

How to Select a Pressure Switch



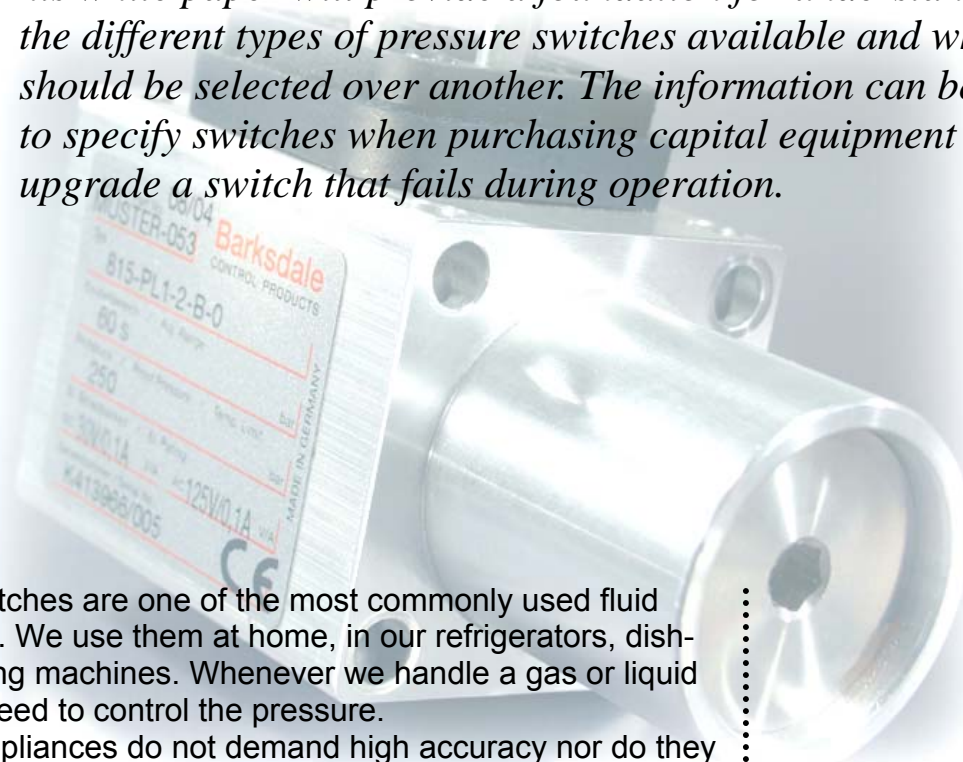
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How to Select a Pressure Switch

This white paper will provide a foundation for understanding the different types of pressure switches available and why one should be selected over another. The information can be used to specify switches when purchasing capital equipment or to upgrade a switch that fails during operation.



Pressure switches are one of the most commonly used fluid control components. We use them at home, in our refrigerators, dish-washers and washing machines. Whenever we handle a gas or liquid we almost always need to control the pressure.

Our home appliances do not demand high accuracy nor do they experience high cycle rates. By contrast, the pressure switches used in industrial machinery and systems must be rugged, dependable, accurate, and have a high lifecycle.

Most of the time we never think about pressure switches. They just show up with such machinery as paper machines, air compressors or pump sets. In this type of equipment, we depend upon pressure switches to act as safety devices, alarms, or as the control element within the system. But in most cases we give little consideration to this component when we make a purchase.

As young engineers, we're commonly told to "take care of the details and the rest will take care of itself." Why the focus on details? Because the tendency is to focus on the big, the expensive or the exotic. However, when we evaluate equipment performance, it is often the simple or inexpensive component failure that shuts a system down or affects performance. The cost of component failure can be measured in unscheduled outages, costly down-time and lost production.

One of the most common components in our plant is the one we may know least about. When a pressure switch fails, we tend to simply buy a replacement that is a duplicate of what just failed. If we are to improve the performance of our plant, however, we should break this paradigm. Rather than simply replacing the switch with "like kind," we need to consider what will best meet our need.

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CHOOSING A PRESSURE SWITCH

There are typically three situations when an engineer thinks about pressure switches:

1. When a hydraulic or pneumatic system fails.
2. When equipment or a system containing a pressure switch is purchased.
3. When designing an in-house system.

