

Matching valve type to function:

A tutorial in valve selection

When selecting a valve for an instrumentation system, your choices may seem overwhelming. Just to name a few, there are ball valves, diaphragm and bellows valves, as well as check valves, excess flow valves, fine metering, gate, multi-port, needle, plug, relief, rising plug, and safety valves. Furthermore, each of these valves comes in many sizes, configurations, materials of construction, and actuation modes. To make the best choice, it is always good practice to ask the first question in valve selection: What do I want the valve to do?

By Michael Adkins, Swagelok Company

Most valves fulfill one of five primary functions: on-off, flow control, directional flow, over-pressure protection, and excess-flow protection. Matching valve type to function is the first and most important step in the valve selection process. It is not unusual in the field to see the misapplication of valves, such as a ball valve used for throttling flow. In some cases, the mismatch can be catastrophic, say, if a ball valve were used in a high-pressure oxygen system. With a source of ignition, the sudden burst of oxygen – enabled by the fast opening of the valve – could lead to an oxygen fire.

Below is a tutorial reviewing the basic types of valves, how they work, what functions they fulfill, and what to think about when choosing one over the other.

On-Off Valves

On-off control is the most basic valve function. Valves in this category stop and restart system fluid flow. Primary on-off valves are ball, gate, diaphragm, and bellows valves.

Perhaps the most common of all valve types, ball valves (see Figure 1) are designed for on-off control. Quarter turn actuation starts or stops flow by positioning a metallic ball in a straight-through flow path. The ball has a large hole through the centre of it. When the hole is lined up with the flow path, it enables flow. When it is turned 90 degrees from the flow path, it stops flow. If you are seeking an on-off valve with quick shutoff and high flow capacity, then a ball valve is a good choice. The position of the handle provides a quick indication of whether the valve is open or closed, and, for safety purposes, ball valves are easy to lock out and tag. They are most practical and economical at sizes between 1/4 inch and 2 inches (6 and 50 mm). Typically used for process control rather than instrumentation applications, gate valves are commonly chosen for on-off control, particularly for lines above 2 inches. They are also frequently used as the first valve off the process line for process instrumentation, often in a double block and bleed configuration. Among the oldest types of on-off valves, they are typically specified in general industrial applications, such as large process or transmission lines. Some can even be larger than 100 inches (2540 mm). Multiple rotations of the handle raise and lower a sealing mechanism in and out of a straight flow path. Shutoff is gradual. Packing surrounds the stem, preventing system media from escaping to atmosphere where the stem meets the valve body. Valves that seal to atmosphere with metal-to-metal seals are referred to as “packless” because they do not contain the soft packing

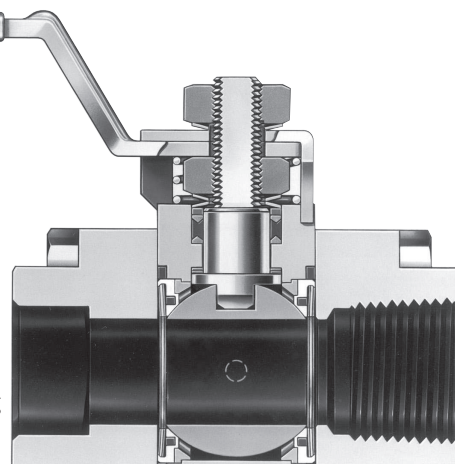


Fig. 1 Ball valves are ideal for on-off control. Quarter turn actuation starts or stops flow by positioning a metallic ball in a straight-through flow path.

material, e.g., gaskets and O-rings, normally found around the stem in other valves.

The valve stem is the cylindrical part that connects the handle (or actuation) with the inner mechanism for shut-off, flow control, and directional control. Usually, the stem turns and/or moves up and down.

All stem seals or packing are subject to wear, and wear can lead to leakage. Valves with packing must be serviced or replaced at regular intervals, although some types of packing create more effective seals and last longer than others, such as the two-piece chevron design.

Contrary to packed valves, diaphragm valves (see Figure 2) are packless, and provide rapid shutoff and precise actuation speeds. In some cases, they may also deliver consistent quantities of process fluid. Typically, diaphragm valves are employed in high-purity applications in the biopharmaceutical and semiconductor industries. Among all valve types, they provide the highest cycle life, a product of the valve's highly engineered anatomy. Each valve contains a thin metal or plastic diaphragm, which flexes up and down, creating a leak-tight seal over the inlet. This robust valve is usually small, with the largest

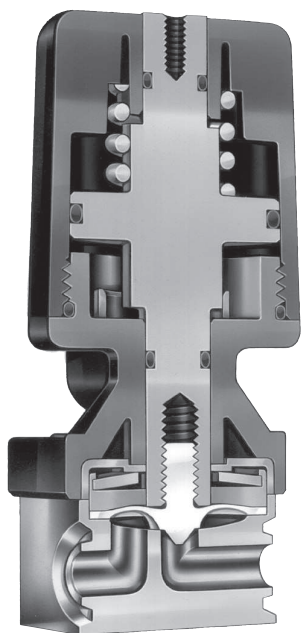


Fig. 2 Diaphragm valves provide rapid shutoff and precise actuation speeds. Among all valve types, they provide the highest cycle life, a product of the valve's highly engineered anatomy.

orifice — or internal pathway — typically less than 2 inches (50 mm).

