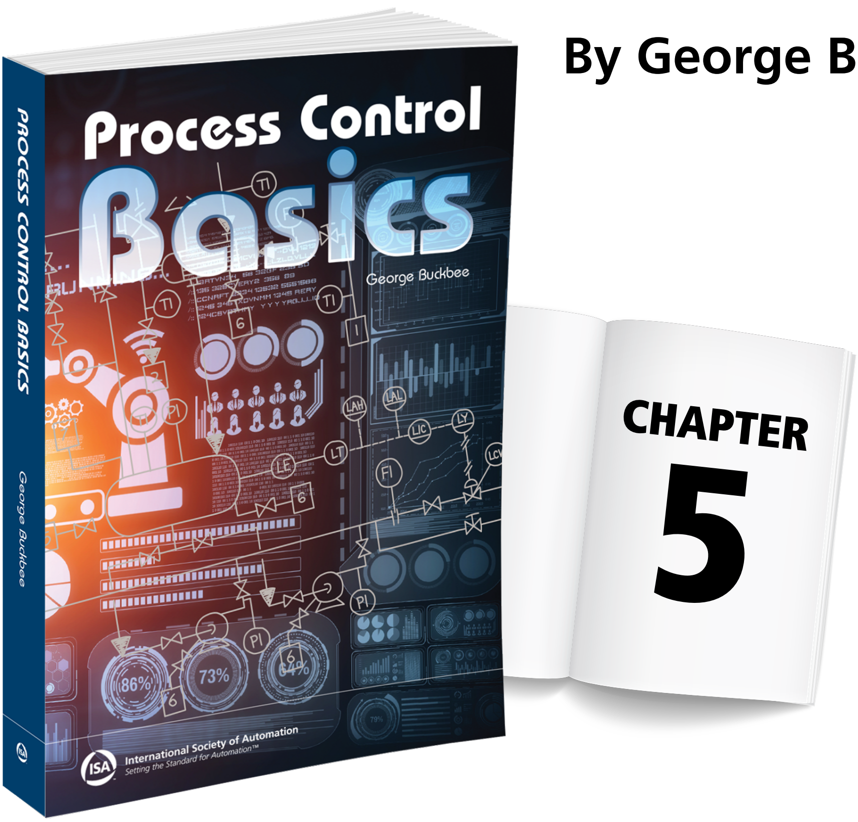
Process Control Basics

By George Buckbee, PE



Book Table of Contents

Buy the Complete Book

Process Control Basics

George Buckbee, PE

ISA™

Notice

The information presented in this publication is for the general education of the reader. Because neither the author nor the publisher has any control over the use of the information by the reader, both the author and the publisher disclaim any and all liability of any kind arising out of such use. The reader is expected to exercise sound professional judgment in using any of the information presented in a particular application.

Additionally, neither the author nor the publisher has investigated or considered the effect of any patents on the ability of the reader to use any of the information in a particular application. The reader is responsible for reviewing any possible patents that may affect any particular use of the information presented.

Any references to commercial products in the work are cited as examples only. Neither the author nor the publisher endorses any referenced commercial product. Any trademarks or tradenames referenced belong to the respective owner of the mark or name. Neither the author nor the publisher makes any representation regarding the availability of any referenced commercial product at any time. The manufacturer's instructions on the use of any commercial product must be followed at all times, even if in conflict with the information in this publication.

Printed in the United States of America.
Version: 1.0

ISBN-13: 978-1-64331-130-2 (print)
ISBN-13: 978-1-64331-131-9 (ePub)
ISBN-13: 978-1-64331-132-6 (Kindle)

ISA
67 T. W. Alexander Drive
P.O. Box 12277
Research Triangle Park, NC 27709

Library of Congress Cataloging-in-Publication Data in process

About the Author

George Buckbee, PE, is a veteran of the process control industry. An experienced author and instructor, Buckbee has more than 30 years of practical experience improving process performance in a wide array of process industries including oil and gas, pulp and paper, pharmaceuticals, and consumer products. Buckbee holds a BS in chemical engineering from Washington University, and an MS in chemical engineering from the University of California, Santa Barbara.

Buckbee's career includes direct industry experience at Procter & Gamble and Sanofi Pasteur, before entering the software development and control system consulting business at ExperTune. Currently head of performance solutions at Neles, he manages global digital solutions for valve monitoring, and the ExperTune family of products and services.

Buckbee was selected as an ISA Fellow in 2011, and he is a member of the ISA Publications Department. He is the coauthor (along with Joseph Alford) of *Automation Applications in Bio-Pharmaceuticals*, published by ISA. He wrote several chapters in *The Instrument Engineer's Handbook* and authored *Mastering Cascade Control* and *Mastering Split-Range Control.* Buckbee has also written dozens of articles and white papers on control system performance.

