PRESSURE SWITCHES - A SHORT REFRESHER

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Pressure switches have become such simple and commonplace items that many people have forgotten how to specify them. This short discourse is intended to refresh those jaded memories. We look at how the pressure switch must interface with the process, the environment, the monitoring system and the operators, and how these interactions influence the switch design.

INSTRUMENTATION

A pressure switch in the traditional sense is a passive device designed to output a binary signal in response to changing pressure conditions. While active devices are making an appearance, and offer the advantage of customised performance, they do nothing that a pressure transmitter and SCADA system cannot already do, and require additional power and associated cabling. The mechanical pressure switch is a passive device, requiring no power to operate, and in process plants offers a completely redundant safety system.

A systems approach to the pressure switch

A pressure switch is an open electro-mechanical system interacting with the process being monitored, the monitoring system, humanity and the environment (see Figure 1). Most of the following discussion will be based on these interactions.

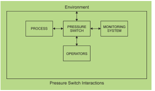

Figure 1.
Pressure switch interactions

The interaction with the monitoring system is the most important set of interactions from the point of view of the user, as it defines what the user expects from the switch. In addition to the user requirements, knowledge of the interactions with the environment and the process enable the vendor to make an appropriate choice of pressure switch design to put forward to the user. The man-machine interface in this application is of less importance, affecting mainly ease of adjustment and access to wiring.

Interfacing with the Monitoring System

I have deliberately not referred to this as the 'electrical system' to allow for the inclusion of pneumatic switching, although most ned as the difference between the point at which the switch sets (changes state), and where it resets (see Figure 2). If a switch had no deadband, it would oscillate at the setpoint, not knowing whether to open or close.

Deadband size: Obviously the deadband must be greater than process noise, otherwise chattering will occur. Other than that, process conditions and monitoring requirements will determine what deadband can be tolerated. The extent of process change is a good indicator, as well as the purpose for which the switch is installed. When the switch is used for monitoring, the allowable deadband should be comparable to the intermediate area between normal operating conditions and the abnormal condition which the switch is installed to warn against. Take care with this decision. Cases are known where a plant had to be shut down to allow the switch to reset. When the switch is used for control, for example on air compressor receivers, greater deadbands are required. Deadband is affected by switch design, pressure sensor design, and the linkage between them.

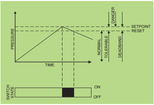

Figure 2. Switch operation and deadband.

Deadband adjustment: many people think deadband adjustment is a good thing, but it immediately restricts choice. The lowest deadbands are always fixed.

Repeatability: This is the forgotten partner of deadband and setpoint parameters, and is in fact the tolerance which must be applied to the setpoint. Top quality switches achieve repeatability figures as good as 0.5%. Switches that do not specify repeatability usually have a sound reason for their amnesia. Don't blame the switch, however, the onus is on you as the specifier to define your requirements and conditions.

Interactions: Due to the interactions mentioned above, small deadbands will be associated with close repeatability, as the result of efficient linking mechanisms

Interfacing with the Process

The requirement to tolerate process conditions is common to all pressure instruments.

Temperature: Switches generally have difficulty in handling process conditions outside the 0 - 100˚C range directly. Remote mounting may be required.

Viscosity and/or solids: The process connection must be compatible with the fluid conditions, so that the sensing element is in touch with process conditions without restriction or blockage.

Chemical seals may be required to interface the chosen pressure sensor with the medium.

Corrosivity: Materials of wetted parts need to be compatible with process fluids.

Pressure: The process will impose a pressure range on the instrument, which need not necessarily coincide with the setpoint requirements, although it must obviously overlap them.

Interfacing with the Environment

The specification item most affected by the environment is the enclosure.

Ingress protection: This is well documented. A known standard should be requested. IP and NEMA ratings are common for Europe and America respectively.

Haxardous areas: Mechanical switches are usually "simple electrical apparatus" not storing or generating electricity, and can be used in intrinsically safe circuits without further certification. For power circuits which do not qualify as intrinsically safe, approved enclosures are required for operation in Zone 1 (Division 1) or Zone 2 (Division 2) areas. For Zone 0 (Division 0) pneumatic switches are the only permissible power switches.

Switching element protection: In corrosive areas, the actual switch (component not instrument) may need to be protected from its environment. Different nomenclature use may be experienced, so we define our understanding of the following:

- ***Unprotected:*** No steps have been taken to prevent the ingress of atmosphere into the switch mechanism. This would be the norm.