Like the diaphragm valve, bellows valves are packless, making them a good choice when the seal to atmosphere is critical and access for maintenance is limited. Frequently, they are specified for the containment area in nuclear power plants. A welded seal divides the lower half of the valve, where the system media resides, from the upper parts of the valve, where actuation is initiated. The stem, which is entirely encased in a metal bellows, moves up and down without rotating, sealing over the inlet.

Bellows valves and diaphragm valves are said to have a globe-like flow path. In globe valves, fluid does not flow straight through on a level plane as it does in a ball valve. The flow path enters the valve under the seat and exits above the seat. Globe valves will have lower flow rates than valves with a straight-through flow path of the same orifice size.

Flow-Control Valves

Flow-control valves enable the operator to increase or decrease flow by rotating the handle. The operator can adjust the valve to a desired flow rate, and the valve will hold that flow rate reliably. Some flow-control valves also provide very reliable shut-off, but many turns of the handle are

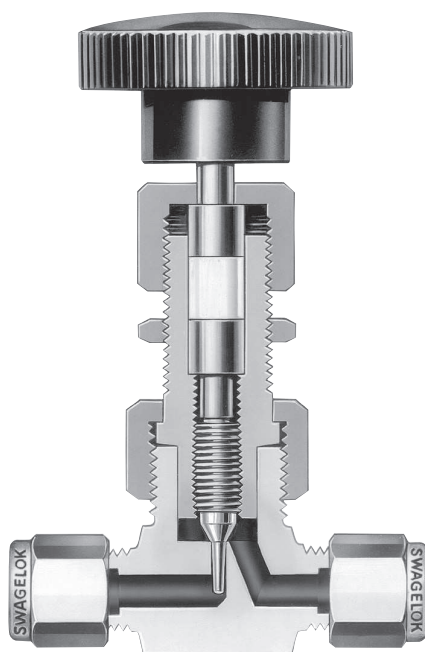


Fig. 3 Needle valves provide excellent flow control. The stem is finely threaded, enabling precise flow control.

necessary to move from the fully open to the fully closed position.

The most common flow-control valves are needle, fine metering, quarter-turn plug, and rising plug. Needle valves (see Figure 3) provide excellent flow control and, depending on design, leak-tight shut-off. They consist of a long stem with a highly engineered stem-tip geometry (e.g., vee- or needle-shaped) that fits precisely into a seat over the inlet. The stem is finely threaded, enabling precise flow control. Stem packing provides the seal to atmosphere. Some designs contain a metal-to-metal seat seal; consequently, needle valves are a good choice for high-temperature applications. As

discussed earlier, flow is limited because of the globe-style flow path. Needle valves are a good choice with lighter, less viscous fluids. For the most precise flow control, consider fine metering valves, typically found in laboratory settings. Fine metering valves are a type of needle valve, with a long, fine stem that lowers through a long, narrow channel. This anatomy makes for a pronounced globe pattern, ideal for marking fine gradations of flow. Some fine metering valves are not designed to shut off.

Quarter-turn plug valves are utility valves, economically priced. Quarter turn actuation rotates a cylindrical plug in a straight-through flow path. The plug contains an orifice to permit flow. Plug valves are commonly used for low-pressure throttling applications, in addition to shut off.

Another type of plug valve is the rising plug valve. Like a needle valve, a tapered plug lowers into an orifice to reduce flow. It differs from a needle valve in its flow path, which is straight-through rather than globe patterned. Because of the straight path, the valve is not as effective at providing fine gradations of flow. The rising plug is roddable, which is a good choice if the valve becomes clogged with system media.