Buckbee resides in Pennsylvania, where he and his wife Mary Ellen enjoy hiking, kayaking, golf, and traveling to visit their adult children.

5 Final Control Elements

Final control elements are the workhorses of control. Without them, control would simply be a bunch of signals bouncing around without any impact on the real world. When a control valve opens, fluid flow increases and the process is affected.

Final control elements are generally physical, mechanical devices. It is important to pay close attention to their sizing, materials, and capacity. Also note that as physical devices, they are subject to wear and tear. Mechanical maintenance is critical to maintaining the reliability and performance of these devices.

This chapter provides an introduction to the most common final control elements used in modern industrial process plants, including:

- Control valves
- Dampers
- Variable-speed drives
- Heaters

At the end of the chapter is a discussion of regulators and limiting elements. These are relatively independent physical devices that perform some direct control of the process.

5.1 Control Valves

The control valve is the workhorse of the process control business. The vast majority of process control happens, in the end, because a valve opens or closes. An on-off valve operates in binary fashion: it opens or closes fully when actuated. A modulating control valve can be adjusted to any position, from 0% to 100% open, thereby affecting the flow through the valve.

Control valve selection and application can be surprisingly complex. Valves may cost a few dollars or hundreds of thousands of dollars, depending on their size, materials, quality, pressure, temperature, and performance specifications.

5.1.1 What Is a Control Valve?

A common notion is that every valve may be used as a control valve. However, that is far from the truth. A control valve is a valve that can be manipulated to precisely regulate the flow of process fluids. Control valves must meet a demanding set of requirements to ensure accurate and precise control.

Manually operated valves are also used throughout plants. They can be opened or closed with a lever, a wheel, or chain. These valves are not considered control valves. However, it is possible for an attentive operator to achieve some control of the process using manually operated valves.

The control valve must be properly designed, sized for the normal range of flows and pressures, made of the correct materials, and perform properly across the full range of operation. Each of these aspects of control valves is examined in this section.

Control valves do not work by themselves. Typically, a complete valve assembly consists of a valve body, an actuator, and oftentimes a positioner, as shown in Figure 5-1.

The *valve body* is a pressure housing through which fluid passes. The body has connections for piping or tubing. A movable valve plug changes position to adjust the flow. The plug may be a disk, a ball, or some other specialized design. The valve stem is connected to the plug and provides a connection to the actuator.

The *actuator* provides the motive force to open or close the valve. There are several types of actuators, including spring-and-diaphragm and electric motor–operated actuators. Compressed air is often used as the motive force for valve actuators.

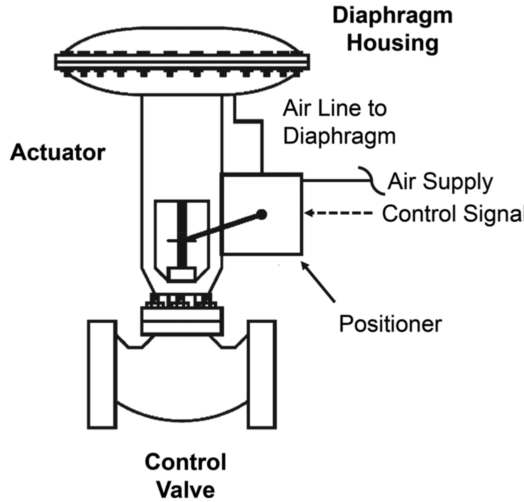


Figure 5-1. A control valve assembly.

A *positioner* is a device that measures the actual valve position and adjusts the inputs to the actuator to achieve more precise positioning of the control valve.

5.1.2 Types of Control Valves

Because there are many types of process fluid, there are many types of control valves. Some of the more common control valve types are covered here.

5.1.2.1 Butterfly Valve

The *butterfly valve*, shown in Figure 5-2, is one of the oldest and simplest control valve designs. It is a single disc that rotates 90° from fully closed to fully open.

Butterfly valves are relatively low cost, and they can provide good shutoff. These can be manufactured in very small or very large sizes, even as large as 48 inches in diameter.

However, the butterfly valve's characteristic curve is very nonlinear. This may make it difficult to control the process across the full range of valve operation. Also, butterfly valves are not well suited for process situations where there is a large pressure drop. At low openings, the butterfly valve is subject to *cavitation*, which can cause extreme damage to the valve. When a liquid passes through the small opening of a valve, its speed increases and its pressure drops. Vapor bubbles can form and then suddenly collapse causing cavitation, which damages the valve or surrounding piping.

