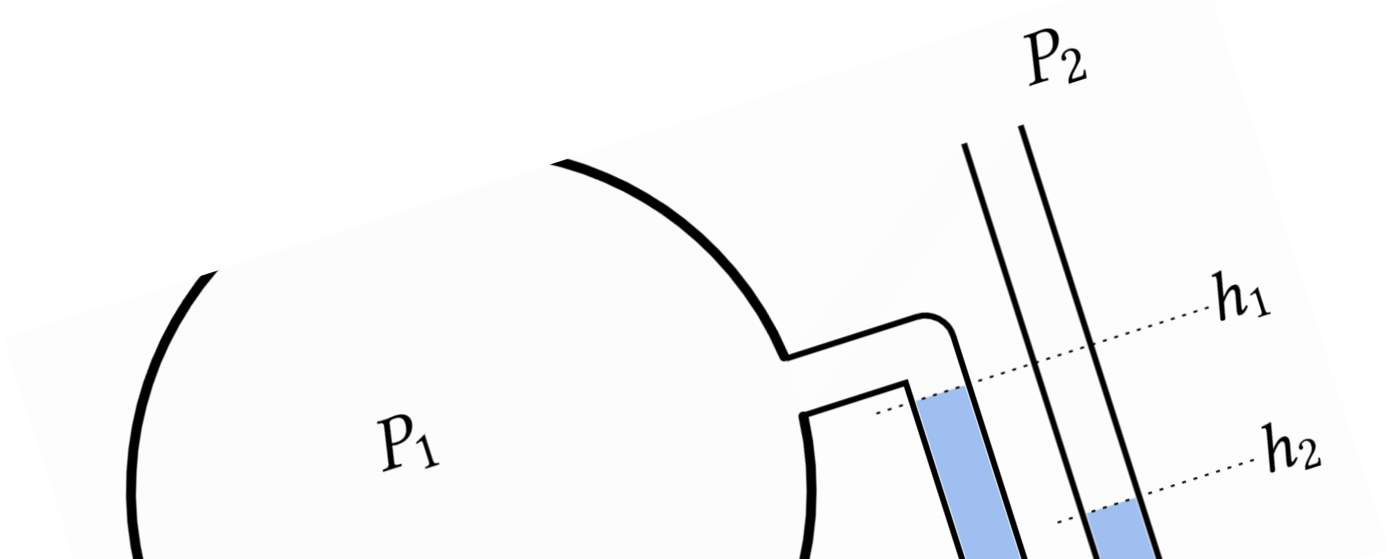
High = Low : 0V Output

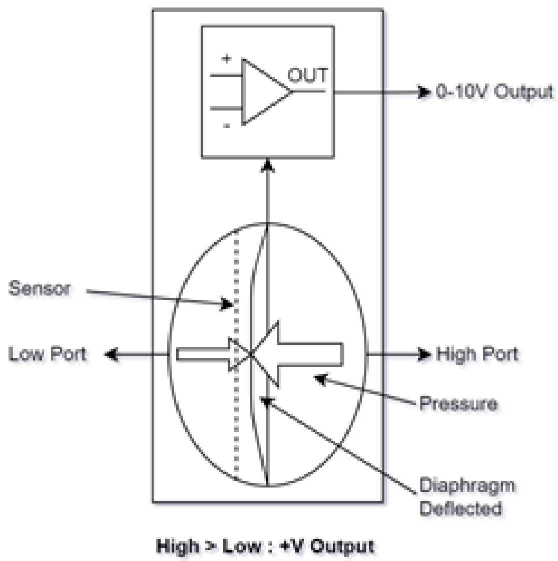


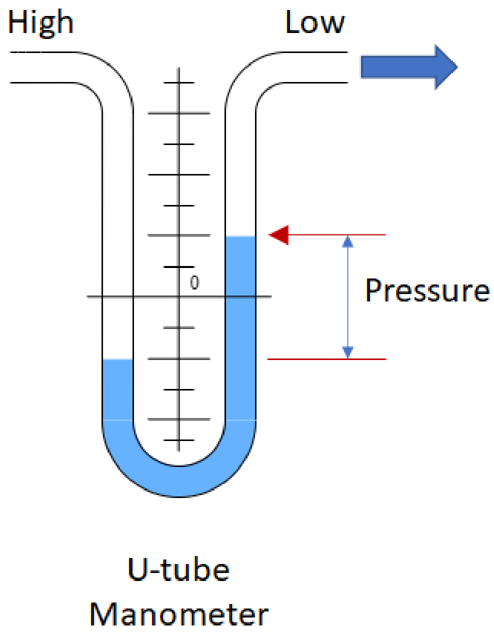
High > Low : +V Output

In this transducer, the diaphragm only moves to the left. In order to properly measure the difference in pressure between the ports, the higher pressure must always applied to the HIGH port and the lower pressure to the LOW port

If the transducer is connected incorrectly (pressures reversed), the diaphragm will not move and the sensor will not sense a difference in pressure.

