

Manual on Installation of Refinery Instruments and Control Systems

Part I—Process Instrumentation and Control Section 6—Control Valves and Accessories

Refining Department

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Part I—Process Instrumentation and Control

SECTION 6—CONTROL VALVES AND ACCESSORIES

6.1 Scope

This section presents recommended practices for the installation and maintenance of control valves and related accessories such as positioners, boosters, and transducers. It also outlines control valve design considerations, discusses control valve sizing and noise, and defines types of commonly used control valves and their actuators.

A number of instruments and accessories can be mounted on and used in conjunction with control valves. Other sections of this manual will be referred to for installation, piping, and electrical practices covering those devices.

6.2 General

6.2.1 ACCESSIBILITY

All control valves should be installed so that they are readily accessible for maintenance purposes and for operation of a handwheel, if one is provided. They should generally be located at grade unless pressure head or other design conditions make such an arrangement impractical. When located above grade, control valves should be installed so that they are readily accessible from a permanent platform or walkway with ample clearances for maintenance purposes.

6.2.2 LOCATION

Where there is a choice of location, it is desirable to have the control valve installed near the piece of operating equipment that must be observed while on local manual control. It is also desirable to have indication of the controlled variable readable from the control valve.

6.2.3 INSTALLATION CLEARANCES

If a control valve is to be maintained in place, sufficient clearance should be provided above, below, or on the side so that the valve trim and the valve actuator may be removed from the valve body.

Extra clearance is required where extension bonnets or accessories are used. Clearance should always be provided on the side of the valve for maintenance of positioners and other devices.

6.2.4 PRECAUTIONS

Control valves that handle combustible fluids should be kept away from hot pumps, lines, or equipment. This prac-

tice reduces the possibility of such fluids contacting hot lines or equipment if the control valve manifold is drained and the valve is removed, or if leaks develop.

Certain rotary-motion control valve types utilize low-friction plastic lined bearings and as a result are susceptible to static electricity and should be grounded. Follow the manufacturer's recommendations.

Users should be aware that long bolts used with flangeless valves can expand when exposed to fire and cause leakage. A fire deflection shield and/or insulation is recommended. In addition, high-tensile-strength bolting is required.

Similarly, control valves used in process lines or fuel lines to fired heaters should be located outside the firewall around the heater. If no firewall is provided, the control valves should be located on the sides of the heater away from the burners or at a sufficient distance from the heater so that the line may be drained and the control valves removed without danger of a flashback. An alternate method is to pipe the drain or bleed connection a safe distance from the heater.

Because high temperatures can cause premature failure of diaphragms and electrical or electronic components, control valves should be located so that topworks are not adjacent to hot lines or equipment or in an area where temperature may be excessive. Consult the manufacturer's literature for maximum permissible ambient temperature.

Electrically operated items—motor actuators, solenoid valves, transducers—should be approved for use under the applicable hazardous area classification.

Control valves are normally protected with covers for flanged openings and threaded plugs for threaded openings during shipment and storage prior to installation.

During startup of any new facilities, care should be taken to keep scale, welding rods, and other foreign material from plugging or damaging control valves. One method is to remove the valve and substitute a spool piece during flushing operations.

6.3 Control Valve Design Considerations

6.3.1 GENERAL

A control valve, as shown in Figure 6-1, consists of two major subassemblies: a valve body and an actuator. The valve body is the portion that actually contains the process fluid. It consists of a body, internal trim, bonnet, and sometimes a bottom flange. This subassembly must meet all of the ap-

plicable pressure, temperature, and corrosion requirements of the connecting piping.

The internal trim controls the process fluid, provides the flow characteristic, and can accomplish the process shutoff requirements. The trim components vary depending upon valve style. Globe valves have internal trim consisting of plug, seat ring(s), plug stem, plug guide(s), and sometimes a cage. Rotary-motion valves have internal trim consisting of a ball, or eccentric plug, or vane, and seal ring, rotary shaft, and bushings.

The actuator subassembly moves the control valve in response to an actuating signal from an automatic or manual device. It must develop adequate power to overcome the forces within the body subassembly and at the same time be responsive enough to position the valve plug accurately during changing process demands.