5.1.2.2 Globe Valve

The *globe valve* is so named because the body of the valve is shaped like a globe. In this valve, the process fluid moves through the valve and around a plug, as shown in

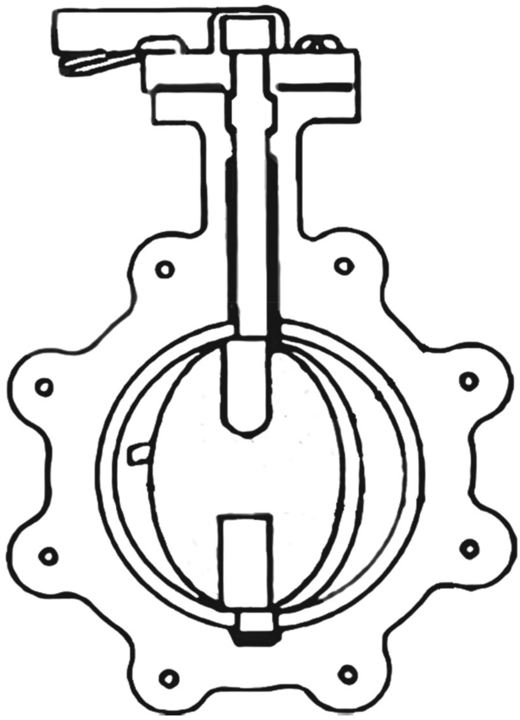


Figure 5-2. A butterfly valve.

Figure 5-3. The plug moves up and down to adjust the flow. There are also three-way globe valves that split the inlet flow between two outlet ports.

Globe valves have many advantages over rotary valve designs.

- Globe valve actuation has typically been performed by a simple spring-and-diaphragm actuator. The globe valve can be designed with a wide range of valve characteristics.
- Due to the tortuous flow path, it is highly unlikely to develop cavitation or noise.
- The solid body also makes the globe valve suitable for high-pressure and high-temperature applications.
- With relatively low deadband and hysteresis, globe valves can sometimes be used without positioners.

However, for a given flow rate, globe valves are typically more expensive than the simpler rotary designs. Also, the linear valve stem seal may not perform as well as rotary valve stem seals. This means it may be more difficult to achieve environmental requirements for fugitive emissions.

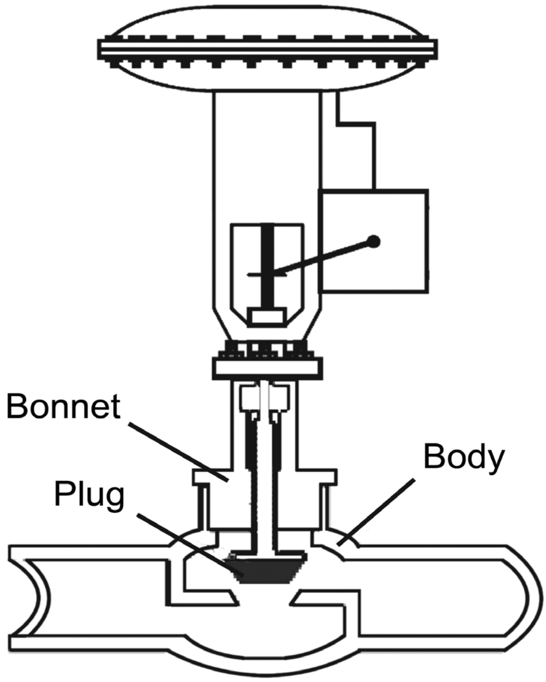


Figure 5-3. Globe valve.

5.1.2.3 Ball Valve

In a ball valve, the plug resembles a ball with a bore through it, as shown in Figure 5-4. These quarter-turn valves are typically of simple construction and can be found in sizes from 1/2 in to 48 in or more.

When fully opened, flow can pass through the full pipe diameter, causing very little pressure drop. For this reason, these valves are often used as on-off valves.

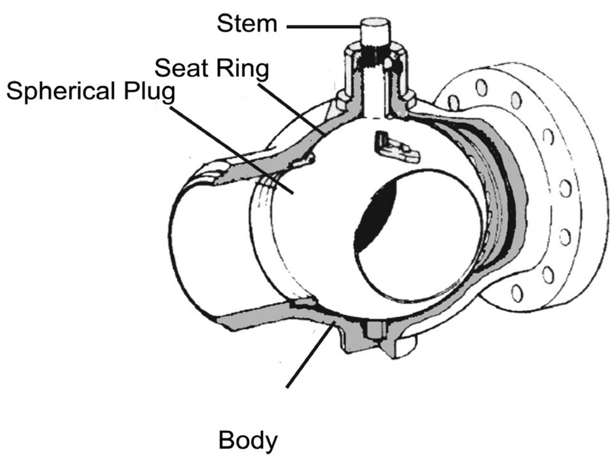


Figure 5-4. Ball valve.