When a pressure switch fails, the engineer is generally on his own in trying to figure out if he should simply replace the switch with "like kind" or try to upgrade to something better. To determine if a different pressure switch should be used, the following process can be useful:

1. Identify the type of switch currently being used and its operating specifications. This information should be printed on the switch label. If it isn't, contact the OEM or the switch manufacturer.
2. Determine the failure mode. For example, if the switch does not actuate at the desired pressure, the problem could be cycle fatigue. Understanding system dynamics and the type of switch will help in diagnosis of the problem.
3. Based on the failure mode, consider replacing the switch with one that better meets your system's dynamics and operating needs. The goal is to eliminate the failure mode. In this example, if the switch type currently used is a diaphragm switch and the system cycles rapidly, the solution could be to select a diaphragm-piston switch if accuracy is not an issue, or a solid-state switch for higher accuracy and rapid cycling.

When purchasing equipment or a system containing a pressure switch, the engineer has at least four options:

1. You can specify the switch type, model number and manufacturer. This can be difficult for complex systems, especially if the system dynamics are not known.
2. You can specify features such as, "Pressure switches shall be rated for a minimum life of 1.0 million cycles, an accuracy of 0.50%, etc.", and leave it up to the vendor to select the correct switch.

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3. Combine the two approaches. For example, specify a quality switch manufacturer, the minimum cycle life and accuracy.
4. Simply do nothing and hope for the best.

Fortunately, when designing your own system it is relatively easy to identify operating parameters and critical switch characteristics. This allows you to optimize accuracy, life, ease of use, and other important features as they relate to your specific needs. All you need to know is the advantages and limitations each pressure switch design has to offer.

To be proactive and specify the correct switch for the application, or to successfully replace a problem switch, one must know the types of switches available and their strengths and weaknesses. And as with all specialties, pressure switches have their own unique language and terminology which needs to be understood simply to improve communications. The balance of this article will provide the reader with the necessary information to make an informed decision.

WHAT IS A PRESSURE SWITCH?

In its simplest form, a pressure switch is a device capable of detecting a pressure change, and at a predetermined level, opening or closing an electrical contact.

Although there are many different types, pressure switches fall under two basic classifications: electromechanical and solid state. Traditionally, pressure switches have been electromechanical devices. Their basic design has been employed for more than two hundred years. Today, however, inroads into this fairly ancient technology are being made by solid-state devices. We will discuss both electromechanical and solid-state switches.

ELECTROMECHANICAL PRESSURE SWITCHES

The most common electromechanical pressure switches are composed of a sensing element and an electrical snap-action switch. A number of different types of sensing elements can be used but they have one thing in common: they move in response to changes in the system pressure. Through their movement they directly act on the opening and closing of the snap-action switch's contacts.

Differential pressure switches are slightly different. As Figure 1 shows, there are two pressure ports, one for the low pressure side and the other for the high pressure side. The low pressure and high pressure fluids act on the same sensing element, in this case a diaphragm. Since the surface areas are equal on each side, the switch is in equilibrium when

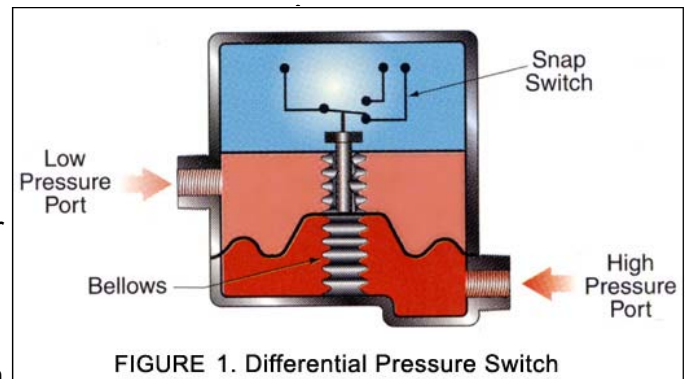


FIGURE 1. Differential Pressure Switch

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the pressures are equal. As pressure on the high-pressure side increases or pressure on the low side decreases, the piston moves up, and at a preset differential pressure, activates the snap switch.

