Limit Stops

When it is impractical to use the handwheel as a limit stop, other limit stops can be provided as part of the body assembly. A typical limit stop may be mounted on the bottom of a globe valve that is guided top and bottom. This stop consists of an adjustable spindle sealed by a cap. This stop can be adjusted while the valve is in operation to meet the exact required minimum or maximum settings.

Stem-Position Indicators

Stem-position indicators show the valve's exact position to operating personnel at a remote location. Such valves may be located in unmanned pumping stations or in a hazardous area closed off to operating personnel (near an atomic reactor, for example). Remote position indicators can be electrical, with a linear variable resistor suitably connected to the valve stem. The electrical signal is then shown on a calibrated panel meter. Another way to indicate stem position remotely is with a pneumatic signal. This is a desirable alternative in areas where there is a risk of explosion. Most pneumatic positioners can be inverted to work as position transmitters. When properly modified, they will transmit a pneumatic signal as a function of valve stroke, which is indicated on a calibrated receiver gage.

Airsets

The most common of all accessories is the airset. This is a compact self-contained air pressure regulator with an integral filter and drip valve and a maximum flow capacity of about 20 scfm of air. This air filter regulator is used to supply pressurized air to either the positioner or a yoke-mounted controller. Its main advantage is that it provides a way of setting the individual pressure supply to a positioner. (Pressures from 20 to 80 psig may be needed to meet the power requirement for a particular valve.) All control valves that use a positioner should include an airset for two functions. First, it filters plant air so as to prevent the plugging of small passages that will cause the valve to stop functioning. Second, it provides a steady-state air supply to the positioner so it can perform optimally and avoid the process variability that can occur when the plant air supply to the positioner fluctuates.

Piping the usual plant air supply of perhaps 80 psig directly to the valves could overstress smaller valve stems or damage receiver bellows in positioners or controllers. Also, instrument air must be clean and moisture-free.

Boosters

Booster relays are essentially air-loaded, self-contained pressure regulators. They can be classified as (1) volume boosters, (2) ratio relays, and (3) reversing relays.

Volume boosters multiply the available volume of the air signal. The air regulator sends its output signal to the volume booster instead of directly to the valve. Volume relays can be used to increase the frequency response of a control valve. This is sometimes preferable to using positioners on fast control loops. Refer to Figure 4-30.

Ratio relays multiply or divide the pressure of an input signal. Ratio relays help in split-ranging applications. For example, a 1:2 ratio relay could change a 3–9 psig controller signal into a 3–15 psig output signal, and another 1:2 ratio relay could change a 9–15 psig controller signal into a 3–15 psig output signal. Thus, one controller signal of 3–15 psig could operate two valves of 3–15 psig without overlapping operation of the valves.

Reversing relays produce a decreasing output signal for an increasing input signal. Reversing relays are employed when two control valves, one air-to-open and the other air-to-close, are operated from the same controller. They might also be used to reverse part of the output pressure from a single-acting positioner to a double-acting piston actuator.

Reversible Electric Motor Drives

This type of actuator or servomotor is suitable for operating valves, dampers, and other lever-operated process regulators. Models are available that have torques ranging from 5 to 75 lb-ft and full-stroke speeds ranging from 10 to 60 seconds. The operating voltage of reversible electric motor drives is usually 120 V AC, single-phase, 50-60 Hz with a maximum running current of one ampere. A handwheel is provided for local manual operation. Internal worm gears prevent back drive caused by unbalanced loads. The linkage may be arranged for characterizing the process regulator. Extra limit switches and feedback transmitters for complex control applications have to be added.

Actuators that have higher torques are also available. Units that have torques ranging from 150 to 4,000 lb-ft are designed to operate large valves and dampers. Their full stroke speeds range from 30 to 300 seconds. Their operating voltage is 220 V AC, 3-phase, 50-60 Hz, and they have a power consumption at full running load that ranges from 0.5 to 5.0 kVA.

Stepping Motors

Stepping motors are also used as electrical actuators for small-sized valves. A stepping motor is an electromechanical device that rotates a discrete step angle when it is energized electrically. The step angle usually is fixed for a particular motor and thus provides a means for ensuring accurate positioning in a repeatable, uniform way. Typical step angles vary from 0.72 degrees to 90 degrees. Several means for energizing stepping motors electrically include DC pulses, square waves, fixed-logic sequences, and multiple-phase square waves.

Some of the basic design types for stepping motors include solenoid-operated ratchet, permanent magnet, and variable reluctance. Variations of these basic types may be combined with gears or hydraulic amplifiers to provide increased-output-torque stepping motors.