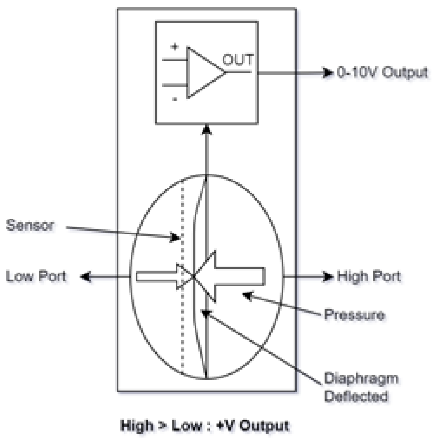


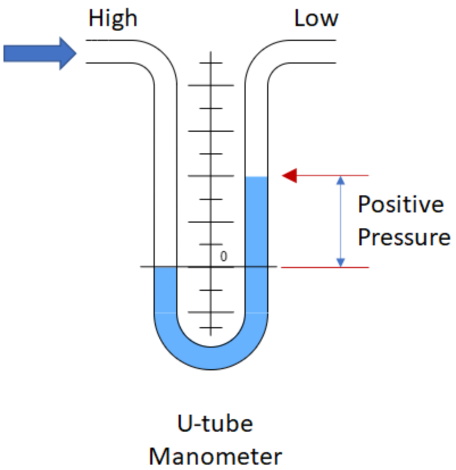




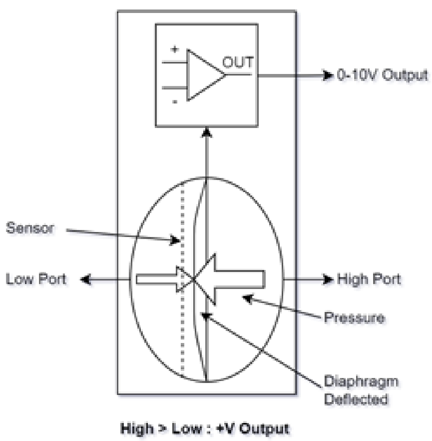
Because the diaphragm only moves in one direction, the transducer does not know whether it is measuring 'positive' or 'negative' pressure. It simply measures the difference in pressure between the HIGH and LOW ports and reads that difference out as a positive number.

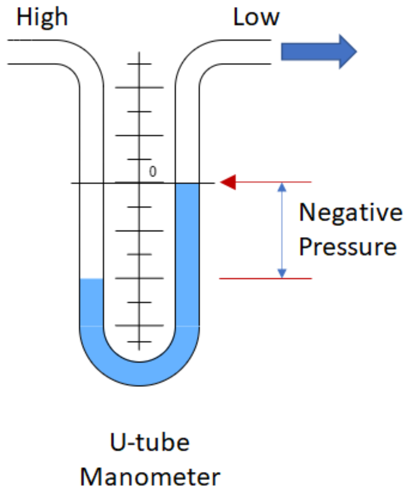
Comparing this to the manometer, we see that, like the pressure transducer, it simply measures the difference in pressure between the two ports. If we label the ends of our manometer HIGH and LOW and always connect them in the same way, our manometer and transducer operate in a similar fashion.



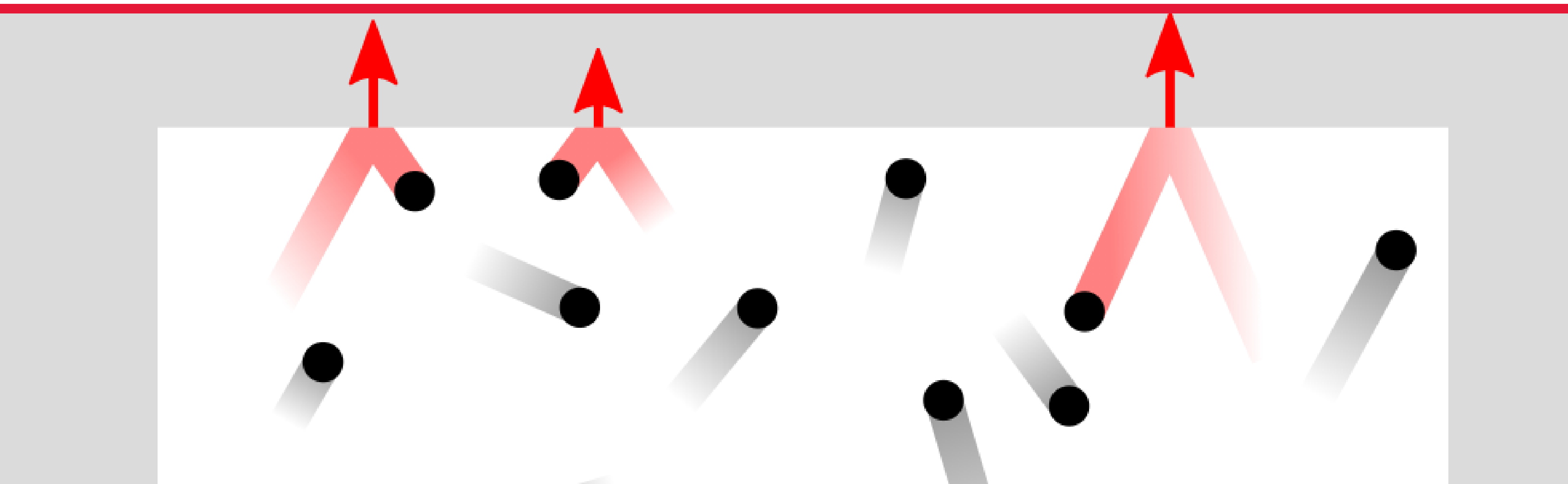


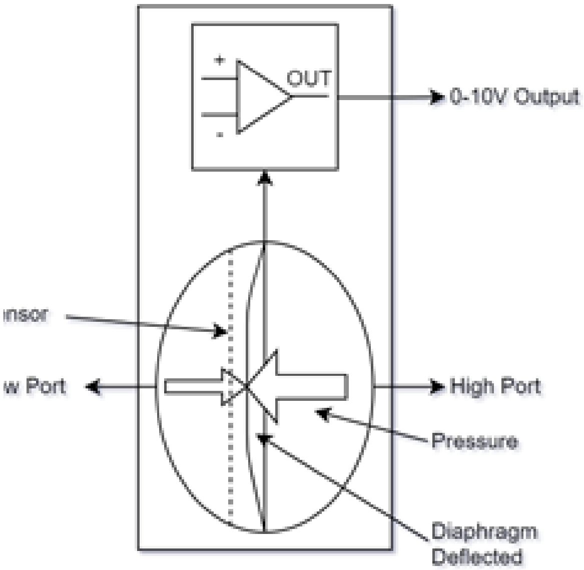
If we apply positive pressure to the HIGH port of the pressure transducer and leave the low port open, we will read positive pressure, just as we saw on the manometer.