Switches are commonly grouped together based on the type of sensor technology employed. The characteristics of the sensor tend to define the relative accuracy and life one can expect from the switch. Typical switch categories and their attributes follow.

Diaphragm Switches.

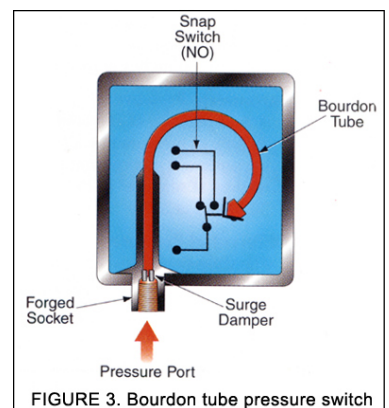
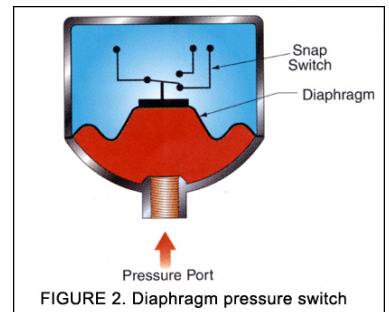
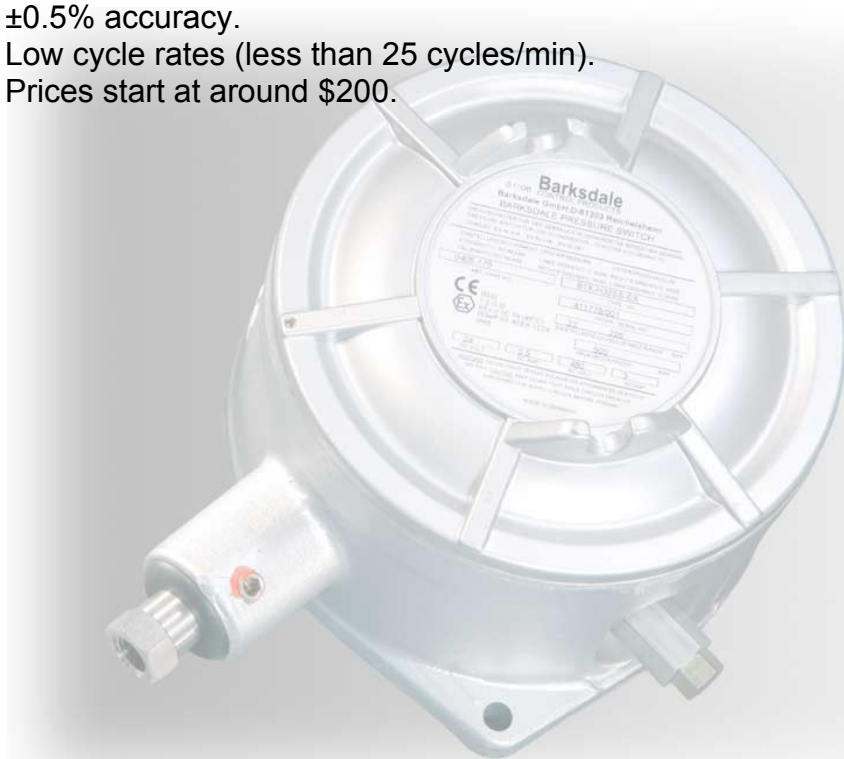
These switches use a weld-sealed metal diaphragm which directly acts on a snap-action switch (see Figure 2). Operating characteristics:

- Pressure up to 150 psi and vacuum.
- Accuracy to $\pm 0.5\%$.
- Low cycle rates (less than 25 cycles/min).
- Prices start at around \$100.

Bourdon Tube Switches.

As the name indicates, a weld-sealed bourdon tube is used to actuate the snap-action switch (see Figure 3). Operating characteristics:

- Pressure from 50 to 18,000 psi.
- $\pm 0.5\%$ accuracy.
- Low cycle rates (less than 25 cycles/min).
- Prices start at around \$200.



Diaphragm Piston (Dia-Seal Piston) Switches.

An elastomeric diaphragm acting on a piston which in turn actuates the snap-action switch (see Figure 4).

Operating characteristics:

- Pressure from vacuum to 1600 psi.
- $\pm 2\%$ accuracy.
- 2.5 million cycles
- Prices start at \$50.