Although most stepping motors can be driven from switches or relays, most drive circuits incorporate solid-state devices that permit high-powered, fast operation. Simple drives convert low-level pulses into power pulses or correctly phased power. More complex drives adjust the power levels to allow the drives to run at very high rates.

At very low rates, the step movement resembles the classic damped oscillation curve. Mechanical or electrical damping can be added to modify the curve in order to provide critical damping. Since stepping motors move in discrete steps, they do not have the problems related to stability and feedback that are inherent in most servo devices. Direct digital control in an open-loop mode is possible with stepping motors. Closed-loop mode may be provided by coupling a pulse feedback to the motor.

Solenoid Valves

A solenoid valve consists of an electromagnetic coil and a valve. The electromagnetic coil actuates an armature or a valve stem in a magnetic field so as to control fluid flow. Solenoid valves have an on-off switching option and are actuated

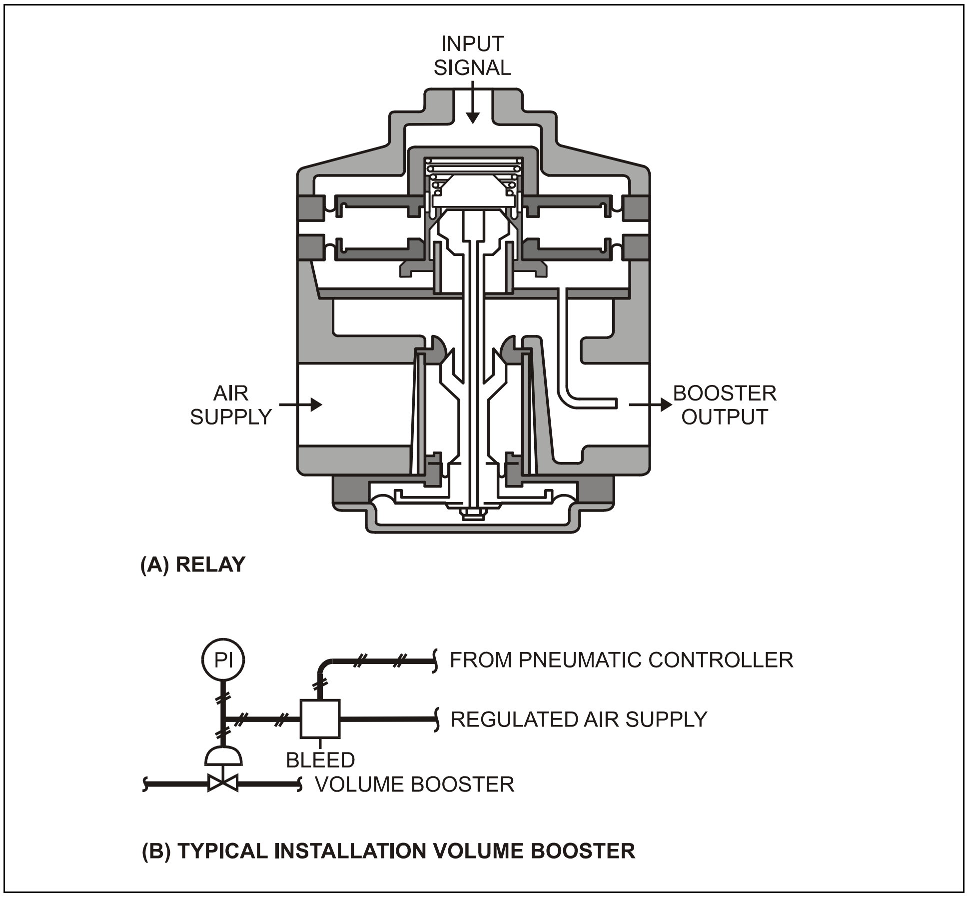

Figure 4-30. Volume Booster Design and Installation

by electric signals from remote locations. They accomplish in a pneumatic or liquid system what an electrical relay accomplishes in an electrical system. They are frequently used in conjunction with control valves to open or close the valve at predetermined conditions or limits.

When electrical power is supplied to the electromagnet, a magnetic field is created that causes the plunger to be positioned in the solenoid coil. The plunger is connected to a valve disc that opens or closes the orifice, depending on whether the valve is energized-to-open or energized-to-close. See Figure 4-31.

Types

The four basic types of solenoid valves are (1) two-way, (2) three-way, (3) four-way, and (4) pilot-operated.