Ball valves may also be used for modulating flow. Some designs change the shape of the bore with a notch shape, to adjust the flow characteristic.

5.1.2.4 Eccentric Disc Valve

An eccentric disc valve is similar to a butterfly valve but the plug looks like a shaped disc, or a segment of a sphere, rather than a flat disc. The disc shape can help to shape the flow characteristic, as described in Section 5.1.4.

5.1.3 Control Valve Sizing

Valve sizing is an important engineering task. The valve should be sized according to the desired flow rate, for the given pressure drop. The flow through a valve increases as the square of valve size. So, if the valve size is off by a factor of 2, the flow will be off by a factor of 4. Also, the correct control valve is often smaller than the pipe diameter.

It is also important to consider the valve's *rangeability*, which is the ratio of the maximum controllable flow to the minimum controllable flow. When requirements call for good control over a wide range, it may be necessary to employ more than one valve.

5.1.3.1 Effects of Valve Sizing

If a valve is sized too small, it will not be able to pass the required maximum flow. Consequently, the valve will operate fully open and there will be control only at low flow rates.

If a valve is too large, it will operate with the plug near the closed position. This presents several control challenges:

- **Large valve gain** – Small movements will create relatively large changes in flow.
- **Poor accuracy and dynamic instability** – It can be difficult to position a control valve more accurately than ±0.5% or 1% of full stroke. If the valve is only open 3%, then ±1% could mean ±30% of flow. A controller may then force instability as it tries to hunt for the correct valve position.
- **Valve damage** – The local fluid velocity through the plug can be higher, which can cause erosion, flashing, or cavitation.

5.1.3.2 Valve Sizing

Control valves are sized using mathematical equations to determine the desired flow rate, given the process conditions and the physical properties of the fluid. The valve-sizing coefficient, C_v, is defined as the number of gallons per minute (gpm) of water at 60°F that can flow through the wide-open valve at a pressure drop of 1 psi.

Valve manufacturers supply listings of C_v for their valves, along with body size, weight, port size, actuator torque requirements, and other factors.

Also, in many control valves, the valve trim or plug may be replaced with another one to provide a different C_v.

5.1.4 Control Valve Characteristics

It is not always easy to configure valves for good control. Every valve has a *characteristic*, which is the relationship between the valve position and the flow rate, for a given fixed pressure drop. The characteristic that is needed for each application depends on the process, the piping, and the control requirements. There are three common valve characteristics:

1. **Equal percentage** – Equal increments in valve movement produce an equal percentage of change to the existing flow.
2. **Linear** – The flow rate is directly proportional to the valve position.
3. **Quick opening** – Gives quick response when first opened, but then produces little change as the valve reaches full-open position. This is often used for on-off valves.

These characteristics are illustrated in Figure 5-5.

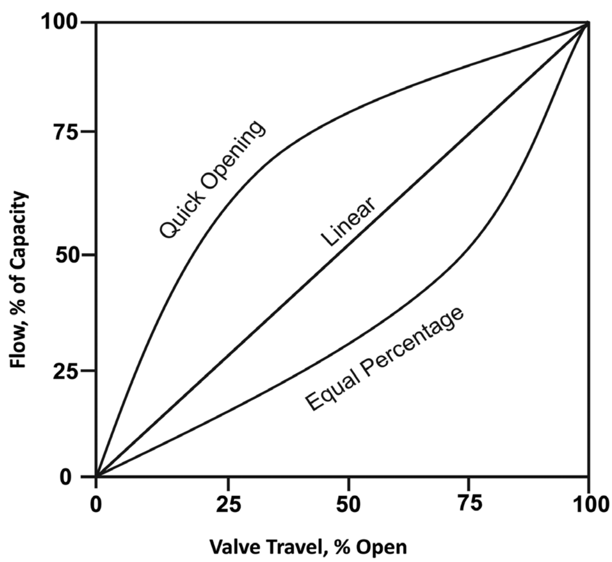


Figure 5-5. Common valve characteristics.

Note that the valve characteristics provided by vendors are the *inherent valve characteristics*, meaning they are determined under a constant pressure drop across the valve. In most plants, the pressure drop across the valve varies due to piping and process arrangement. The actual characteristic in your plant is called the *installed flow characteristic*.