Directional Flow Valves

A third type of valve directs fluid flow. Check valves (see Figure 4) ensure flow in one direction only. In most designs, the upstream fluid force pushes a spring-loaded poppet open, allowing flow. In the case of an increase in downstream or back-pressure force, the poppet is forced back into the seat, stopping reverse flow. Check valves are available with fixed or adjustable cracking pressures. Some ball valves and diaphragm valves

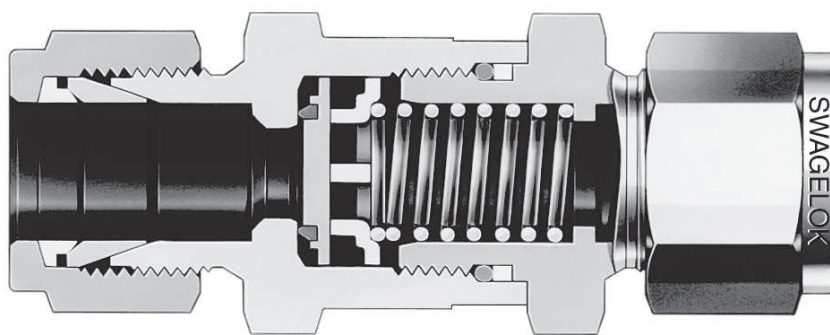


Fig. 4 Check valves ensure flow in one direction only. Check valves are available with fixed or adjustable cracking pressures.

are designed with multiple ports. In most multi-port valves, fluid enters through a single inlet but may exit through one of many outlets, depending on the position of the actuator. Multi-port valves may or may not have a shut-off position (see Figure 5).

Overpressure Protection Valves

Valves in this category prevent the build-up of system pressure beyond a certain pressure setting. They are available in two types: relief valves and rupture discs. One type of relief valve is a proportional relief valve (see Figure 6). It contains a vent to atmosphere that opens when pressure in a system exceeds a certain point set by the operator. A spring-loaded poppet enables the measured release of fluid. The vent closes when pressure returns to a point below where it was set. A safety relief valve is designed to open very quickly, releasing a large amount of system media. Due to their critical safety function, safety relief valves are required by code in certain applications. Safety relief and proportional relief valves are not to be used interchangeably with check valves, since the three have different functions. Rupture discs are used mainly on sample

cylinders to protect against over-pressurization, which may occur, for example, when temperatures rise during transport. Similar to relief valves, rupture discs vent to atmosphere. A metal diaphragm bursts when pressure reaches a set point. This value is preset by the manufacturer. Once activated, the rupture disc must be replaced. Transportation codes require that compressed gas cylinders be equipped with a pressure relief device. A rupture disc is an economical choice for this application.

Excess Flow Valves

Excess flow valves stop uncontrolled release of system media if a downstream line ruptures. Under normal conditions, a spring holds a poppet in the open position. In an excess flow condition downstream, the poppet moves to a tripped position stopping almost all the fluid flow. When the system is corrected, the valve returns to its

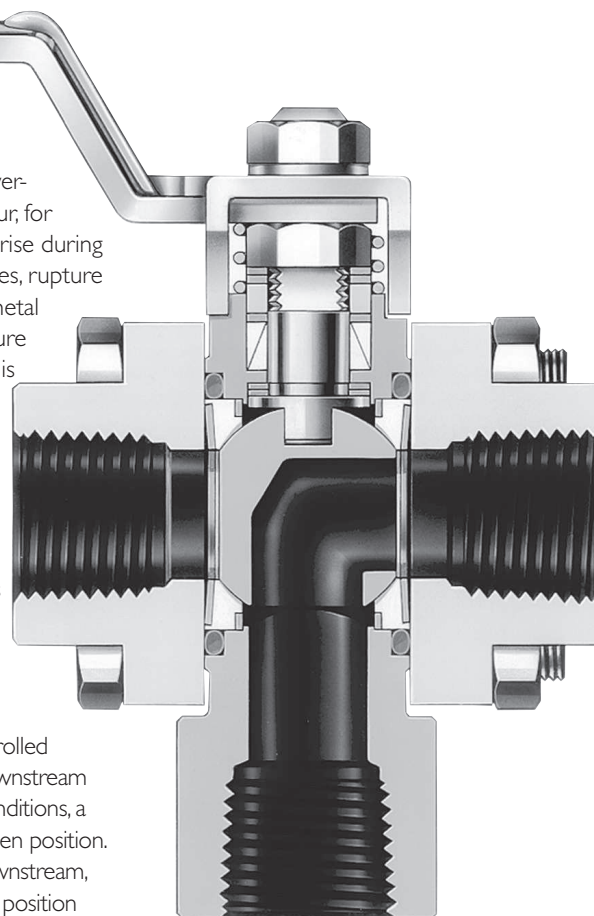


Fig. 5 Some ball valves and diaphragm valves are designed with multiple ports.

Tips and Traps

Know your application. When choosing a valve, you must have certain pieces of information in hand, including the chemical composition of the system media and the full range of pressure and temperatures over the course of the valve's life. Make sure your valve choice can accommodate these parameters. Don't go with hunches or approximations. Consult the product data.

Check for material compatibility. It is possible to have the right valve but the wrong materials of construction. Valves will often come with a standard set of materials, but there are alternatives. You should always check the product catalogue to identify temperature and pressure ranges, as well as compatibility with different system media (chemicals). When in doubt, consult your manufacturer.