6.3.2 MATERIALS OF CONSTRUCTION

Materials of construction are very important in control valve design since control valves are required to handle all types of fluids. These fluids can vary from clean, dry air to corrosive chemicals at temperatures ranging from near absolute zero to well above 1000 F (538 C) and pressures from near vacuum to 50,000 pounds per square inch (345 megapascals) or higher.

Most control valve materials can be placed in two categories: (1) the pressure containment materials for the valve body, bonnet, bottom flange, and bolting; (2) the valve trim materials.

For pressure containment components, there are many materials available. Some services require the use of exotic alloys and metals to withstand corrosive fluids. However, for the majority of applications carbon steel is the most common material used. Some of the other materials used are chromium-molybdenum, stainless steel, cast iron, and bronze.

Selection of valve trim material is generally influenced by the factors of corrosion, erosion, wear, galling, pressure drop, and temperature, instead of pressure containment considerations. Commonly used materials are AISI Types 304, 316, 416, and 440, and 17-4 PH (precipitation hardened) stainless steels. Other materials such as aluminum-nickel alloy¹, cobalt-chromium alloy², and nickel-based alloys³ are sometimes required. A common practice is to utilize a base material, such as Type 316 stainless steel, faced with cobalt-chromium alloy at points of expected wear such as seating surfaces and guide posts.

¹ For example, Monel.

² For example, Stellite.

³ For example, Hastelloy B or C.

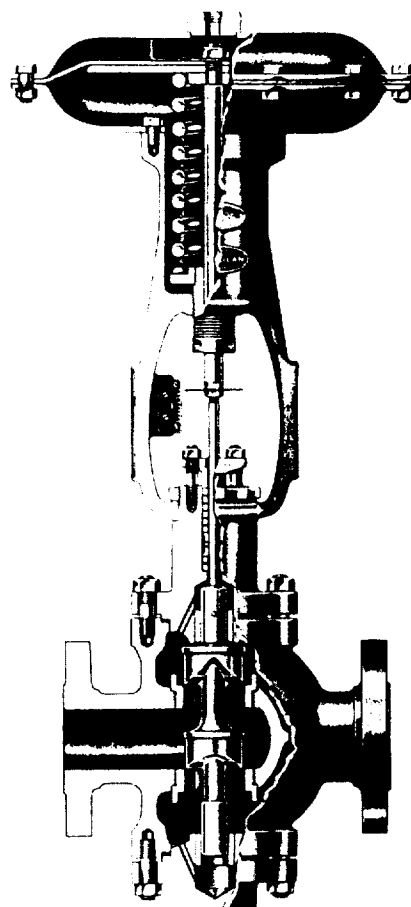


Figure 6-1—Control Valve Assembly

6.3.3 PRESSURE CONTAINMENT

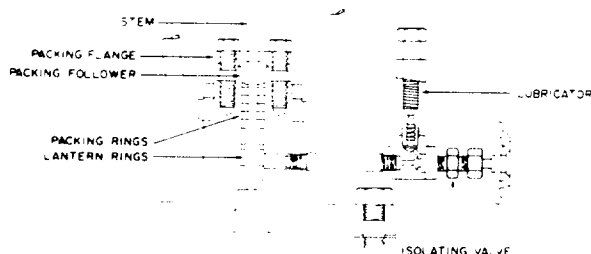
Pressure and temperature ratings for the pressure containment parts have been established for the more common materials by the American National Standards Institute (ANSI).

Since the allowable working stress of most materials decreases at elevated temperatures, the pressure-temperature rating must be considered in the choice of materials.

A control valve must have a pressure-temperature rating compatible with the system in which it is employed. In smaller sizes, it is often more economical to standardize on a minimum rating (such as ANSI Class 300).

6.3.4 END CONNECTIONS

Control valve end connections may be classified as threaded, butt-welded, socket-welded, flanged, or flangeless.



NOTE: Many packing box assemblies available today do not require lubrication. In such cases the lubricator and isolating valve shown in this figure are not required.

Figure 6-2—Packing Box Assembly (Bolted) With Lubricator and Isolating Valve

Female National Pipe Thread connections are common in valve sizes 1 inch and smaller and are sometimes used for control valves up to 2 inches.

Welded ends may be used where high pressure, high temperature, or highly toxic fluids are encountered. Care should be taken that the valve body material specified is compatible with the adjoining pipe material.