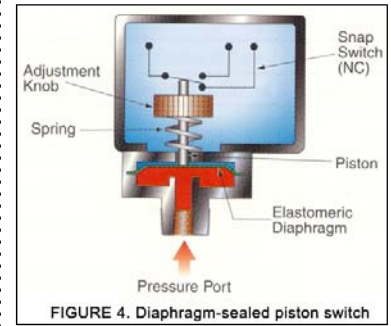


FIGURE 4. Diaphragm-sealed piston switch

Piston Switches.

An O-ring sealed piston acts directly on the snap-action switch (see Figure 5). Operating characteristics:

- Pressure to 12,000 psi
- $\pm 2\%$ accuracy
- 2.5 million cycles
- Prices start at \$100.

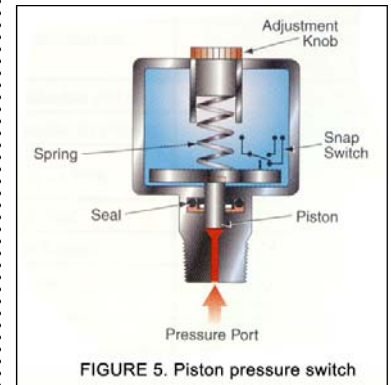


FIGURE 5. Piston pressure switch

SOLID-STATE PRESSURE SWITCHES

In 1980, Barksdale Inc., a subsidiary of Crane Co., introduced the first solid-state pressure switch. It was a simple device which combined a bonded strain gage sensor and triac switch. Today, there are a wide variety of solid-state pressure switches having one to four or more switch points, digital displays, analog and digital outputs, and full programmability. Figure 6 shows a diagram of a simple solid-state pressure switch without enhancements. In many cases they cross the line from being simply a switch to an open-loop controller. In addition to opening or closing the pressure switch circuit(s), they provide a proportional analog 4-20 mA signal or digital output. The analog signal can interface with PLCs (Programmable Logic Controls), DCSs (Distributed Control Systems) and computers.

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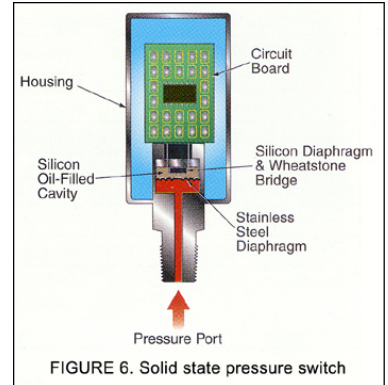
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Solid-state pressure switches provide a number of advantages over electromechanical switches, including:

- Much longer cycle life
- Improved accuracy to $\pm 0.25\%$
- High resistance to shock and vibration
- The ability to handle a wide range of system pressures
- Broad frequency response
- Excellent long-term stability.

The major advantage, however, lies in cycle life. Solid-state switches routinely have an operational life of 100 million cycles.

One concern with solid-state switches used in industrial and process settings is electromagnetic interference which can corrupt signal data. One should select a solid-state pressure switch that carries CE or other similar designations, to be in compliance with approved electronic standards. Additionally, a solid state switch requires an input power source to function. EMI/RFI does not affect electromechanical switches because the circuit is a mechanical switch that is either open or closed.