Know your maintenance schedule. Different valves have different maintenance schedules, and your system parameters, including the number of times the valve is cycled, will affect this schedule. The valve's maintenance schedule needs to be manageable for your maintenance team. This seems like an obvious point but it is often overlooked. Are you willing to service that valve once every 20 days when it is 100 feet in the air?

Understand pressure drops. Most every valve or other component produces a drop in pressure. You need to be aware of the cumulative pressure drop because otherwise you may end up with too little pressure at a certain point in the line. Every valve is rated with a flow coefficient (C_v), which describes the relationship between the pressure drop across an orifice, valve, or other assembly, and the corresponding flow rate. The higher the C_v , the lower the pressure drop. A ball valve and needle valve of the same size will produce very different pressure drops. A ball valve will produce very little pressure drop, whereas a needle valve (or other globe valve) will produce a significant pressure drop.

Consider cost of ownership. The true cost of a valve is not its purchase price. The true cost is the purchase price plus the cost of owning and maintaining or replacing that valve over time. To calculate the cost of ownership, you must know how long a valve will operate in your particular system between maintenance checks. Maintenance costs must be figured not only in replacement parts, but also in labor and downtime. Note that some valves are much easier to service than others. Some can be serviced in place; others must be removed from the process line. Also, given your valve choice, what are the chances of unscheduled maintenance and downtime?

Selection Guideline Summary

Table 1 On-Off Valves

Valve Type	Flow Path	Visual Indication of Shut-Off?	Shut-Off Speed	Packing or Packless?	Typical Use
Ball	Straight	Yes	Rapid	Packing	Widely used in many applications. Practical and economical
Gate	Straight	No	Gradual	Packing	General industrial use, typically for large process or transmission lines
Diaphragm	Globe	Yes	Rapid	Packless	Applications, often high-purity, requiring rapid shut-off, precise actuation speeds, and high cycle life
Bellows	Globe	Sometimes	Gradual	Packless	Applications where a high-integrity seal to atmosphere is critical and access for maintenance is limited

Table 2 Flow-Control Valves

Valve Type	Flow Path	Precision of Flow Control	Shut-Off Capability?	Typical Use
Needle	Globe	Excellent	Yes	Applications requiring precise flow control and leak-tight shut-off. Often used for high-temperature applications and lighter, less viscous fluids
Fine Metering	Globe	Excellent	Sometimes	Applications are often in laboratory settings, requiring the most precise flow control
Quarter-Turn Plug	Straight	Good	Yes	Economical utility valves typically chosen for low-throttling applications
Rising Plug	Straight	Good	Yes	Applications where the valve needs to be cleaned out, such as when system media becomes clogged or coagulates

open position. These valves are available with fixed tripping values.

Conclusion

Once you have matched valve type to function, you are well on your way in the valve selection process. Many details remain, though. You will need to give detailed attention to each of the following, if you have not had occasion to so far in the process:

- Installation issues, maintenance schedules and access;
- Safety and code requirements; and
- System parameters, such as pressure, temperature, flow rates, and system media.

Ultimately, you will need to determine:

- Valve size and actuation types; and
- Materials of construction (including O-rings and seals), which must be compatible with the chemical composition of the system media, pressures, and temperatures.

The manufacturer's representative will be your guide in this process. Product catalogues and product test reports are also valuable resources in refining your valve choice.

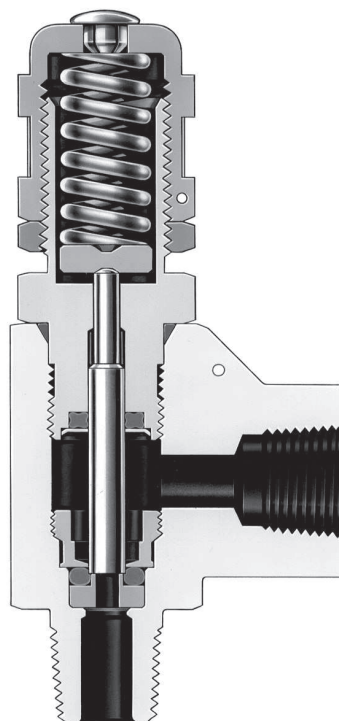


Fig. 6 A proportional relief valve is a type of overpressure protection valve. It contains a vent to atmosphere that opens when pressure in a system exceeds a certain point set by the operator.

About the Author

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current role, he assesses market needs and develops product strategy, positioning, and pricing. He also works internally with engineering and production teams to develop new products and product enhancements, as well as reduce costs. Prior to this role he served as supervisor of new product development, quality control supervisor, project manager, and manufacturing engineer. Adkins holds a Bachelor's Degree in Mechanical Engineering Technology from the University of Dayton and a Master's in Business Administration from John Carroll University.