Flanged-end globe bodies generally conform to the standardized face-to-face dimensions listed in the Instrument Society of America (ISA) standard S75.03-1984, *Face-to-Face Dimensions for Flanged Globe-Style Control Valve Bodies*, with the exception of Saunders types, angle bodies, and rotary valves. The flange rating is determined by the type of service, required material, maximum pressure, and maximum fluid temperature.

Flangeless valves have no flange connections as part of the valve body and are simply bolted or clamped between the adjoining line flanges. Flangeless valve face-to-face dimensions generally conform to ISA S75.04-1984. Note that butterfly valves are not covered by a standard.

6.3.5 PACKING

The packing box assembly, Figure 6-2, provides a means for preventing the leakage of process fluid past along the surface of the valve stem. Packing boxes should be easily accessible for periodic adjustment and should permit the addition of at least one more split packing ring without disassembly. The packing material should (1) be elastic and easily deformable, (2) be as chemically inert as possible, (3) be able to withstand applicable process conditions, (4) provide a degree of fire resistance, and (5) minimize friction.

Polytetrafluoroethylene⁴, because of its excellent inertness

and its good lubricating properties, is one of the most popular valve packing materials. It may be used in solid molded, braided, or turned form (chevron rings) or as a lubricant for asbestos packing. Its temperature limit with standard packing box construction is 450 F (232 C).

Another popular packing type is braided asbestos with nickel-chromium-iron alloy⁵ wire employing additives such as mica or graphite for lubrication. This packing may be used in high-temperature steam and petroleum service, approaching 1000 F (538 C). Manufacturers should be consulted to ensure proper valve construction.

A recent addition is an all-graphite⁶ product that is essentially chemically inert except when strong oxidizers are handled. This type of packing can be used for temperature applications approaching 2000 F (1093 C). Manufacturers should be consulted to ensure proper valve construction.

6.3.6 SEAT LEAKAGE

The control valve plug is the moving component of the valve that throttles flow by positioning itself within the seat orifice and shuts off flow by contacting the seat.

The degree of sealing (shutoff) accomplished is dependent upon the valve construction, the materials and condition of the seating surfaces, and the actuator power available. Double-seated globe valves, due to machining tolerances, do not seat tightly. Manufacturers therefore publish a leakage rate of 0.5 percent of the rated valve capacity coefficient (C_v). Single-seated valves with metal-to-metal seating surfaces provide less leakage, and the normal published leakage rate is 0.01 percent of rated C_v .

Most control valve manufacturers follow the voluntary test and leakage standards established by ANSI B16.104-1976.

With additional considerations, such as careful lapping of the seating surfaces and increased actuator power, single-seated globe valves with metal-to-metal seating surfaces can meet even more stringent seat tightness requirements.

For specialized applications, control valves can be provided with a resilient composition insert (soft-seat construction) in either the plug or seat ring that will allow the valve to obtain bubble-tight sealing with relatively small actuator force. Common insert materials are nitrile rubber⁷ or polytetrafluoroethylene.⁸ However, before an insert material is selected, it should be determined that the insert is compatible with the process.

⁵ For example, Inconel.

⁶ For example, Grafoil.

⁷ For example, Buna N.

⁸ For example, Teflon.

⁴ For example, Teflon.

6.3.7 CONTROL VALVE CHARACTERISTICS

Control valve flow characteristics are determined principally by the design of the valve trim. The three inherent characteristics available are quick opening, linear, and equal percentage. These are shown in Figure 6-3. A modified percentage characteristic generally falling between the linear and equal percentage characteristics is also available.

The three inherent characteristics can be described as follows:

1. *Quick Opening.* As the name implies, this characteristic provides a large opening as the plug is first lifted from the seat, with lesser flow increase as the plug opens further. This type is most commonly used where the valve will be either open or closed with no throttling of flow required.
2. *Linear.* Linear trim provides equal increases in C_v for equal increases in stem travel. Thus the C_v increase is linear with plug position throughout its travel.
3. *Equal Percentage.* Equal percentage trim provides equal percentage increases in C_v for equal increments of stem travel. This is accomplished by providing a very small opening for plug travel near the seat and very large increases toward the more open position. As a result, a wide rangeability of C_v is achieved.