- *Two-way* solenoid valves have two ports and provide a simple on-off switching action.
- *Three-way* solenoid valves have three pipe connections. A typical application is for two of the ports to be used to load or unload cylinders or diaphragm actuators.
- *Four-way* solenoid valves are used principally for controlling double-acting cylinders.
- *Pilot-operated* solenoid valves apply pressure to a diaphragm or piston, or they may release pressure, allowing higher upstream pressure to open the valve. A widely employed device is a small solenoid pilot valve that sup-

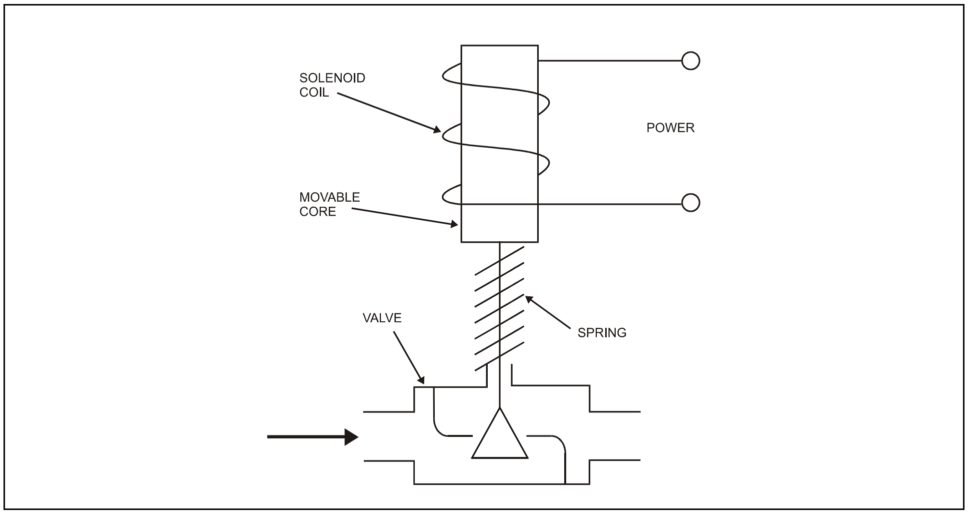

Figure 4-31. Schematic of a Solenoid Valve

plies pressure to a diaphragm or piston for a wide range of output forces. Solenoid valves are used either directly to supply signal air to the actuator or indirectly by blocking the air supply to the positioner.

Solenoid valves are the least expensive form of electrical actuation. They come in a variety of styles and flow capacities and with explosion-proof housings. It is usually specified that the valve supplier mount them directly to the diaphragm case by means of a suitable nipple, although large quantities of solenoid valves are often gang-mounted in local panels.

Electric Motor Drive Control

Motor controls are usually selected and specified by the electrical engineer. However, the instrumentation or control engineer and designer should also have some knowledge of this technology, since some of the process controls are interfaced with the motor control center (for example, electric motors used for variable speed pumps, metering pumps, screw conveyers, belt feeders, and so forth). Electric motor drives can be classified as constant-speed and variable-speed.

Constant-Speed Drives

Constant-speed applications have employed induction motors, wound-rotor motors, and synchronous motors mainly because alternating current is the more readily available source of electrical power. These AC motors can be started by full-voltage starters or by reduced-inrush starters. The latter method reduces the initial drain on the power system. The wound-rotor motor with a secondary control is also suitable for starting and accelerating a high-inertia load when low inrush currents are a requirement. Figure 4-32 shows diagrams of a full-voltage and a reduced-inrush starter.

These starters may be interlocked with process control devices such as programmable controllers for sequencing control (a start/stop loop, for example), limit switches, level, pressure, temperature, flow switches, and safety switches. The interlock contacts are usually in series with the push-button contacts and are activated by relays.