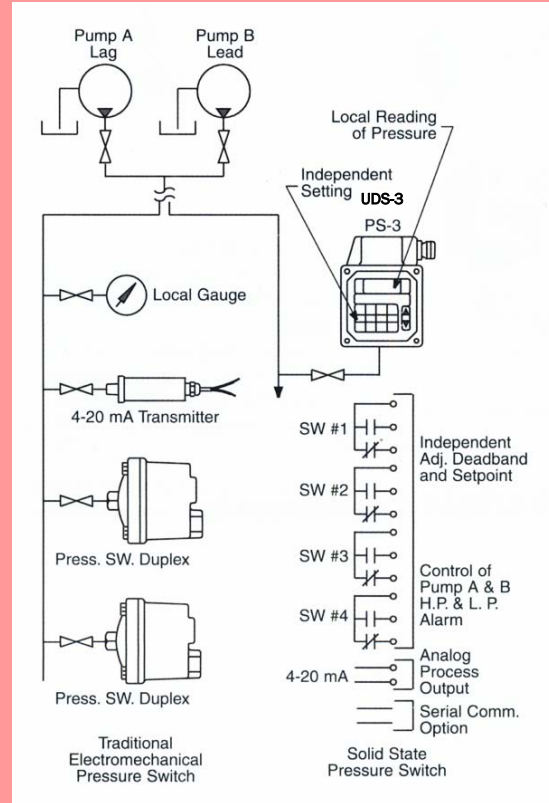


USING A SOLID STATE PRESSURE SWITCH TO MONITOR FOUR PRESSURE POINTS

The measurement and control of multiple pressure points is a common application. Four pressure points, for example, typically require as many as 12 different pieces of hardware. The same goal can be accomplished with a single solid-state pressure switch. The result is a savings in time and money.

A duplex pump control system, for instance, requires control logic based on four pressure settings with low- and high-pressure alarms and activation of either the leading or lagging pump. Conventional systems use either four individual or two duplex electromechanical pressure switches. Visual display is supplied by a pressure gauge, while a transmitter is added to provide a remote 4-20 mA signal. Each device requires an instrument valve, piping and wiring.

Current solid-state technology can replace this complexity with a single device that improves accuracy, extends life, and reduces installed cost. In addition, many applications require high/low alarms or start/stop values for the process variables. The electronics on the latest generation of solid-state pressure switches can be adapted to handle not only pressure, but level, temperature and flow as well.



Even with their list of attributes, however, the initial price of \$300 prevents many users from upgrading to this technology. If one is designing a new system, the selection of a solid-state switch may, in fact, be the most cost-effective solution. When a system requires multiple switch points, a local gauge and transmitters using a solid-state pressure switch can reduce the installed cost by one-half.

PRESSURE SWITCH CHARACTERISTICS

Understanding system dynamics is crucial to switch selection. The goal is to obtain a pressure switch that will meet your expectations in terms of life, accuracy, reliability, and ease of use.

The following lists the questions that need to be asked (and answered) and a summary of how each switch type is rated.

How Often will the Switch be Activated?

This issue will have a direct impact on switch life, system downtime and the overhaul schedule. Due to their design, electromechanical switches are subject to metal fatigue. A bourdon tube or diaphragm switch will typically provide one million cycles whereas a piston or diaphragm sealed piston switch will provide 2-1/2 million cycles. Because a solid-state pressure switch is not subject to metal fatigue, it will typically have a 100 million cycle life. An exception may be made when pressure changes in the system are very slight (20% or less of the adjustable range). Under such conditions, a bourdon tube or diaphragm switch can be used up to 2-1/2 million cycles before metal fatigue occurs.

What is the Cycle Speed?

This is another issue that affects switch life and preventive maintenance programs. The metal of a bourdon tube or diaphragm switch acts very much as a spring and high speed cycles should be avoided. When the cycle rate is less than 25 per minute, a bourdon tube or diaphragm switch is a good choice. For cycle rates to 50 cycles per minute, a diaphragm piston or piston switch will provide 1 to 2-1/2 million cycles, respectively. A solid-state switch should be selected whenever the cycle rate exceeds 50 cycles per minute since metal fatigue is not a problem.

How does the Switch Point Relate to Operating Pressure Range?

Selecting the proper relationship between the switch point and the operating pressure range of a switch is important because this relationship can affect accuracy and useful life. The general rule is different for solid-state and electromechanical pressure switches. When a solid-state pressure switch is selected, the switch point should normally be in the upper 25% of the operating range. For an electromechanical switch, the switch point should be in the middle of the operat-

“Understanding system dynamics is crucial to switch selection”

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ing range. A system which requires a switch to activate at 140 psi should use a solid-state pressure switch with an operating range of 150 psi, or an electromechanical switch with an operating range of 300 psi. Exceptions should be made when the system experiences dramatic pressure surges or when either life or accuracy is an overriding concern. The relationship between life and accuracy of an electromechanical switch will be discussed later in this article.

What is the Proof Pressure Requirement?

