Choosing the Proper Regulator for Applications with Corrosive Fluids or Aggressive Environments

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Regulators are highly technical, highly specialized fluid handling components. So, the next time you need one please do not just grab one out of the supply cabinet and install it with the vague sense that it will work. Even if it seems like it the regulator was properly selected, it may not be doing what you think. Contamination of your gas stream or inaccurate pressure are possible results that can lead to off-spec product.

In any application with even the smallest mix of corrosive gases or liquids or aggressive environmental conditions, a stainless steel regulator should be considered. There are several types of stainless steel regulators, including pressure-reducing, back-pressure, and vaporizing. Within each of these three classifications, there are additional choices to be made between piston and diaphragm regulators, and two-stage and one-stage regulators. Once the appropriate type of regulator has been identified, further choices should be made concerning the materials employed for critical components, such as the diaphragm and the poppet seat.

In sum, regulators are available in a variety of types, designs, and materials of construction, and choices between them should be deliberate, with specific consideration given to the gases, phases, pressures, and temperatures in question.

Basic Types of Regulators

Regulators control pressure. They are the pivot point between high and low pressure. It will always be the case that on one side of the regulator there is higher pressure, and on the other there is lower pressure. On the high-pressure side, the regulator mechanically controls a pressure drop, so that on the low-pressure side pressure will remain relatively constant. Most common applications require a pressure-reducing regulator, which means the inlet pressure undergoes a mechanically controlled pressure drop, resulting in a relatively constant pressure at the outlet. In some cases, the reverse may be required. In such cases, a back-pressure regulator would be used to mechanically control the outlet pressure, so that a relatively constant pressure is maintained at the inlet.

Figure 1 shows an analyzer system with pressure-reducing and back-pressure regulators performing typical functions. Note that the pressure-reducing regulator is receiving high pressure (35 to 40 bar) from the process line and reducing pressure to a stable supply pressure (1.975 to 2.025 bar) as the gas flows into the analyzer. In this application, the analyzer system needs to maintain a pressure of 2 bar. Because of pressure fluctuations in the process stream where the sample is being returned, a back-pressure regulator is employed. It maintains a stable pressure on the inlet side and shields the analyzer from the downstream pressure fluctuations.

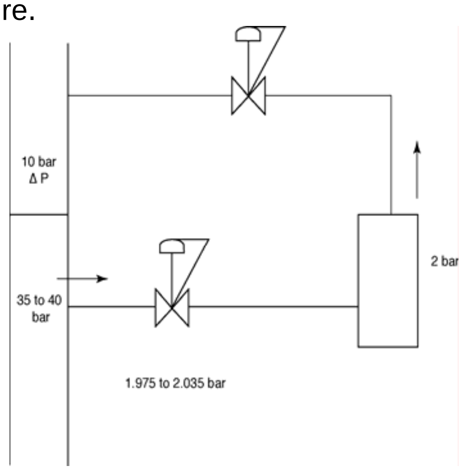
A vaporizing regulator is a pressure-reducing regulator used either to prevent a phase change or to induce one. A steam or electric heating element is part of the vaporizing regulator. In some cases, a rapid pressure drop may result in the Joule-

Thompson effect, where a gas loses heat as it undergoes a complete or partial phase change from a gas toward a liquid. In these cases, the regulator may freeze-up. A vaporizing regulator applies heat at the point of the pressure drop, preventing the phase change and freezing from occurring. In other cases, a liquid may need to be analyzed in a vapor form, typically in gas chromatograph applications, in which case the regulator applies heat to vaporize the liquid to a gas.

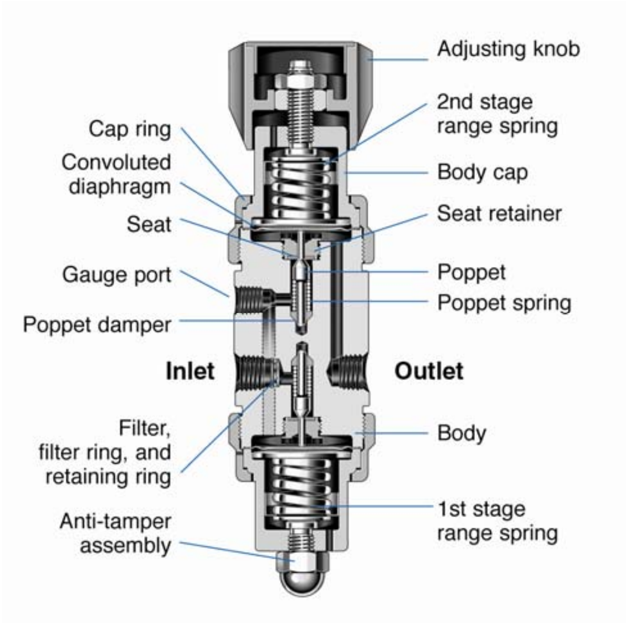
One- or Two-Stage Regulators?