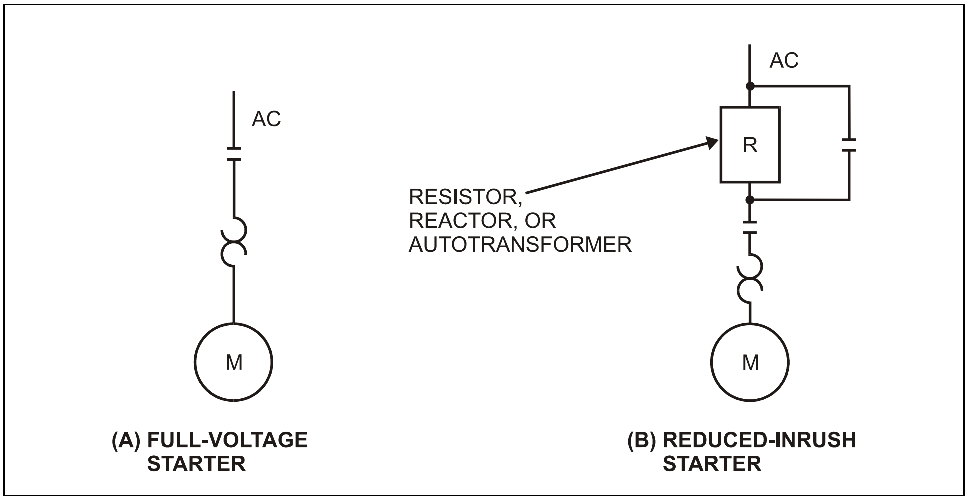

Figure 4-32. Constant-Speed AC Motor Control Diagram

Variable-Speed Drives

Variable-speed drives can use both AC and DC motors. Three major categories for DC drive systems are: (1) constant-potential with motor-field control, (2) rotating motor-generator set, and (3) static converter.

Most variable-speed DC motor drives are regulated by a silicon controlled rectifier (SCR), except for the rotating motor-generator type. A DC motor can be wired to large, constant-potential DC sources and regulated over a limited speed range by motor-field control. Very wide speed ranges can be achieved with rotating motor-generator sets and static SCR conversion technologies that are capable of providing adjustable armature voltage. Figure 4-33 shows a schematic diagram of a variable-speed DC drive control using an SCR.

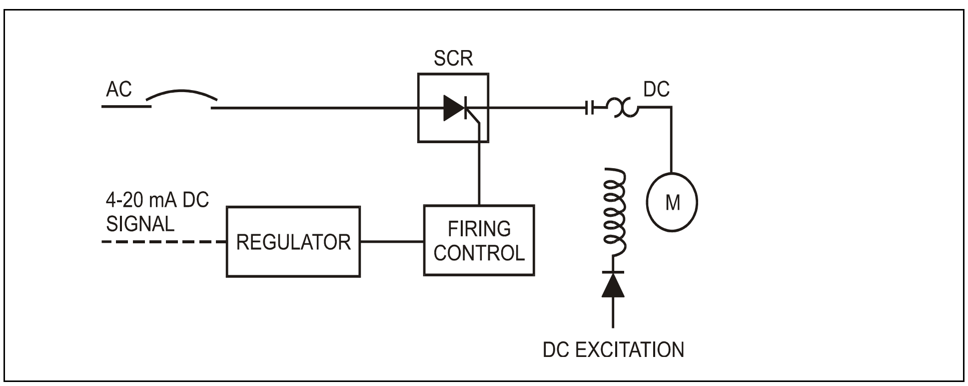

Figure 4-33. SCR Power-Conversion Variable-Speed DC Drive System

The firing control is the open and close switching activity of the SCR when the AC voltage passes through zero. One limiting factor in DC motor applications is that energy is supplied to the rotor of the motor through the commutator. Large amounts of power must pass from the DC line to the rotor through stationary carbon brushes that rub against the rotating commutator bars. This energy transfer reduces the practical top speed and upper voltage rating of large-horsepower DC drives. Such a method of energy transfer also precludes the application of DC motor drives in erosive and corrosive environments and in areas where explosive gas is present. The ideal drive system for such conditions would be a variable-speed AC drive.

Many combinations of variable-speed AC drives are available, especially some types with the latest solid-state technology, such as power transistors, gate turn-off thyristors, and microprocessors. The following classification of variable-speed AC drives shows how many possibilities exist:

(1) Adjustable voltage with wound-rotor motor.

(2) Adjustable voltage with high-slip induction motor.

(3) Adjustable frequency by:

- Rotating DC/AC motor-generator set with induction motor.
- Static converter/inverter with induction motor.
- Static cyclo-converter with induction motor.

(4) Synchronous motor adjustable-frequency drive.

(5) Induction motor with eddy current coupling.

(6) Induction motor with mechanical transmission.

Figure 4-34 shows a schematic diagram of a static SCR converter/inverter, power-conversion type, adjustable-frequency AC drive system.

In this system, constant-frequency AC power first is converted into constant-voltage DC power by means of a static rectifier. This DC power, in turn, is inverted into an adjustable-frequency power supply by means of static logic circuitry (microprocessor).