- ***Environmentally sealed:*** The switch is protected from its environment by an enclosure sealed with elastomeric seals, eg. O-Rings, which may degrade.
- ***Hermetically sealed:*** The switch is protected from its environment using fusion seals, eg. glass to metal joints or all welded enclosures, providing permanent sealing.

Contact protection: Many contacts are considered self-cleaning due to the switched current burning off contamination. This does not apply in low current circuits, eg intrinsically safe, where gold-plated contacts can provide extra reliability. Hermetically sealed contacts are often inert gas purged, eliminating oxidation.

The Human-Machine Interface

We can use buzz-words too! Somebody is going to have to install, adjust and maintain this device.

Access: The electrician is going to want a roomy enclosure with sound terminal blocks to attach his wiring.

Setpoint adjustment: The operator is going to want a scale to indicate where the setpoint is. There should be some locking mechanism to prevent the adjustment changing.

Pressure switch design

Now that all the interactions have been defined, the pressure switch vendor is now in a position to make a proposal.

The pressure switch mechanism comprises a pressure-sensing element, a switching element, plus a transmission mechanism to transfer the sensor deflection to the switch, all packaged in a suitable enclosure. This assembly has to accommodate the conflicting demands made by all the above interactions.

Pressure Sensors: the usual types of pressure sensor are found once again

- ***Piston:*** A piston acting against a range spring is the simplest mechanism. It can tolerate high overpressures and can be used for medium to high pressure applications. It does not tolerate solids well, and tends to be insensitive. It requires venting to deal with leakage past the piston seals, and fugitive emissions must be considered.
- ***Sealed piston:*** This uses a flexible diaphragm to seal the piston from the process fluid, making use on dirty fluids and high pressure gas feasible, while retaining high overpressure capability. Actual example: setpoint range 1 to 6 bar, maximum 27 bar, best deadband 40 mbar.
- ***Bellows:*** This is best used on fairly clean fluids at low to medium pressures. Fluid is sealed within the bellows stack. The bellows mechanism offers good sensitivity but limited overpressure capability. Actual example: setpoint range 50 to 350 mbar, maximum 1 bar, best deadband 2 mbar.
- ***Bourdon tube:*** This is best used for clean fluids at medium to high pressures. The fluid is sealed in the tube. The bourdon tube is bulky, but offers good sensitivity, but little overpressure is available. Actual example: setpoint range 0 to 100 bar, maximum 125 bar, best deadband 1.2 bar.
- ***Diaphragm:*** This design offers an open connection which can be of hygienic design, which will tolerate solids and viscous media. The diaphragm design is suited to lowish pressures with very high overpressure capability, while providing fair sensitivity. Actual example: setpoint range 50 to 350 mbar, maximum 200 bar, best deadband 15 mbar.

These varied designs are roughly listed in order of increasing cost. These each tend to have well-defined areas of application, and often select themselves.

Sensor: switch mechanism: These can be simple or complex, depending on requirements. Often in fixed deadband applications a direct link from sensor to switch is all that is required. Sensitive designs may include knife-edges to reduce friction and provide leverage. Designs with good scales may provide calibration adjustments. In general, mechanisms can be divided into two types:

- ***Fixed deadband:*** Alarm monitoring switches are usually of this design, which presents the lowest possible deadbands. Specific deadband requirements may be achieved by judicious switch selection.
- ***Adjustable deadband:*** An auxiliary mechanism allows the deadband to be adjusted within wide limits.

Switch Element: These are usually of the microswitch design. Sample unprotected switches offer the best performance per Rand. Increasing capacity and complexity usually increase both deadband and cost. Light duty switches are often limited to ac or dc only. General-purpose switches handle heavier currents in both ac and dc modes.

Environmentally sealed versions are more complex. Hermetically sealed capsules can provide reliable high current dc switching under extreme environmental conditions such as acid spillage, but at deadbands often 10 to 15 times higher than the most sensitive solutions.

Combined functions: Some users will want to combine indication with switching. Usually a combined unit ends up a compromise, making a poor pressure gauge and a poor switch. Dedicated units provide the best performance. These may be mounted on a common manifold requiring a single process entry.

Quality: This is always difficult to define, but switch quality should be related to the plant it is protecting. Use a cheap switch to control a DIY air compressor or a brake light in a car, but look to something better to protect a jumbo jet or a power station turbine.

Conclusion

Like most things when you delve into them deeply, pressure switches present complex relationships between contradictory requirements. (Although we have discussed pressure switches, the same principles apply to pressure difference switches and filled system temperature switches.) Be aware of the more important of these relationships, and split your specification into essentials and desirables. You might just get lucky!