If we apply negative pressure or suction to the LOW port and leave the HIGH port open, we will read negative pressure, as we did with the manometer.





High > Low : +V Output

A pressure controller takes the measurement from the transducer, compares that measurement to a setpoint and, based on the difference, outputs a signal. In our case, the signal is a 0-10V signal that can be used to control an air moving device.

In order for the controller to know how to convert the pressure reading into an output signal, it must also know whether the signal is to be 'direct acting' or 'reverse acting'.

Next, we will define these two terms and how to use them.

DIRECT ACTING PRESSURE CONTROL

When an **INCREASE** in input signal (pressure) requires an **INCREASE** in output signal (0-10V) to reduce the difference between the setpoint and the actual pressure to '0'. <u>For our purposes, we will refer to the difference between setpoint and actual pressure as the 'error'.</u>

Input Signal (Pressure)

Output Signal (0-10V)

Inversely, when a **DECREASE** in input signal (pressure) requires a **DECREASE** in output signal (0-10V) to correct the 'error'.

Input Signal (Pressure)

Output Signal (0-10V)

REVERSE ACTING PRESSURE CONTROL

When an **INCREASE** in input signal (pressure) requires an **DECREASE** in output signal (0-10V) to reduce the difference between the setpoint and the actual pressure to '0'.

Input Signal (Pressure)

Output Signal (0-10V)

Inversely, when a **DECREASE** in input signal (pressure) requires a **INCREASE** in output signal (0-10V) to correct the 'error'.

Input Signal (Pressure)

Output Signal (0-10V)

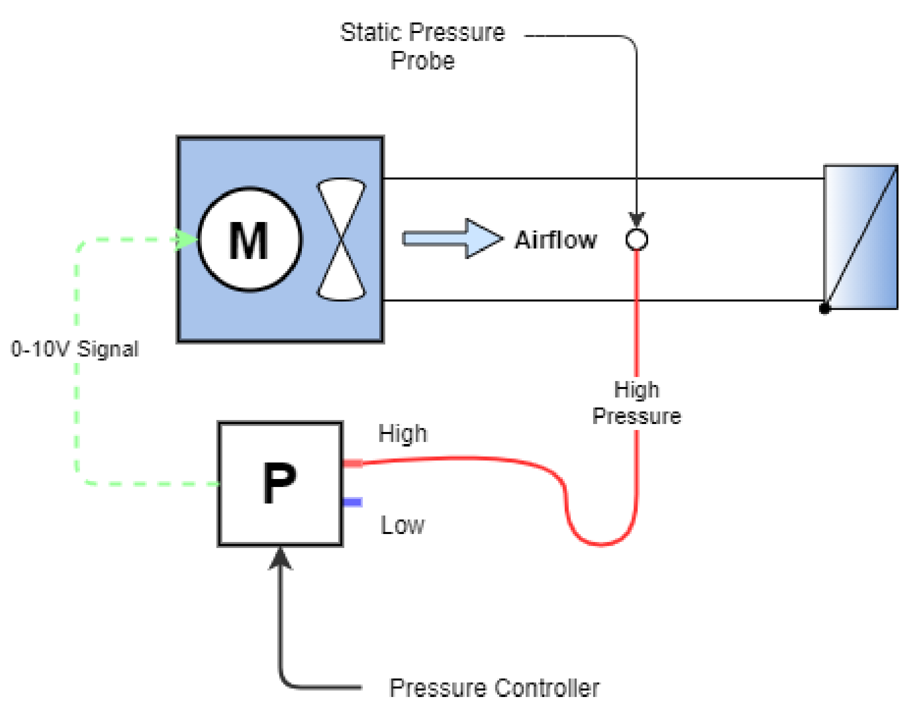
To reinforce the concept of Direct and Reverse Acting control, let's look at some examples.

DUCT STATIC PRESSURE CONTROL

In this scenario we want to maintain a constant duct pressure as system changes occur such as dampers opening and closing. The pressure controller is configured with a static pressure probe, downstream of the fan, connected to the HIGH side of the pressure transducer. The LOW side is left open.The difference in pressure between these two ports is the static pressure in the duct.

The static pressure probe should be installed along the midline of the duct and 2-3 equivalent duct diameters downstream of the fan. The controller will measure the differential pressure between the two ports, compare it to the pressure setpoint and modulate the fan to close the gap between setpoint and actual pressure. The controller monitors the system and as changes occur, modulates the fan motor to maintain the pressure setpoint.

If the pressure drops below the setpoint, the controller will send an increasing signal to the fan motor, speeding the fan up to increase the duct pressure. If the pressure rises above the setpoint, the control signal to the fan will drop, slowing the fan until the setpoint is met. Per our definitions, this is 'reverse acting control'



CONSTANT VELOCITY OR AIRFLOW CONTROL

Maintaining a constant velocity or airflow in a system is often desirable. This can be a useful strategy, for example, if there is a filter bank in the system. As the filter bank loads up, the air volume (and velocity) through the system will be reduced. In order to overcome this, the fan must speed up. A pressure controller can accomplish this by connecting a total pressure probe to the HIGH side of the pressure transducer and connecting a static pressure probe to the LOW side (see page 13). The pressure transducer is now measuring the difference between total pressure and static pressure, which is velocity pressure. Now let's take a look at how to determine the controller setpoint.