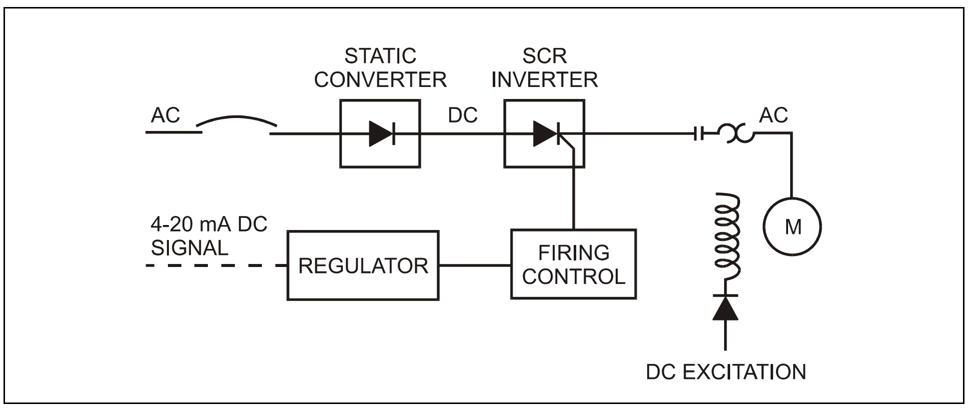

Figure 4-34. Adjustable Frequency AC Drive System

Metering Pumps

Metering pumps, also known as controlled-volume pumps or proportioning pumps, are utilized in process control as a final control element. Combining the functions of a pump, a measuring instrument, and a control valve, they control the rate at which a volume of fluid is injected into a process. They have inherently high steady-state accuracy and can be adjusted while in operation.

All three liquid-end designs rely on positive or swept-volume displacement to meter a wide range of substances. In each case, a metered pulse of fluid results from the combined motion of plunger or diaphragm and the one-way check valves located at the inlet and discharge ends of the pump. In all three designs, the check valves operate 180 degrees out of phase to permit the displacement chamber to be filled during the suction stroke and to prevent backflow during the discharge stroke.

The key to constant, precise delivery of liquid is the liquid-end of a metering pump. There are three basic types of liquid-ends: (1) packed plunger, (2) disc diaphragm, and (3) tubular diaphragm.

The powered drive unit may be either an AC or DC motor. Through an SCR unit, the speed of the metering pump can be automatically varied in proportion to changes in process line flow so as to maintain a fixed ratio of chemical additive to the process line flow. A controller may also transmit a signal to automatically reset the stroke length of the pump by using a stroke adjustment actuator. Figure 4-35 shows an application of a metering pump.

In this example, both flow and pH values are measured, but only the pH value is controlled. The motor speed depends upon the flow rate, and the stroke adjustment is a function of the pH value. The example in Figure 4-35 is indicative of the additional applications where a variable-speed motor drive may be used as final control element.

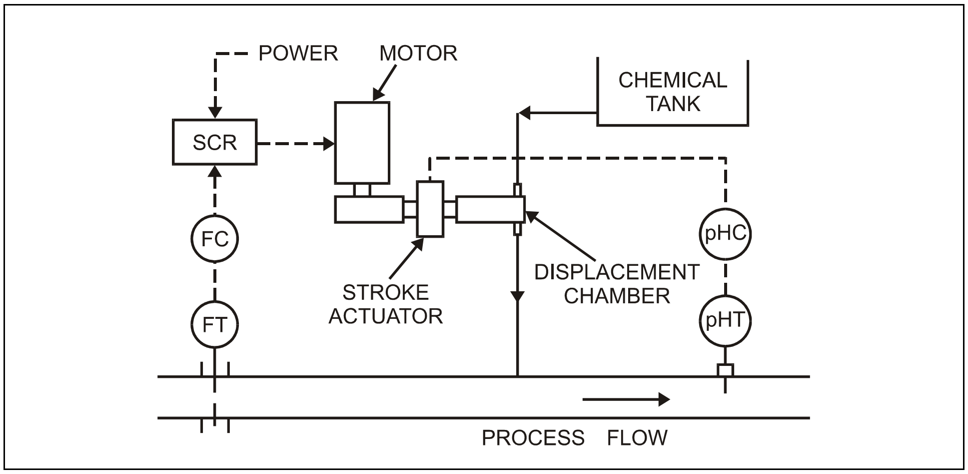

Figure 4-35. pH Control and Additive Metering

Regulators, Relief Valves, and Other Control Elements

Regulators

One of the simplest of automatic process controllers is the regulator valve.

A regulator is a self-contained device that performs all the control functions necessary to maintain a constant, reduced downstream pressure, flow, level, or temperature. All the energy required to operate it is derived from the controlled system.