One-stage pressure-reducing regulators are sufficient in most applications where the inlet pressure is relatively constant. While one-stage regulators are more susceptible to a phenomenon known as supply pressure effect (SPE) than two-stage regulators, the determining factor resides in the pressure variation of the high-pressure supply. SPE is the ability of a regulator to adjust to changes in the high-pressure supply to the regulator. In applications where the high-pressure supply is subject to large variations, a regulator with a low SPE will provide the most stable low-pressure delivery. Therefore, a one-stage regulator will generally deliver a stable outlet pressure when the high-pressure supply is stable.

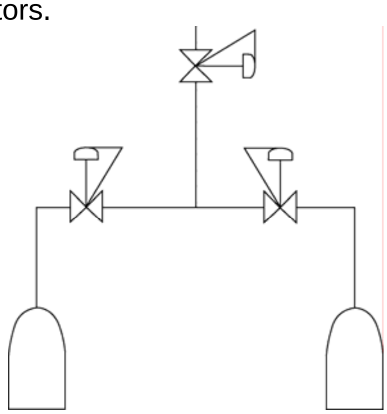
A high-quality, one-stage regulator will deliver an outlet pressure that may be estimated using the following formula: ΔP (outlet) = ΔP (inlet) x 0.01. In other words, outlet pressure is 1 percent of the difference in inlet pressure variability. In Figure 1, inlet pressure varies by 5 bar (40 to 35 bar), so 5 bar x 0.01 equals an outlet pressure variability of 0.05 bar. If the outlet pressure is set for 2 bar, and the inlet pressure rises from 35 to 40 bar, the outlet pressure will drop from 2 to 1.95 bar. The inverse relationship between the high-pressure (inlet) rising and the low-pressure (outlet) dropping is typical of one-stage regulators. The high-pressure rise causes the valve seat to constrict slightly, reducing the regulator orifice size and the corresponding outlet pressure.



A two-stage regulator consists of two one-stage regulators in series and combined into one component (figure 2). The first regulator reduces the high-pressure supply to an intermediate point between the inlet pressure and the desired outlet pressure. The second regulator reduces the intermediate pressure to the desired outlet. To calculate the variability of outlet pressure for a high-quality, two-stage regulator, the variability in the inlet, high-pressure supply is multiplied by 0.0001 because each regulator reduces the variability by 1 percent (0.01 x 0.01 = 0.0001). In a typical application for a two-stage regulator, a cylinder gas is emptied at a near constant outlet pressure. As the cylinder empties, pressure at the regulator inlet will drop from 175 bar to 5 bar, for example, as the cylinder becomes depleted. In this example, the variability in inlet pressure is 170 bar. If the target outlet pressure is 2 bar, the outlet pressure with a two-stage regulator will drop from 2 to 1.983 bar. On the other hand, if the same gas cylinder were outfitted with a one-stage regulator, the pressure would drop from 2 bar to 0.3 bar.



While a two-stage regulator is handy, two one-stage regulators may work just as well or better in some applications, such as a cross-over arrangement, where two gas cylinders feed one point of entry (Figure 3). One cylinder is used until its pressure drops below a certain point; then, the other cylinder starts to be used. One-stage regulators are located off each cylinder. An additional regulator (often referred to as a line regulator) is located at the entry point to the system, so at all times the gas is passing through two regulators.



Diaphragm Regulators

Diaphragm regulators generally are the most sensitive in response to changes in pressure, especially in low-pressure applications. Depending on their rating, they may be used in pressures up to 248 bar. In a diaphragm regulator, a thin metal diaphragm flexes as the high-pressure inlet varies. This flexure causes the regulator poppet to move in and out of the regulator seat. This compensating action is what causes the downstream pressure to remain constant. As inlet pressure rises, the diaphragm flexes up, which allows the poppet to rise into the seat and reduces the effect of the increasing inlet pressure so as to provide a constant outlet pressure. As the inlet pressure drops, the force on the diaphragm is reduced so that it flexes down and pushes the poppet out of the seat. This action allows for an increase in flow to pass through the regulator, which in turn creates a stabilizing pressure at the outlet. The flexibility of the diaphragm is vital to the long-term performance of the regulator. Flexibility is attained in one of two ways. The diaphragm could be perforated and then coated in PTFE or another, flexible material. In this design, the PTFE may erode, in which case a leak can occur since the diaphragm is designed with holes in it. An alternative design is to use a solid, convoluted diaphragm, which is a diaphragm with a fluted configuration around its perimeter to enhance flexibility.