Proof pressure is the maximum pressure that the switch should ever see. When calculating the switch proof pressure, include spikes and surges. This is necessary to avoid damage to the switch.

Will the Switch be Subjected to High-Pressure Spikes and Surges?

Pressure surges and transient pressure spikes can greatly exceed the normal operating pressure of a system. It is not unusual for a switch to fail because the pressure spike exceeds the proof pressure. Bourdon tube, diaphragm and solid-state pressure switches are all sensitive to surges and spikes. If it is anticipated that the system is subject to surges, then one should select a switch with a higher proof pressure or install a snubber which will allow fast spikes to move by the switch without damage.

What Accuracy is Needed?

Accuracy for a pressure switch is defined differently than accuracy for an instrument. For a pressure switch, accuracy is the ability of the switch to repetitively operate at its setpoint. When in doubt, it is always easier to specify the best accuracy available. But one pays a premium for something that may not be needed. Typically, if the switch is used to alarm, 2% accuracy is sufficient. If one is controlling a process where the error of various devices is additive, then 0.25% accuracy may be absolutely necessary. The accuracy of piston and diaphragm-sealed piston switches is 2%, bourdon tube and diaphragm switches are 0.5%, and solid-state switches 0.25%. Remember, accuracy is referenced at the high end of the operating pressure range and decreases at lower pressure.

How Many Switch Points are Needed?

When sensing pressure at one point, it is normal that only one switch point is required. However, it is not unusual for a system to require two or even four switch points (e.g., high, low, high-high, low-low) to be monitored, controlled or alarmed. In designing a system, one could select a single switch for each switch point, or a single pressure switch capable of handling as many as three separate switch points. Most of the different sensor technologies have duplex switch

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capability, with a few having built-in triple switch functions. Solid-state switches can have as many as four independent switch points. There is normally an economic advantage to having a single switch handle as many functions as possible.

What Type of Housing is Needed?

Stripped switches don't have their own housing. They are normally installed inside a panel or multi-function enclosure. Due to cost and space considerations, this is a favored choice of OEMs.

Housed switches avoid possible hazards from loose wires in exposed locations. They are normally available in a variety of ratings with the most popular industrial switch housings being NEMA 4 and NEMA 4X for corrosive environments.

Terminal block pressure switches are housed and, in addition, equipped with enclosed terminal blocks. This eliminates the expense of buying and installing external junction boxes.

Explosion proof pressure switches are designed with heavy housings built to conform to accepted ATEX, UL and NEMA standards for containing explosions in hazardous environments.

Is There a Need to Adjust the Setpoint?

In some applications, one doesn't want anyone changing the setpoint. In other situations, adjustment is required based on system dynamics. Electromechanical switches have models that are factory set, have blind adjustment capability, or offer calibrated adjustment knobs. Solid-state switches offer precise keypad adjustments with digital readout.

Is a Tight or Broad Deadband Needed?

Deadband is the difference between the actuation point and the re-actuation point in a pressure actuation switch. For example: if a pressure switch is set to operate at 100 psi on increasing pressure, the switch will close when pressure rises to that point. As pressure drops to 95 psi the switch opens (this is the re-actuation point). The deadband of this switch is 5 psi, the difference between the set point of 100 psi and the re-actuation point of 95 psi. Deadband is sometimes referred to as actuation value, differential or hysteresis.

The deadband of a switch can be fixed or adjusted over a percentage of the full pressure range. Traditionally, a narrow deadband is used in safety services. A wider deadband is used on control circuits like hydraulic units. Tight or narrow deadbands tend to be found on bourdon tube and diaphragm switches, wide deadbands are available

“It is not unusual for a system to require two or even four switch points”

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in piston-type switches, while solid-state switches offer a fully adjustable deadband to 100% of full scale.

Accuracy or Life?

When one selects a solid-state pressure switch there is no trade-off between accuracy and life. One simply chooses a pressure switch where the switch point is in the upper 25% of the pressure range. Electromechanical switches have sensing elements (diaphragms, tubes and pistons) that are constantly being stressed and thus the location of the switch point versus the operating range is critical to both accuracy and life. The life of an electromechanical switch will be maximized by operating the switch in the low quarter of the operating range. Accuracy will be the greatest when operating the electromechanical switch at the upper end of the range. The best compromise is to operate the electromechanical pressure switch in the middle of the operating range. Figure 7 details the relationship between accuracy and life.