In general, regulators are simpler than the alternative: a control valve with its external power sources and transmitting and controlling instruments.

All regulators, whether they are used for pressure, level, or flow control, are either direct-operated or pilot-operated. Direct-operated regulators are adequate for narrow-range control and situations where the allowable change in outlet pressure can be 10 to 20 percent of the outlet pressure setting. Pilot-operated regulators are preferred for broad-range control or where the allowable change in outlet pressure must be less than 10 percent of the outlet pressure setting. They are also commonly used when a regulator application requires that a set point be adjusted remotely. Figure 4-36 compares regulator and control valve characteristics.

LEVEL

Level regulators are used to maintain liquid level within a tank. A complete level regulator consists of a float as a sensing element, an actuator, and a valve body. A level regulator may be an integral unit assembled from a ball float sensor, a level actuator, and a valve. Figure 4-37 shows different types of level regulators.

SELECTED REGULATOR CHARACTERISTICS	SELECTED CONTROL VALVE/INSTRUMENT CHARACTERISTICS
PURCHASE PRICE, INSTALLATION, AND MAINTENANCE COSTS ARE NORMALLY LOWER.	WIDE VARIETY OF CONSTRUCTION MATERIALS AND ACCESSORIES AVAILABLE.
REQUIRES NO ADDITIONAL POWER SOURCES FOR BASIC OPERATION.	TRANSMITTING AND CONTROLLING INSTRUMENTS ARE SEPARATE AND MAY BE REMOTE MOUNTED.
LESS COMPLEX, AND OFTEN LIGHTER AND MORE COMPACT.	SPECIFIC CONSTRUCTION HAS BROAD APPLICATION FLEXIBILITY.
CONTROLLER, WHICH PROVIDES FIXED-BAND PROPORTIONAL CONTROL ONLY, IS BUILT IN.	SEPARATE CONTROLLER ALLOWS FOR ADJUSTABLE-BAND PROPORTIONAL CONTROL WITH RESET AND/OR RATE OPTIONS FOR EXCELLENT CONTROL RESPONSE.

Figure 4-36. Regulator versus Control Valve
(Courtesy of Fisher Controls International, Inc.)

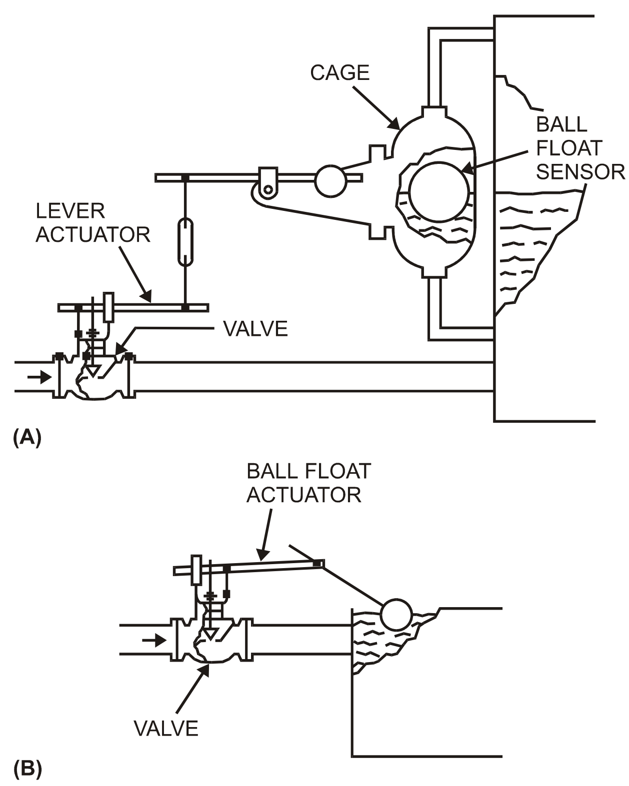

Figure 4-37. Level Regulators
(Courtesy of Fisher Controls International, Inc.)

PRESSURE

A pressure-reducing regulator maintains a desired reduced outlet pressure while providing the fluid flow necessary to satisfy a variable downstream demand. The value at which the reduced pressure is maintained is the outlet pressure setting of the regulator.

A direct-operated pressure-reducing regulator, as shown in Figure 4-38, senses the downstream pressure through either an internal pressure tap or an external control line. This downstream pressure opposes a spring that moves the diaphragm and the valve plug so as to change the size of the flow path through the regulator. Adding a pilot to a regulator provides a two-path control system. The main valve diaphragm responds quickly to downstream pressure changes, causing an immediate correction in the main valve plug position. The pilot diaphragm responds simultaneously, diverting some of the reduced inlet pressure to the other side of the main valve diaphragm so as to control the final positioning of the main valve plug. See Figure 4-38.