The flow characteristic of the butterfly valve is nonlinear. At low flow rates, small valve movements will generate large changes in flow. When the valve is more than 50% open, it takes much more valve movement to increase the amount of flow. Also, the fluid moving through the butterfly valve puts pressure on the disk. So, different forces are required to open the valve than to close it.

5.1.4.1 Adjusting for the Valve Characteristic

The selected valve characteristic has several effects. First, it affects the opening time. Large valves may take a full minute to fully open. If it is important for the process to get flow quickly, the quick-opening characteristic may be required.

The installed valve characteristic also affects the controller tuning. From a control standpoint, it would be ideal if 1% valve movement always caused 1% process variable movement. However, that is not the case with all valve characteristics. The *valve gain* refers to the ratio of change in flow for each percentage change in valve position. If the valve gain varies greatly, you may need to compensate for this nonlinearity. There are several ways to compensate, including:

- Installing a shaped cam on the valve positioner
- Using a digital characterizer in the positioner or in the distributed control system (DCS)
- Adjusting the controller tuning according to valve position

5.1.5 Performance Factors

When fluids flow through the restrictions of a control valve, the fluid velocity must speed up to squeeze the fluid through. This can cause several significant issues, such as:

- **Pressure drop** – The pressure drop across the valve can be significant, and it represents lost energy. When there are large energy costs, a variable-speed pump may be considered instead of a pump and valve.

- **Erosion** – The high-speed fluid can wear the valve materials. When the valve is only partially opened, this has the greatest effect. Eventually, erosion can wear the seats or the plug so much that the valve will leak when closed.
- **Flashing** – Bernoulli's equation states that when fluid speed increases, the pressure drops. Hot liquids may flash (boil) as they pass through the tight restrictions in the valve. This can create vibration, noise, flow restrictions, or cavitation.
- **Cavitation** – Cavitation describes a situation where the liquid flashes and then the bubbles collapse immediately after the valve. This is a violent and noisy phenomenon that will damage the valve and/or piping. Cavitation is often easy to detect, as it sounds like rocks are passing through the valve.
- **Pluggage** – When the fluid contains solid materials, as in a slurry, some material can get trapped at the plug. The buildup can eventually trap more and more material, and it can plug the line. As the solid material becomes dewatered, it can create a plug of materials, requiring a shutdown to remove the valve and clean it out.

It is important to consider all these possible issues to select the proper valve type, actuator type, and valve size.

5.1.6 Control Valve Maintenance

Control valves come in direct contact with process fluids, which may be extremely hot, cold, abrasive, corrosive, acidic, or even radioactive. Process equipment and piping may vibrate, stressing the valve connections and materials. Valves are also moving frequently, which results in wear and tear on all points of contact between the valve body and the plug. Regular inspection and maintenance are required to ensure that the valve assembly will not fail during normal operation and that the valve will survive for its expected life span.

Manufacturers provide recommendations for valve maintenance based on the number of valve strokes or elapsed time since the previous installation. Valve maintenance may include replacement of soft parts such as seals and rings, or a full rebuild of the valve.

Preparation and shutdown planning are key to valve maintenance. Most valve maintenance actions require removal from the piping, and many require sending the valve to a repair shop.

5.2 Dampers

5.2.1 What Is a Damper?

A damper is a type of valve or series of plates that are used to restrict the flow of gases, especially the flow of air through a duct. The damper found in a home chimney is a simple form. Larger, more complex dampers are used in industrial processes to manage the flows of gases, as shown in Figure 5-6.

In most dampers, the plates, or *louvers*, are attached to a common linkage, and they all move together. A motor or pneumatic actuator drives the linkage.

One common application of a damper is to control the flow of air into an industrial furnace or boiler.

5.2.2 Damper Characteristics

Like control valves, dampers exhibit nonlinear flow characteristics. Typically, the characteristic resembles the shape of the quick-opening valve. That is, the airflow increases quickly on opening and then increases only gradually after the damper is 50% open.

To obtain good control, a characterizer may be used to create a more linear profile.

Figure 5-6. A damper.

Source: Photo courtesy of Mestek Commercial Damper & Louver Group.

5.2.3 Damper Maintenance

The linkages between the damper actuator and the damper usually contain several mechanical joints. For good control, these joints must move freely. Proper alignment, lubrication, and tightness are essential to good control. When linkages are too loose, the control will oscillate, or hunt, back and forth, as it tries to properly position the damper. Too much stiffness or tightness in the linkage can cause the linkage to bind or stick, which then causes the controls to oscillate.

Proper training of maintenance personnel is required to ensure that the damper moves smoothly without sticking.