First, we look at the relationship between air velocity and velocity pressure:

$$\boldsymbol{Velocity\ Pressure = (Velocity \div 4005)^2}$$

We also will need to know the relationship between the airflow and the duct velocity:

$$\boldsymbol{CFM \div Area = Velocity}$$

Let's look at an example:

Maintain a constant 1800 CFM through a 16" x 16" duct (1.778 sq. ft.)

Knowing the CFM and duct area we calculate:

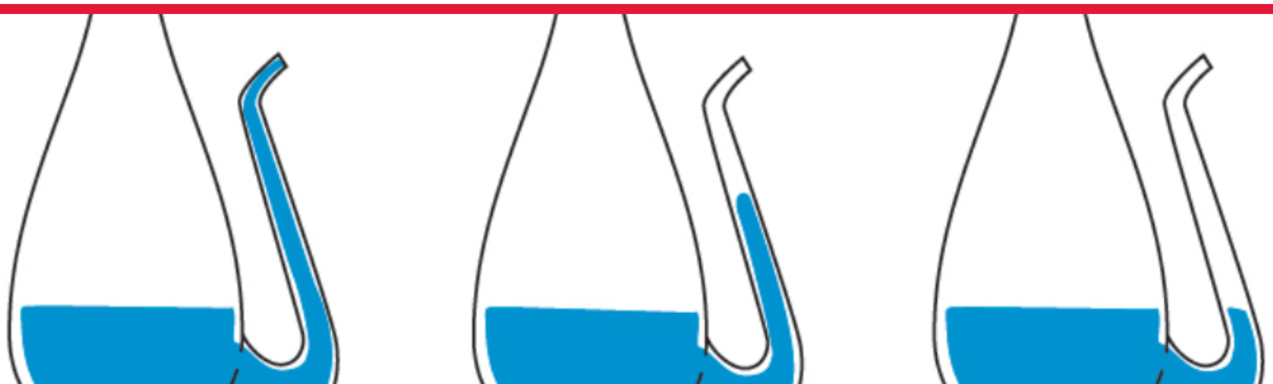
$$\boldsymbol{CFM \div Area\ (SF) = Velocity\ (FPM)}$$

$$1800 \div 1.778 = 1013\ fpm$$

We can then calculate the velocity pressure correlating to the duct velocity:

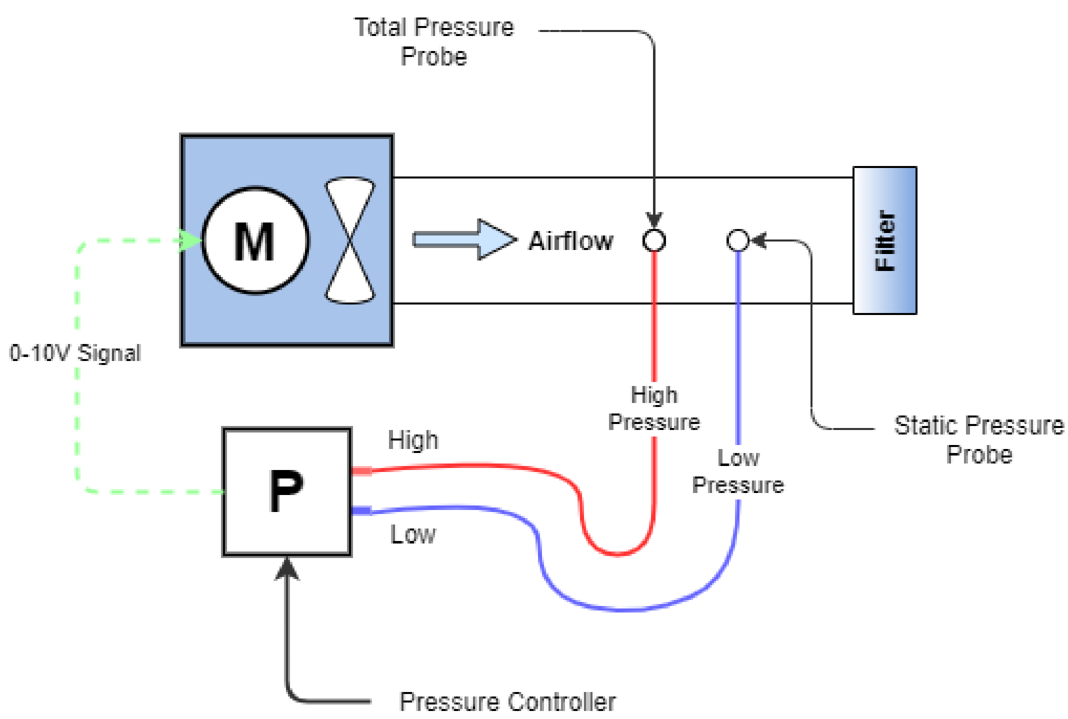
$$\boldsymbol{Velocity\ Pressure = (Velocity \div 4005)^2}$$