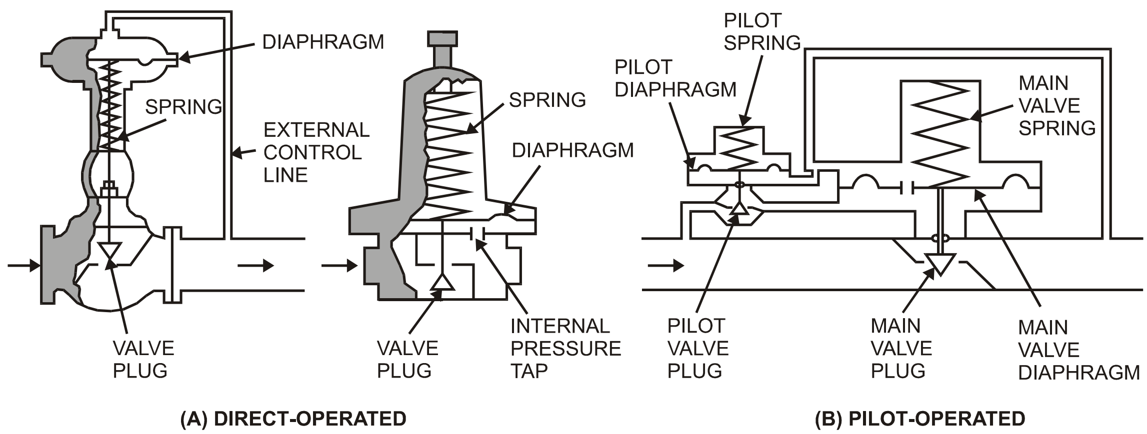

Figure 4-38. Pressure Regulators
(Courtesy of Fisher Controls International, Inc.)

FLOW

A self-contained flow regulator or differential pressure-reducing regulator maintains a pressure difference between two locations in the pressure system. The value at which the pressure difference is maintained is the differential pressure setting of the regulator.

As shown in Figure 4-39, a differential pressure-reducing regulator has two pressure taps. Output pressure from a remote-mounted instrument or a pressure loader is applied to the top of the main diaphragm through an external pressure tap. The outlet or control pressure is applied to the bottom side of the diaphragm through an external pressure tap.

In some differential pressure-reducing regulators, this control pressure is applied to the bottom side of the diaphragm through an internal pressure tap. The differential pressure is applied to a spring-and-diaphragm mechanism that moves the valve plug so as to change the size of the flow path through the regulator.

TEMPERATURE

The temperature regulator is a self-contained control device that consists of a primary detection element or bulb, a measuring element or actuator, a reference input adjustment, and a final control element or valve. As with pressure regulators, there are direct-operated and pilot-operated devices.

With the direct-operated temperature regulator, the components of the actuator (bellows, diaphragm) are connected directly to the valve plug, thus developing the force and travel necessary to open and close the valve. Direct-operated temperature regulators generally have a more simplified construction and operation than the pilot-operated type and are less expensive.

In the pilot-operated type, the actuator moves a pilot valve (internal or external). The pilot controls the amount of pressure from the fluid through the valve to a piston or diaphragm, which in turn develops power and thrust to position the

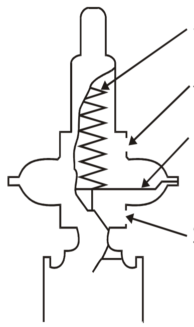

Figure 4-39. Differential Pressure Regulator
(Courtesy of Fisher Controls International, Inc.)

main valve plug. Pilot-operated temperature regulators have smaller bulbs, faster response, and higher proportional gain. They can also handle higher pressures through the valve.

Temperature regulators may be either self-contained or remote-sensing. Self-contained regulators contain the entire thermal actuator within the valve body, the actuator being part of the primary detecting element. They can sense only the temperature of the fluid flowing through the valve. The regulator regulates the fluid temperature by regulating the fluid's flow.

In remote-sensing regulators, the bulb is connected to the thermal actuator by flexible capillary tubing. This construction allows them to sense and regulate the temperature of a fluid aside from that of the fluid flowing through the valve. This type of regulator, although frequently lower in cost, is limited in application to such uses as regulating the temperature of water or some other type of coolant.