“When selecting a solid-state pressure switch there is no trade-off between accuracy and life”

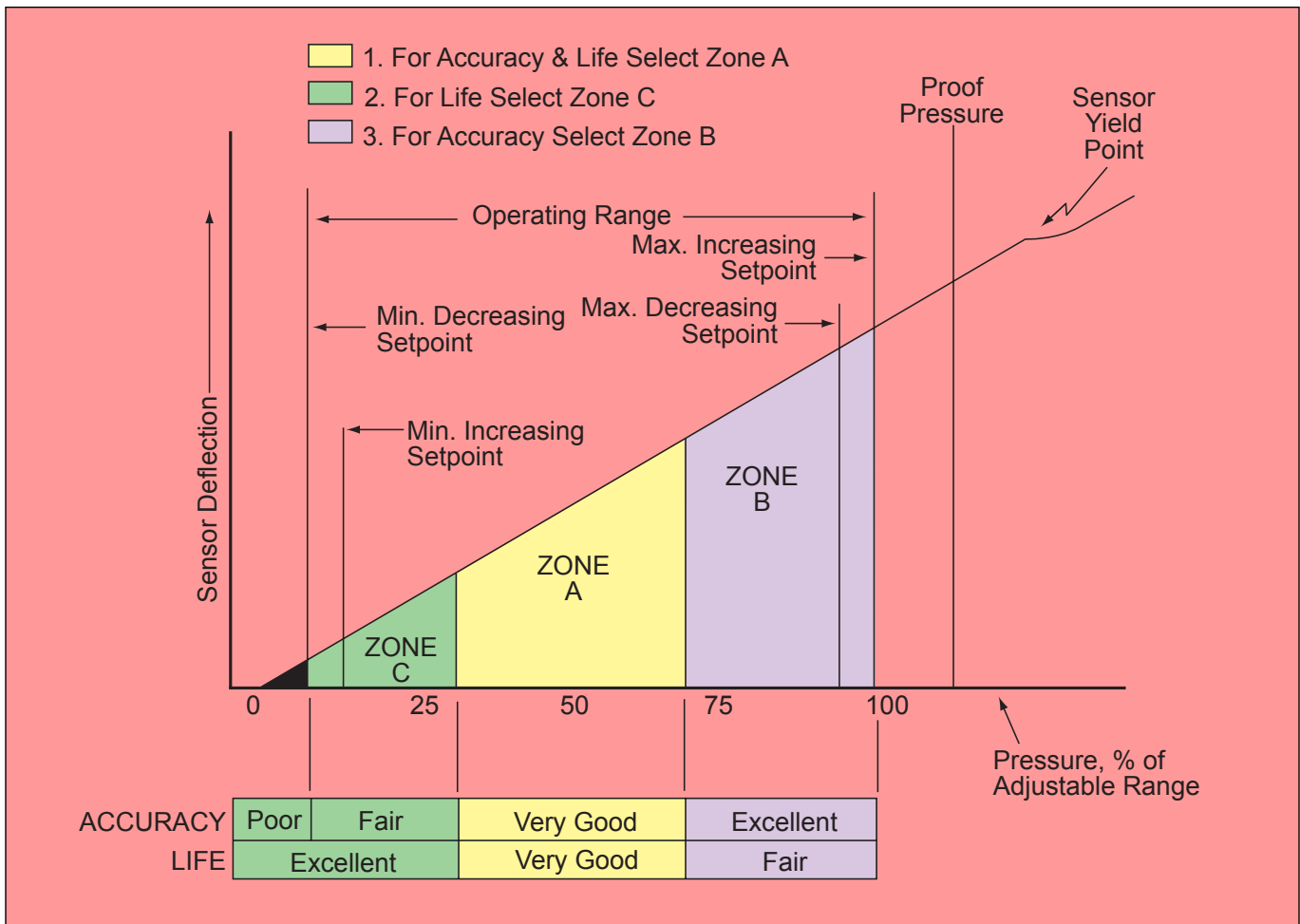


FIGURE 7. Selection of adjustable range for electromechanical pressure switches

Are More Features Needed Than Just a Switch?