Perhaps the best seal for a diaphragm regulator is a metal-to-metal seal. In this design, the diaphragm sits in the regulator body and is held in place by the cap assembly without the aid of an elastomeric or polymeric seal. A metal-to-metal seal provides a reliable seal and is less sensitive to changes in temperature.

Between the diaphragm and the cap assembly, the use of a backing plate, which is a sturdy stainless steel disk, can guard against diaphragm rupture. It also helps apply uniform pressure across the entire surface of the diaphragm.

The poppet is a critical piece in a diaphragm regulator. The poppet looks like an upside down funnel with a thin, cylindrical stem extending up from the top and down from the bottom. The poppet is made of high-grade stainless steel (e.g., S17400 stainless steel) and electropolished to provide a high-tolerance seat seal. In a pressure-reducing regulator, the poppet is spring-loaded and held vertically in the inlet channel, with the tip in constant contact with the diaphragm. With the poppet pushing up and the diaphragm pushing down, the two work together toward the desired balance. The poppet closes or opens the regulator inlet as its conical shape fits against a precision machined seat. A damper fitted to the bottom of the poppet supports and centers the poppet to reduce noise and vibration in high-flow conditions.

Piston Regulators

Piston regulators are generally used in higher pressure (>35 bar) applications, although they may also be used at lower pressures. In a piston regulator, pressure is controlled by means of a spring-loaded piston, which is a stainless steel, inflexible disk that lies flat in the vertical cylinder of the regulator, that is a piston. The piston seals against the cylinder walls by means of an elastomeric O-ring seal. The thickness of the piston, along with the O-ring seal, allows a piston regulator to achieve higher working pressures than diaphragm regulators. Compatibility of the O-ring material with the regulated process stream is an important consideration when specifying piston regulators. Likewise, the surface finish of the inside chamber is critical so that the O-ring seal between the piston and the cylinder wall can move freely up and down, thereby increasing the overall sensitivity of the regulator. The operation of a piston regulator is very similar to that of a diaphragm regulator. Adjusting the knob to achieve a higher outlet pressure causes the piston to push down on the poppet, which moves it out of the seat and creates a higher outlet pressure.

“Droop” and “Creep”

"Droop" and "creep" are two undesirable conditions. Droop determines the overall functionality of a regulator and occurs when more flow is required at the outlet than the regulator can provide. In other words, the throughput of the regulator (often measured in C_v) is not suited to the application.

Creep occurs when the poppet is in the closed position, yet the seat allows pressure to escape to the outlet side. It generally occurs because the seat may have been damaged or eroded. Regulator seats can be compromised by particulates in the process stream, which can cause minor imperfections in the sealing surface. The high flow and small orifice that is created during the regulation of pressure combine to turn a very small particle into a very fast projectile. As such, these small particles can nick the surface of the seat and cause leakage of pressure from the high-pressure inlet to the low-pressure outlet. In closed systems, this leakage can equalize the outlet and inlet pressures, which can result in an undesirable condition. When the system is opened via a control valve, a burst of high pressure could be the result.

Materials of Selection

With stainless steel regulators for high-purity applications, particular attention should be paid to the materials of construction. For the diaphragm, 316 stainless steel may not be sufficient, and an alloy such as X-750 may be more appropriate.

Likewise, the poppet seat is critical. A harder fluorpolymer is not as forgiving and will not seat as well as a softer material. On the other hand, the harder material will be more resistant to abrasion. The poppet seat should be modular so an appropriate material (e.g., PEEK, PCTFE) may be chosen based on gas/liquid content, pressure requirements, and temperature.

Conclusion

When selecting a regulator, the principal rule is to know the application, including the gas/liquid content, temperature, and flow rate. The regulator should be chosen with these particular parameters in mind. Once the type of regulator has been chosen (back-pressure or pressure-reducing, piston or diaphragm, one-stage or two-stage), close attention should be paid to regulator construction, including the quality of the shell seal, ease of stem adjustment, diaphragm/piston seal, integral filtration, and poppet seating. Ask your sales and service representative to explain the inner workings of the regulator so that you can make the most educated decision when specifying regulators for your particular applications. Finally, quality and type of materials should be given special attention. The same regulator may be outfitted with different diaphragms and seat materials to ensure safe and proper functioning of the regulator over time.

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