Valve action (direct or reverse) is selected as a function of the process. Direct action is used for heating control. The direct-acting valve reduces the flow of the heating medium on temperature rise. The reverse-acting regulator is generally used for cooling control to increase the flow of coolant on rising temperature.

The mixing of two media at different supply temperatures to control the mixed temperature is accomplished with three-way valves.

Bronze and cast iron are standard construction materials for the body of regulators. Composition discs are used for tight shutoff on low pressure or temperature applications.

Dampers

Dampers may be used to control the flow of gases and vapors as well as solids, or to throttle the capacity of fans and compressors. Dampers are suitable for controlling large flows at low pressure where high control accuracy is not a requirement. They are usually larger in size compared to control valves and, therefore, are restricted to lower operating and shutoff pressures. Typical applications include control of air conditioning systems and furnace draft.

TYPES OF DAMPERS

Two quality levels of dampers are available: (1) commercial, which are used primarily for HVAC (heating, ventilating, and air conditioning) applications, and (2) industrial, which are used in process control to handle higher pressures, temperatures, and corrosive vapors.

Dampers are classified as to type of construction, namely, louvered, guillotine, butterfly, and iris.

- *Louvered*, or multiblade, dampers consist of two or more rectangular vanes that are mounted on shafts one above the other and interconnected so as to rotate together. The vanes are operated by an external lever that can be positioned manually, pneumatically, or electrically. These dampers may be parallel-blade or opposed-blade. See Figure 4-40.

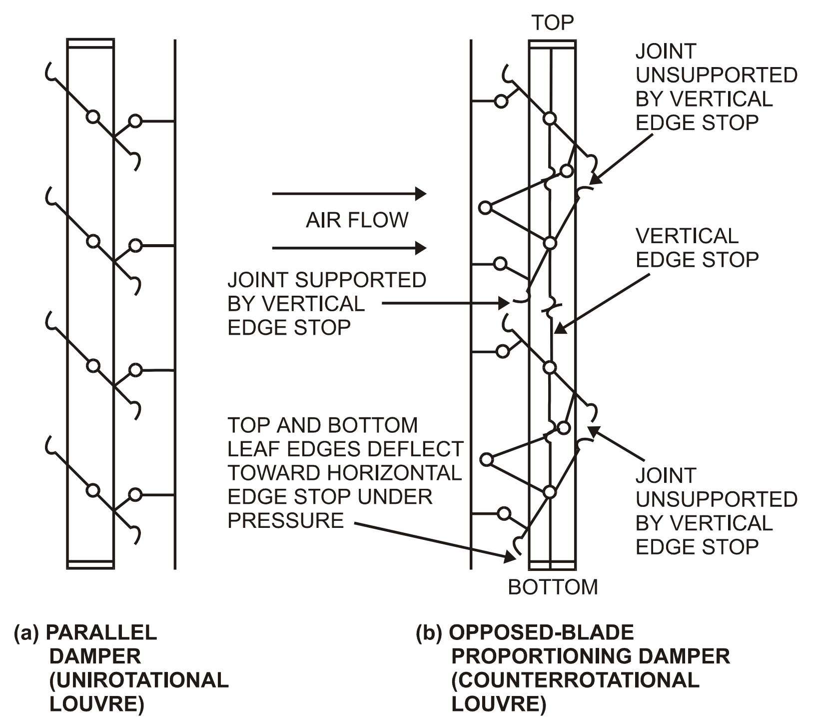

Figure 4-40. Louvered Dampers
(From Lipták, B., Instrument Engineer's Handbook, Chilton Book Co., 1985)

- *Guillotine* or slide-gate dampers are similar in principle to knife-gate valves.
- *Butterfly* dampers are similar in principle to butterfly valves.
- *Radial-vane* dampers are used on blowers and fans. The damper consists of a number of radial vanes arranged so as to rotate about their radial axis. This type of damper has a high leakage rate. See Figure 4-41.
- *Iris* dampers are also known as variable-orifice valves. The closure element moves within an annular ring in the valve body and produces a circular flow orifice of variable diameter. Tight shutoff is not possible, and the maximum allowable differential pressure is 15 psi. Dual valve units are available that have a common discharge port for blending two streams. When iris dampers are used for throttling on solids service, they must be installed in a vertical line. See Figure 4-42.

DAMPER ACTUATORS

Damper actuators may be manual, electric, hydraulic, or pneumatic. Standard spring ranges include spans of 3–7, 5–10, or 8–13 psig. Actuators may be provided with positioners, which assure more accurate throttling.