Many times the system requires more than a pressure switch to open and close a circuit. A local gauge and remote signal may also be required. The traditional approach is to use individual devices. However, microprocessor-based solid-state pressure switches change the dynamics. One solid-state switch can offer up to four independent switches, digital readouts and analog/digital outputs.

SELECTING THE RIGHT PRESSURE SWITCH

The most important factor in selecting a pressure switch is to fully understand your requirements before beginning the selection process. Armed with that knowledge, you must consider a number of parameters in making a final selection: what kind of pressure sensor, cycle speed and life, pressure range, accuracy, proof pressure, number of switch points, deadband, housing type, adjustable vs. non-adjustable, electromechanical vs. solid state—all these factors must be contemplated. But with a clear understanding of the basics and by taking a reasoned, methodical approach you should find the selection process much easier.



Pressure Switch Selection Guide

		Switching Technology			
Characteristic	Solid state	Diaphragm	Bourdon Tube	Piston	Diaphragm Piston
					
Life (typical)	100 million Cycles	1 million cycles	1 million cycles	2.5 million cycles	1 million cycles
Cycle Speed	Greater than 50 cycles/minute	To 25 cycles/minute	To 25 cycles/minute	To 50 cycles/minute	To 50 cycles/minute
Operating Range	Vacuum to 10,000 psi Differential to 3,000 psid	Vacuum to 150 psi	50 to 18,000 psi	15 to 12,000 psi	Vacuum to 1,000 psi
Accuracy	±0.25% adjustable range	±0.5% adjustable range	±0.5% adjustable range	±2.0% adjustable range	±2.0% adjustable range
Switch Deadband	0 to 100% of adjustable range	2 to 7% of adjustable range	2 to 15% of adjustable range	2 to 15% of adjustable range	2 to 25% of adjustable range
Operating Ambient Temperature Range	0°F to 160°F	-65°F to +165°F	-65°F to +165°F	-20°F to +165°F	-20°F to +165°F
Proof Pressure	15,000 psi	300 psi	24,000 psi	20,000 psi	2,000 psi
Output	Relay, Analog, Digital, Visual Display	Snap Switch	Snap Switch	Snap Switch	Snap Switch
Operating Indicators	LED Indicator Lights to 4 Figure Digital Readout Calibrated Dial	Dial Option	N/A	Dial	Dial
Price Range (List \$)	From \$350.00	\$100.00	\$200.00	\$100.00	\$50.00
Warranty (typical)	3 Years	1 Year	1 Year	1 Year	1 Year

About Us

Barksdale is an ISO 9001 registered manufacturer of controls for industrial applications, specializing in the control and measurement of fluids. As a subsidiary of Crane Co., Stamford, CT, we have the financial resources of a large company, while our size allows individual customer partnerships. Founded in 1949, we are based in Los Angeles, CA, have a manufacturing facility in Reichelsheim, Germany and distributors around the world.

Professional Services

With a standard product line as the base, Barksdale prides itself in supplying specially designed or adapted products to meet customers' specific requirements. A wide range of optional modifications are offered on most of Barksdale's products, allowing you to customize the products to meet your specific application while using standard components. If, however, your requirements go beyond the available modification options, Barksdale's engineers are ready to assist, even if your application requires new technologies. For more than fifty years, customers have turned to Barksdale's engineers for custom designed components. The next time you are faced with a difficult, or even an "impossible" problem, call the Barksdale distributor nearest you.

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Throughout the world, Barksdale components can be found in steel mills, on machine tools, in auto plants, in power generation and distribution facilities, in chemical processing plants, in pulp and paper mills, textile mills, amusement parks, and food processing plants, on offshore drilling rigs, in oil and natural gas fields, rescue equipment, and on many forms of transportation equipment, both on- and off-road. Many industries use a variety of Barksdale's product lines. In agriculture, for example, you'll find Barksdale pressure switches monitoring "center pivot" irrigation systems, while Barksdale temperature switches help maintain optimum growing climates in greenhouses. Barksdale valves control the on-off operation of "drip" lines in orchards and vineyards and the water supply in cattle feedlots. In almost every industry, Barksdale products are at work, helping to build a better tomorrow.

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