A damper can also become a trap or filter for dust and other foreign material that finds its way into the ductwork. Routine inspection and cleaning are needed to reduce the buildup, plugging, and associated fire hazards.

5.3 Actuators

The *actuator* is the mechanical drive or power element that moves the part of the final control element to manipulate the flow or other manipulated variable. In the case of a control valve, the actuator moves the plug. There are many types of actuators, and they are selected according to the valve requirements noted in this section.

5.3.1 Type of Actuator Movement

Linear actuator movement is required for globe valves, gate valves, and many others. With these valves, the plug moves up and down in a straight line. A spring-and-diaphragm design, shown in Figure 5-7, is commonly used.

Piston actuators are similar, but they use a solid piston rather than a flexible diaphragm to separate the chambers. A *double-acting piston* actuator uses air on both sides, rather than a spring.

Rotary actuator movement is needed for butterfly valves, ball valves, and eccentric disc valves. Various actuator designs may convert linear motion into the rotary torque needed to manipulate these valves.

Solenoid valves are valves connected to an electrical coil. When the coil is energized, the valve opens (or closes) completely. Solenoid valves often control the supply of compressed air to a larger actuator.

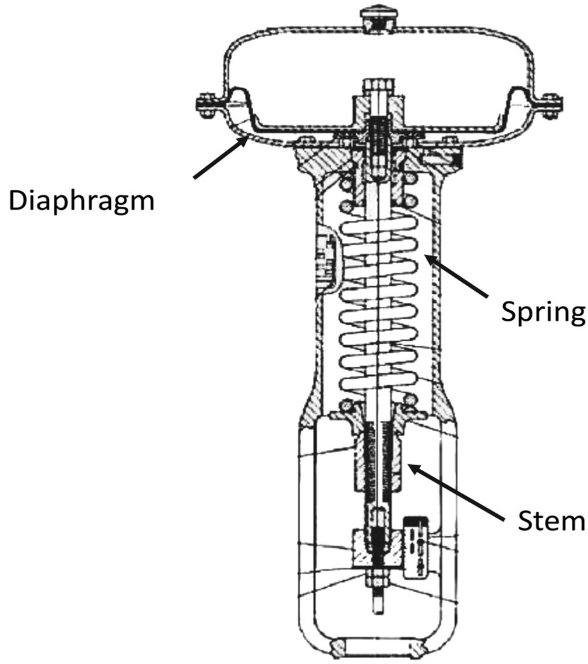


Figure 5-7. Spring-and-diaphragm actuator.

5.3.2 Actuator Control Action

Actuators are used for modulating service or for on-off service. In fact, the same actuator may be used in both scenarios.

Spring-and-diaphragm actuators may be configured to require air to open the valve, or air to close the valve. The configuration is usually selected based on the desired fail-safe condition for the valve. In other words, if the compressed air supply were lost, which would be the safest position? For combustible gases, you typically want the valves to fail in the closed position. For air supply to a combustor, you usually want the valve to fail open, to purge the combustion chamber. Some actuators will fail in the last state, meaning that they will not open or close, but just stay in the same position. There are also some that fail in an indeterminate or unpredictable way.

5.3.3 Actuator Power Source

The most common actuators use compressed gas, such as compressed air, as their power source. Common air supply pressures for on-off valves are 50 psig, 80 psig, or 100 psig. For modulating valves, compressed air in the range of 20 to 35 psig is used, which is then applied based on the 3–15 psig signal representing 0% to 100% of valve travel.

Although compressed air is most commonly used, some systems may use other gases. For example, remote stations for natural gas transmission pipelines often use compressed natural gas.

For on-off valves, electric solenoids can be used to open or close the valve. Solenoids are electromagnets that can actuate the valve directly. Alternately, a solenoid-operated valve could control the pneumatic air supply to a larger valve.

Compressed gas is an expensive source of power. Consider that it is normally produced using an electric motor to drive a compressor and then transported through long lines of pipes and tubing. Electric motor actuators connect directly to the valve and can be used for both on-off and modulating control actions. Electric actuators can become hot, so they are not suitable for all applications.

Manual valve actuation may be included for emergency or override scenarios. A handwheel or chain operator may be used to manually adjust the valve position.

5.3.4 Actuator Sizing

The actuator must, of course, be powerful enough to move the valve. Linear actuators are sized for their *linear thrust*, measured in pound force (lbf). Rotary actuators are sized for torque, which is measured in foot-pounds (ft • lbf). The SI unit for torque is the newton meter (N • m).

In any case, the actuator must be powerful enough to overcome the valve friction and any process fluid pressure against the plug, and to move the valve quickly enough in emergency situations. Some actuators include a horsepower rating, which is basically used to determine how quickly the valve can move with the maximum torque applied.