$$Velocity\ Pressure = (1013 \div 4005)^2 = 0.064\ in.wg.$$

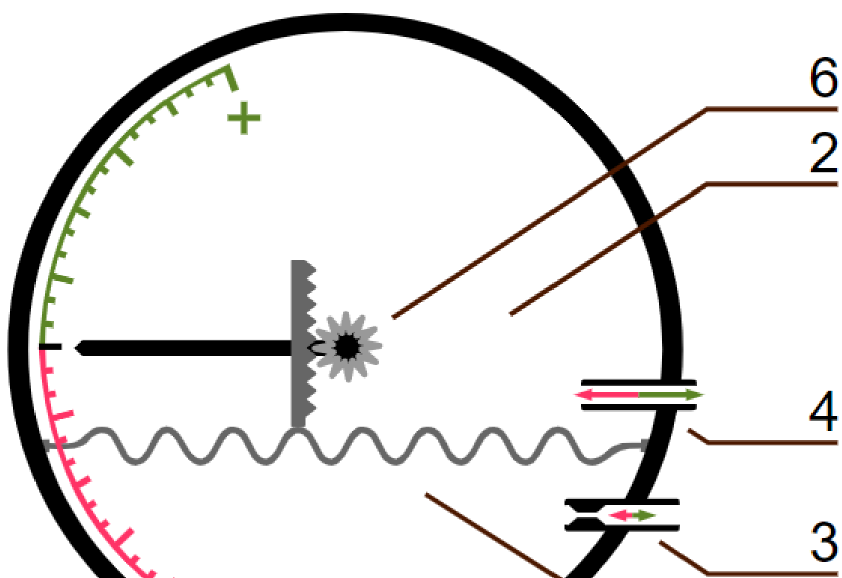


Set the pressure controller setpoint to 0.064 in. wg. The controller and fan work together to maintain 1800 CFM even as the filter loads up.

The velocity pressure control is configured as shown here:



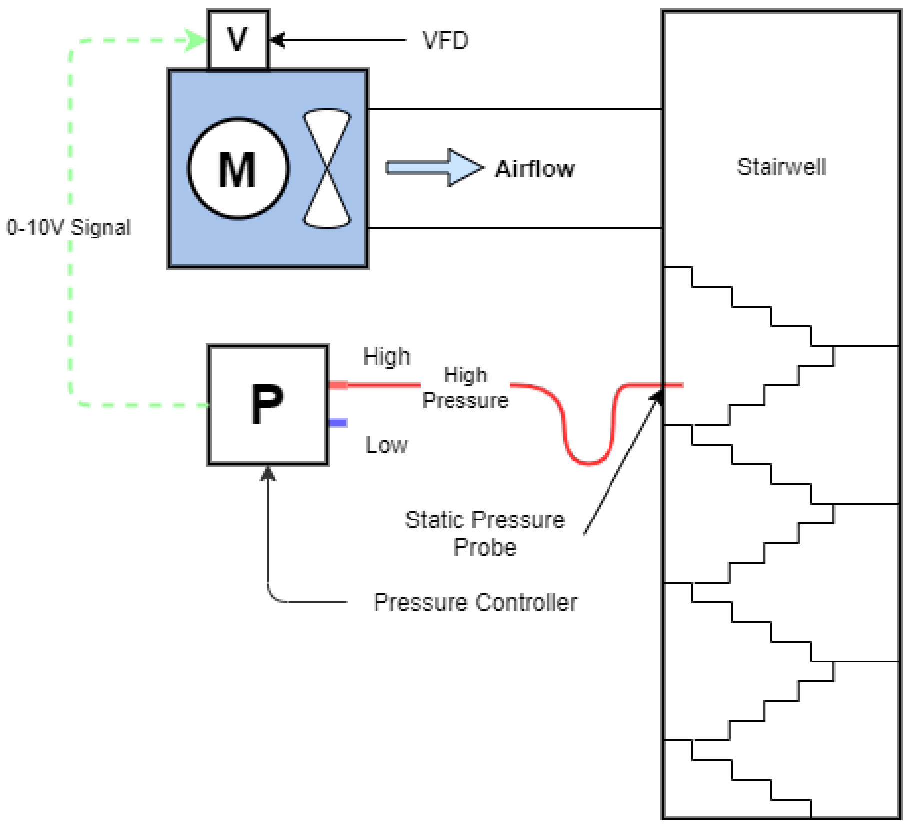
As the filter loads up, the velocity pressure will fall below the setpoint. The signal to the fan must increase to reduce the error and return the pressure to setpoint. Therefore, the controller must be wired and setup as REVERSE ACTING.



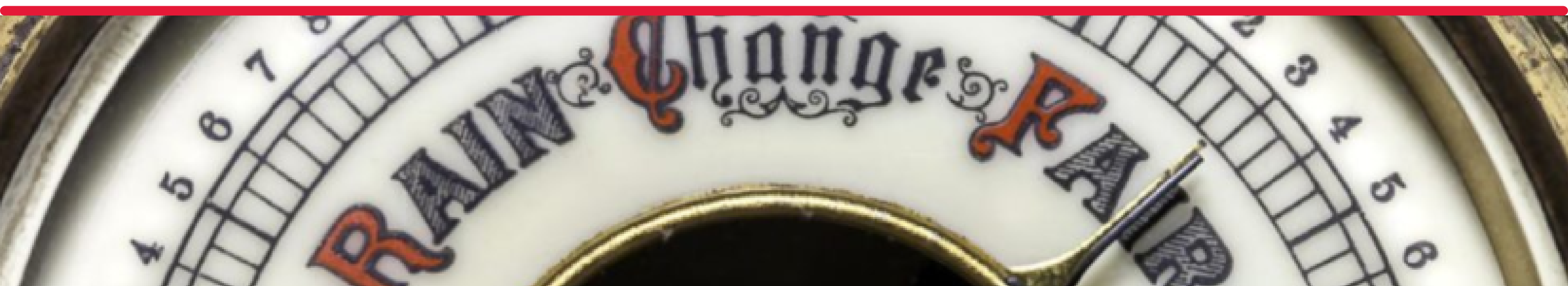
STAIRWELL PRESSURIZATION

A very common application for pressure control is stairwell pressurization. This is implemented when the building fire/smoke control system is in alarm, indicating the stairwell must be pressurized (kept smoke free) to allow for safe egress from the building.

The pressure controller is configured with the HIGH pressure routed to a static pressure probe located inside the stairwell and the LOW pressure port mounted outside the stairwell. When the fan is energized, it ramps up until the setpoint is met.