5.4 Switches and Positioners

A variety of electric and electronic devices may be used to ensure better performance of the valve or damper, or to provide feedback to the operator about the actual position of the final control element.

5.4.1 Switches

It is not enough for the control system to command each valve to open. The valve may fail to respond due to one of many points of failure along the way, such as electrical failures, broken tubing, and mechanical issues. Switches can provide position feedback, confirming the actual position of the valve. The most common of these are switches confirming that the valve is either fully open or fully closed.

Some valves, such as pressure relief valves, may be fitted with switches to notify the operator that a process incident has occurred.

5.4.2 Positioners

A positioner is a small self-contained controller. It takes the commanded valve signal from the control system (i.e., the 3–15 psig signal) and measures the actual valve position. It then adjusts the motive force to the actuator to ensure that the valve actually reaches the desired position. This helps to overcome local issues at the actuation of the valve, such as hysteresis, stiction, or actuator performance issues. The plant benefits from improved control.

Digital positioners also calculate a variety of statistics and perform diagnostics on the air supply, the actuator, and the valve. These statistics and diagnostics may be conveyed digitally to the control system or to a parallel communications network. Valve performance and the valve life cycle may be greatly improved when the information from digital positioners is used to manage a fleet of valves.

5.5 Variable Speed Drives

5.5.1 What Is a Variable Speed Drive?

A *drive* is simply a motor plus a controller. Both alternating current (AC) and direct current (DC) drive controllers are commonly used in industry, although the recent trend is toward more and larger AC drives. Variable speed drives (VSDs) work by adjusting the electrical supply to the motor, to vary its speed.

In most process control applications, a motor is connected to a centrifugal load, such as a pump, or to a rotating roll, press, or agitator. When a VSD is connected to a pump, it can perform many of the functions of a pump and valve combination, all while consuming less energy. This is because there is no longer a pressure drop across the valve. However, note that a VSD does not have the tight shutoff characteristic of a valve. It cannot be used for process isolation and may not be suitable in all processes.

5.5.2 Types of VSDs

5.5.2.1 Cones and Belts

The cone and belt system, or cone and pulley system, is an old type of VSD unit used heavily in pulp and paper and textile applications. A cone is mounted on the motor shaft. A parallel opposing cone is on a shaft and connected to the process. A belt is stretched across the two cones to connect them. To increase the speed, the belt is shifted from the narrow end to the wide end of the drive cone. The speed changes according to the ratio of the diameters between the cones at the location of the belt.

5.5.2.2 DC Drives

A DC VSD uses a DC motor. These motors have been in use since the 1870s and are still widely used in appliances, toys, and other small drive situations. The motor speed can be adjusted either by changing the supply voltage or by changing the current in the field windings.

Large DC motors can drive steel mills, paper machines, and other large equipment. Some DC motor designs use brushes, while others are brushless. Although brushed DC motors with commutators may be lower cost than AC drives, they typically require more maintenance. Brushless DC drives use permanent magnets, which reduces the level of maintenance required.

5.5.2.3 AC Variable Frequency Drive

A commonly used drive is the AC variable frequency drive (VFD). This drive unit adjusts the electric power input frequency and voltage to control both motor speed and torque. This enables precise control of the process, especially through start-up and shutdown operations.

Typically, solid-state electronics are used to control the supply power to the motor. A standard AC motor is often used, although some applications require special insulation and motor cooling.

The AC VFD also permits regenerative braking. During regeneration, or *regen*, the process is slowed down, with the motor acting as a generator, to recover the energy from the process. This can significantly reduce costs in applications with large, heavy loads and frequent speed changes.

5.5.3 Other Drives

There are many clever ways to vary and control the speed of rotating equipment, such as by using hydraulic drives, pneumatic drives, linear motors, and servomotors.

5.5.4 Drive Sizing

The VSD must be sized for the maximum required flow rate and maximum head through the pump. One must also consider the turndown ratio to ensure that the motor can operate at the slower speed without overheating

5.5.5 Drive Characteristics

Drive controllers are highly programmable. It is possible to establish and adjust many drive characteristics through configuration. Some of these adjustments are:

- **Ramp rate** – This is the rate of change to be used when changing speeds. This will be a compromise between fast control performance and overloading the motor.
- **Speed loop and current loop tuning** – These two loops are cascaded. The current loop should be tuned fairly fast. The speed loop can be tuned according to process needs.
- **Minimum speed** – Set this to attain the minimum flow rate, but beware of the allowable minimum speed of the motor to avoid overheating.