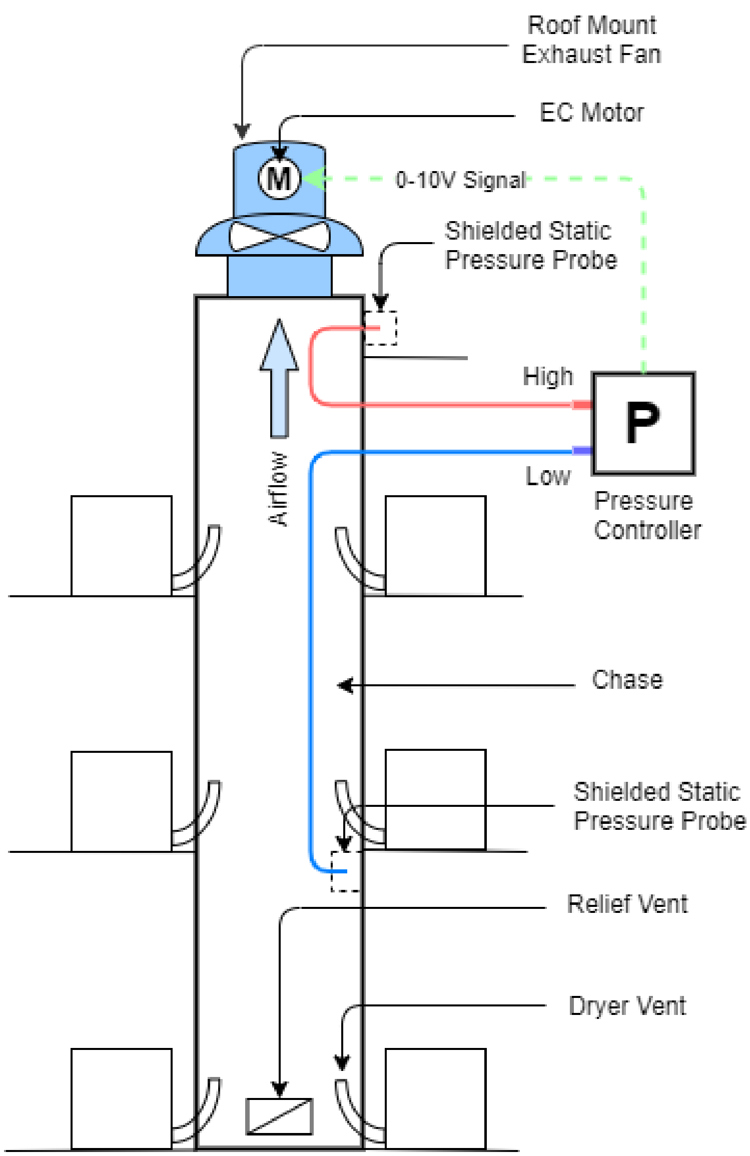
If the pressure in the stairwell drops below setpoint, an increasing output signal must be sent to the fan to speed it up and move the pressure to setpoint. This is reverse acting control.



DRYER EXHAUST

One strategy for dryer exhaust in multistory buildings is to create a chase with an exhaust fan on the roof. The fan runs at low speed (20-30% of max demand) to maintain negative pressure in the chase. There will normally be a relief opening at the bottom of the chase. The LOW pressure port is terminated in the chase about 2/3 of the way down the shaft and is shielded from dryer exhaust. The HIGH pressure port would terminate outside the chase, sheltered from moving air.

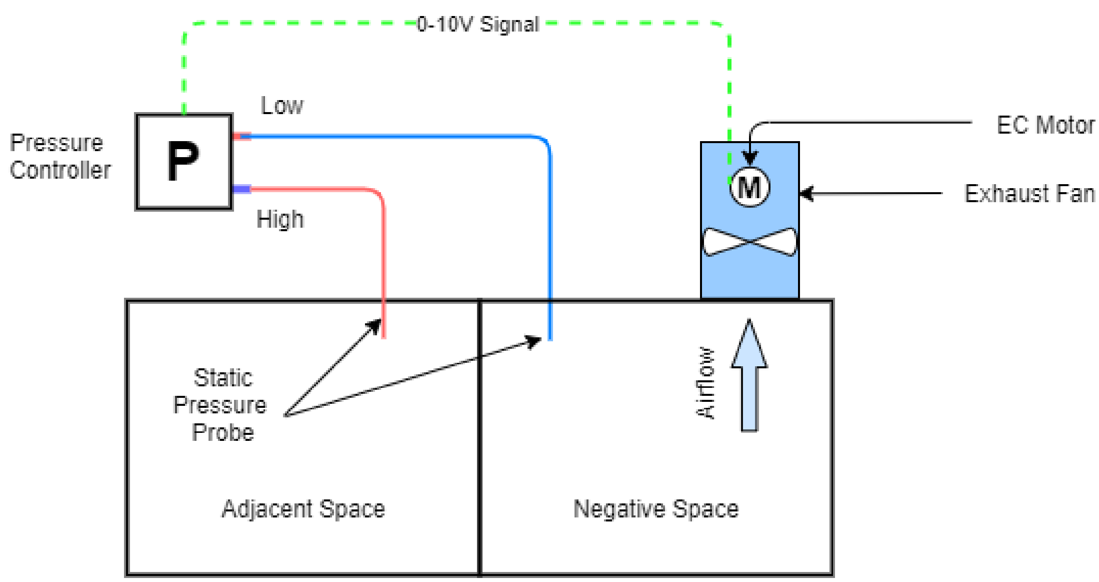
As individual dryers dump air into the chase the pressure increases. As the pressure increases, the pressure controller sends an increasing signal to the fan motor to speed up, moving the pressure toward setpoint. This is DIRECT ACTING CONTROL.