5.5.6 Drive Maintenance

Both the motor and the drive unit need periodic inspection and maintenance. Vendor recommendations are readily available for each. Brushed DC motors have carbon brushes that wear over time and must be periodically replaced.

5.6 Heaters

Heaters may be used as the final control element to increase temperature in a control loop. Electrical heaters provide fast response and good control, without the need for piping to deliver the heating fluids. Keep in mind that a heater can only increase temperature, not decrease it.

Heat from electric energy is relatively expensive when compared to combustion, steam, or thermal fluids. However, electricity may often be available at remote locations where the infrastructure for steam distribution does not exist.

5.6.1 Heater Sizing

The heater must be sized to accommodate the largest temperature increase at the largest possible flow rate. If the process fluid will go through a phase change (i.e., boil), then the heater may need to be significantly larger to supply the latent heat of vaporization.

5.6.2 Heater Characteristics

Electric heaters typically exhibit some lag time between supplying power and when the process fluid temperature rises. This is largely due to transmission of heat through the walls of the piping or vessel, or due to the distance from the heater to the temperature measurement. Also, the heater itself and its casing may introduce a thermal lag.

5.6.3 Heater Maintenance

Regular inspection of heater wiring and heater elements is recommended. When electric heaters fail, they tend to fail completely, so detection of the issue is relatively straightforward.

5.7 Other Final Control Elements

There are many other ways to manipulate a process. Gates may be used to adjust flow in open channels. Many combustors use the burner tilt to adjust the combustion process and efficiency. A wide variety of specialty valves can be used for unusual process conditions such as slurries.

5.8 Regulators

5.8.1 What Is a Pressure Regulator?

A *pressure regulator* is a mechanical spring-diaphragm device that can be used to maintain a constant downstream pressure. It may be applied to liquids or gases. For example, most homes that use natural gas have a regulator before the gas line comes into the house. Regulators are adjusted locally by changing the spring tension.

If the downstream pressure set point does not vary, a regulator can be much more cost-efficient than a pressure control loop with a sensor and control valve. Regulators are also widely used in remote locations where no electricity is available.

5.8.2 Regulator Maintenance

Regulators can fail in many ways, including:

- Diaphragm rupture
- Buildup of foreign material
- Corrosion

Regular inspection is required to prevent the regulator from failing.

5.9 Limiting Elements

5.9.1 What Is a Limiting Element?

A limiting element is a control device that provides some control of the process when regular limits are exceeded. These devices are often the last line of defense to prevent equipment damage and/or safety incidents.

5.9.2 Types of Limiting Elements

Some of the most common forms of limiting elements are:

- **Safety valves** – These are required on pressurized tanks and vessels. If the tank pressure approaches the limits of the tank's safe design, the pressure relief valve opens, venting the tank's contents to the atmosphere or to a containment area.
- **Vacuum relief valves** – A tank with an internal vacuum can collapse when outside atmospheric pressure pushes inward on it. The vacuum relief valve opens to let air inside, raising the tank's pressure closer to atmospheric pressure.
- **Rupture disks** – Like an electric fuse, the rupture disk is a single-use device to relieve pressure or vacuum.

These limiting elements are often outfitted with switches or other feedback devices that alarm the operator when an incident occurs.

5.9.3 Maintenance

The most important concern for a limiting element is having confidence that it will work when needed. However, we hope that the process never reaches such conditions. So, how can you be sure that it will operate?

Regular inspection and maintenance programs can be instituted to confirm operation, either in the field or on bench tests. In recent years, smart positioners have been created to perform *partial stroke testing*. These positioners can make small adjustments to the safety valve spool position to test that the valve actually starts to move. Smart positioners satisfy the need for confirmation at a much lower cost, and with less process disruption, than traditional testing.

References

ANSI/ISA-75.01.01-2012 (IEC 60534-2-1 MOD). *Industrial-Process Control Valves – Part 2-1: Flow Capacity - Sizing Equations for Fluid Flow Under Installed Conditions*. Research Triangle Park, NC: ISA (International Society of Automation).

Baumann, Hans D. *Control Valve Primer, A User's Guide*. Research Triangle Park, NC: ISA (International Society of Automation) 2009.

Fisher Controls Company. *Control Valve Handbook*. 2nd ed. Marshalltown, IA: Fisher Controls Company, 1977.

Liptak, Bela G., ed. *Instrument Engineer's Handbook: Process Control.* 3rd ed. Radnor, PA: Chilton Book Company, 1995.

Spitzer, David W. *Variable Speed Drives: Principles and Applications for Energy Cost Savings*. 4th ed. New York: Momentum Press, 2012.

Contents