NEGATIVE PRESSURE CONTROL | EXHAUST FAN

In this example, a variable speed exhaust fan is used to maintain negative pressure in one space relative to an adjacent space. A tube is connected to the LOW pressure port and terminated in the negative space. The HIGH pressure port is terminated in the adjacent room. Both are terminated with static pressure probes.

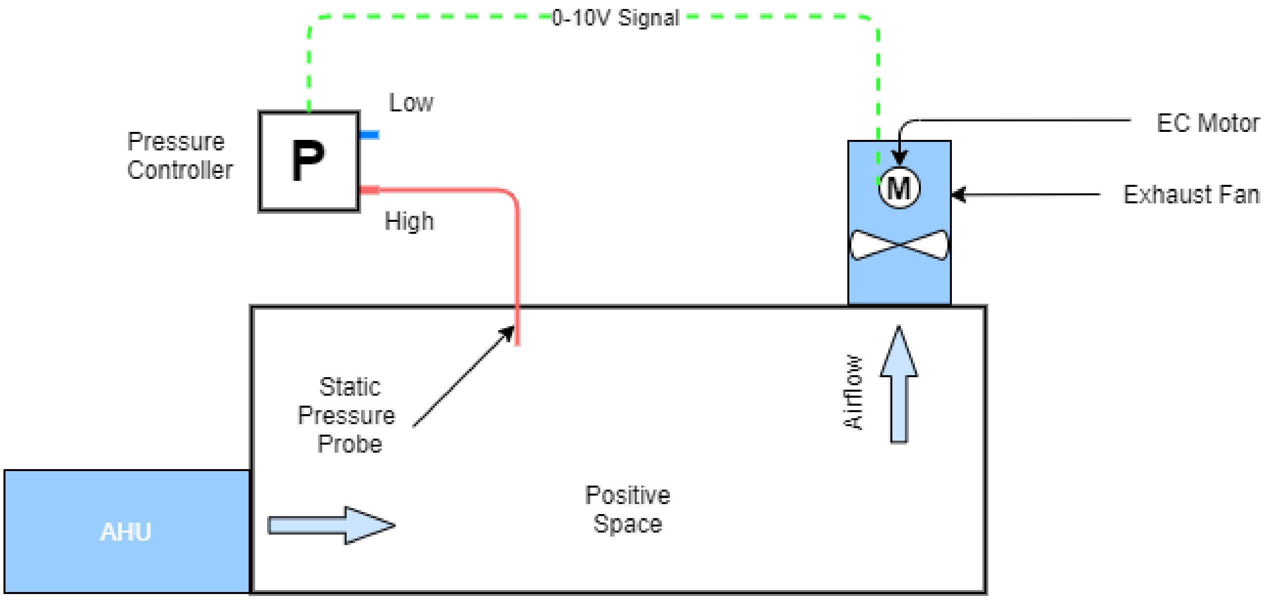
As the pressure in the negative space increases, an increasing output signal (0-10V) is sent to the exhaust fan motor, causing the fan to speed up, until the actual pressure and the setpoint are the same. As we have shown, this is direct acting control, therefore the controller is wired and setup as DIRECT ACTING CONTROL.



POSITIVE PRESSURE CONTROL | EXHAUST FAN

In this example, an air handling unit (with no return) supplies air to a space. This causes the pressure in the space to rise. A variable speed exhaust fan pulls air out of the room, and is maintaining a slight positive pressure in the space. We route the HIGH pressure port to the space and terminate with a static pressure probe. The LOW pressure port is left open.

As the input signal (pressure) rises above setpoint, the signal to the exhaust fan is increased to move the pressure to the setpoint. Therefore the controller must be wired and setup for DIRECT ACTING CONTROL.



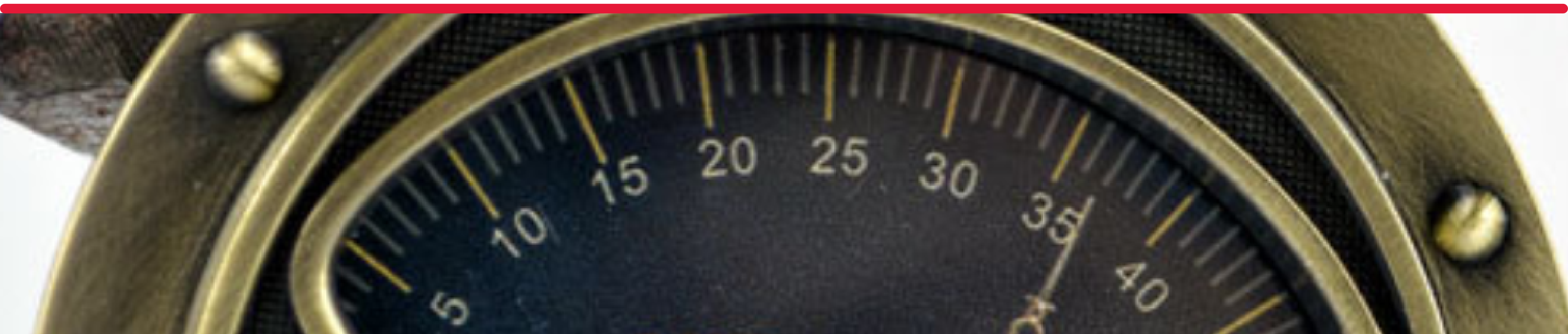
VARI-FLOW® PRESSURE CONTROLLER

The COOK Vari-Flow pressure controller (VFPC) is suitable for all the previously mentioned applications and more. By properly connecting the HIGH and LOW ports, proper wiring and setup, it can be configured to operate a fan to maintain a desired pressure and/or flow. A brief introduction to the basic connections and settings is presented below. ***For detailed installation instructions, the installation, operation and maintenance manual should be referred to.***

VFPC | DIRECT ACTING CONTROL

For DIRECT ACTING CONTROL, the VFPC is wired as shown here:

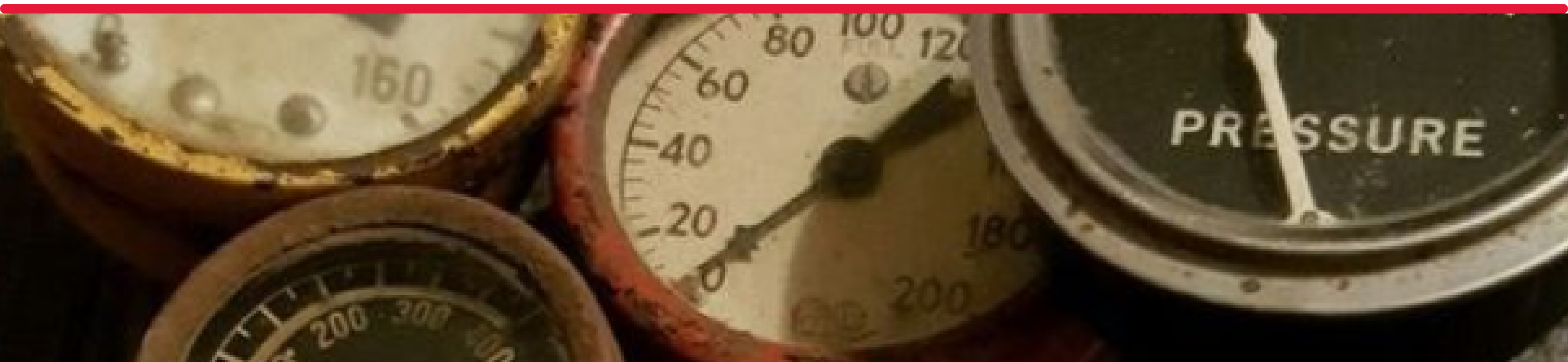
Within the menu there is an option to select the action. This is the selection for DIRECT ACTING CONTROL:



VFPC | REVERSE ACTING CONTROL

For REVERSE ACTING CONTROL, the VFPC is wired as shown here:

Within the menu there is an option to select the action. This is the selection for REVERSE ACTING CONTROL:



PRESSURE PROBES

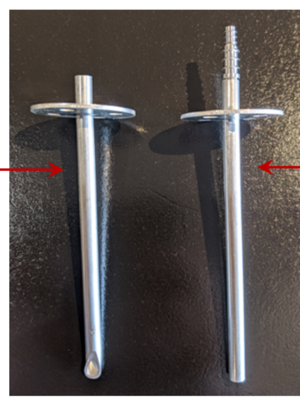
At this point, we should talk a bit about pressure probes. There are two basic categories of pressure probes commonly used in HVAC systems, static pressure probes and total pressure probes. Total pressure probes are typically used where velocity measurement is important, generally within ducts.

As we mentioned earlier, the difference between total pressure and static pressure at any point in a ducted system is velocity pressure. When we want to maintain velocity pressure (for constant airflow), we will connect a total pressure probe to the HIGH port and a static pressure probe to the LOW port.

$$\boldsymbol{Total\ Pressure - Static\ Pressure = Velocity\ Pressure}$$

Below, we see an example of each type of probe:

Typical Total Pressure Probe. Orientation of the tip is important on this probe. Open end is to face upstream.



Typical Static Pressure Probe. Orientation is normally perpendicular to the airflow.

SUMMARY

With an understanding of a few basic principals, pressure control in HVAC systems is a powerful tool that can be used in many applications.

This application guide is designed to give a high level overview of ways pressure control can be utilized. ***<u>For more detailed information, the Installation, Operation and Maintenance manual should be consulted for specifics related to installation criteria for the VFPC and pressure control applications.</u>***

NOTES

NOTES

COOK

Vari-Flow

Vari-Flow® blends ultra-efficient EC and PM motors and application-specific controllers to create energy saving demand-based ventilation systems.

Standard EC

Pre-Programmed EC

Pre-Programmed PM

Controls

2 Speed Controller

Air Balance Kit

Universal Controller
Temp/RH/VOC/CO_2

Remote Speed
Controller

Pressure Controller

Essential Advantages:

- **Ready to Run**
  Vari-Flow motors are pre-wired & pre-programmed from factory
- **Cost Savings**
  maximized by combining Vari-Flow motors and controls
- **Greater Efficiency**
  across entire RPM range
- **Equipped with**
  Air Balance Kit on all external control packages
- **Application-specific**
  control packages available for pressure, humidity, temperature, CO_2, VOC control and more!
- **Convenient**
  remote manual or automatic adjustability

Vari-Flow®

EC motors and compatible controls

Makes Demand-Based Ventilation Easy

Vari-Flow Electronically Commutated Motors and Controls create a powerful combination that can save you money.

Standard Features:

- Superior part-load efficiency and demand-driven control allow you to fine-tune your ventilation system to achieve minimum energy consumption and optimum ventilation.
- The Cook Vari-Flow motor and control offering provides the tools you need to start saving energy now.
- Vari-Flow Controls available for pressure, temperature, humidity, VOX, CO_2, two-speed and more.

Extra Benefits:

- Vari-Flow EC and PM motors provide superior part-load performance.
- Maximum potential for savings is reached when Vari-Flow motors and controls are combined.
- Each Cook fan provided with Vari-Flow motors and ordered with external signal capability will be supplied with a Vari-Flow Air Balance Kit.
- The entire offering of Vari-Flow motors and controls is integrated in Compute-A-Fan to simplify the selection process.

COOK®

Contact your **Cook Representative** or visit **lorencook.com** for more information!