The pressure difference across the valve often varies with flow. This results in an "installed characteristic," which will differ from the inherent characteristic.

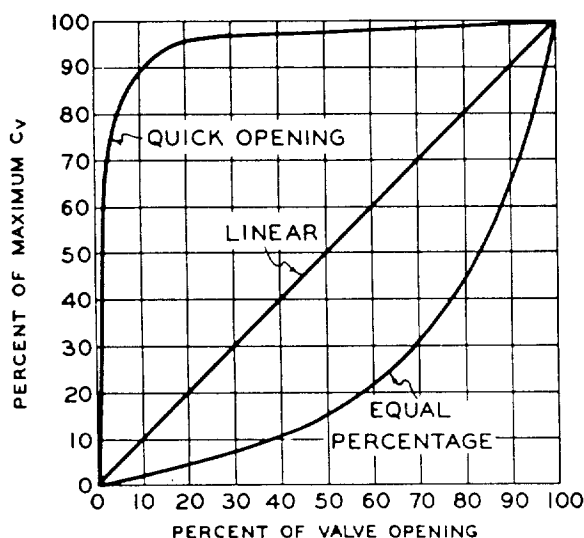


Figure 6-3—Representative Inherent Flow Characteristic Curves

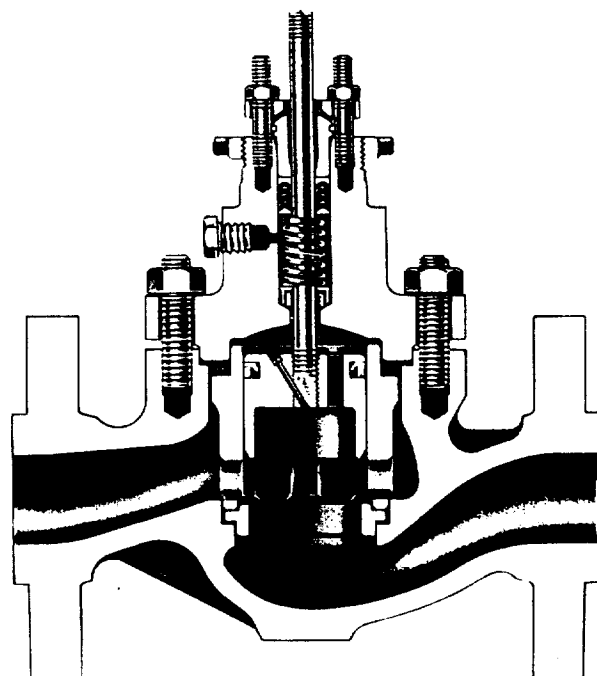


Figure 6-4—Globe Body Valve, Cage Guided

6.4 Control Valve Types

6.4.1 GENERAL

Today's control valves operate by one of two primary motions: reciprocating (sliding stem) motion, or rotary motion. The selection of a valve for a particular application is primarily a function of the process requirements, and no attempt will be made here to cover this subject. Some of the more common types of control valve bodies are discussed in 6.4.2 through 6.4.8.

6.4.2 GLOBE BODY VALVE

The globe valve design illustrated in Figure 6-4 is known as cage guided. This design uses a piston or plug moving inside a cylindrical guide (cage) having characterized ports. In this design two options are available:

1. A single-seat construction for minimum leakage in the closed position.
2. A balanced construction requiring less actuator force, but possibly allowing more leakage in the closed position. The

valve trim may be replaced without removing the valve body from the line.

The globe valve design illustrated in Figure 6-5 is known as top guided. In this design the plug guiding is accomplished within the lower portion of the valve bonnet. This design is a single-seat type and provides minimum leakage in the closed position. Because of the unbalanced construction, it requires considerable actuator power, particularly in larger sizes.

The globe valve design illustrated in Figure 6-6 is known as top and bottom guided. In this design the plug guiding is accomplished in the valve bonnet and the valve bottom flange. It is a double-seat type and has a higher leakage rate in the closed position than a single-seat type. The plug design does provide a balancing feature, which reduces required actuator forces.

A similar design, but with single-seat construction, is also available from some manufacturers.

Another variation is the split body valve shown in Figure 6-7, which is available both in globe- and angle-type patterns. In this valve, the seat ring is clamped between the two

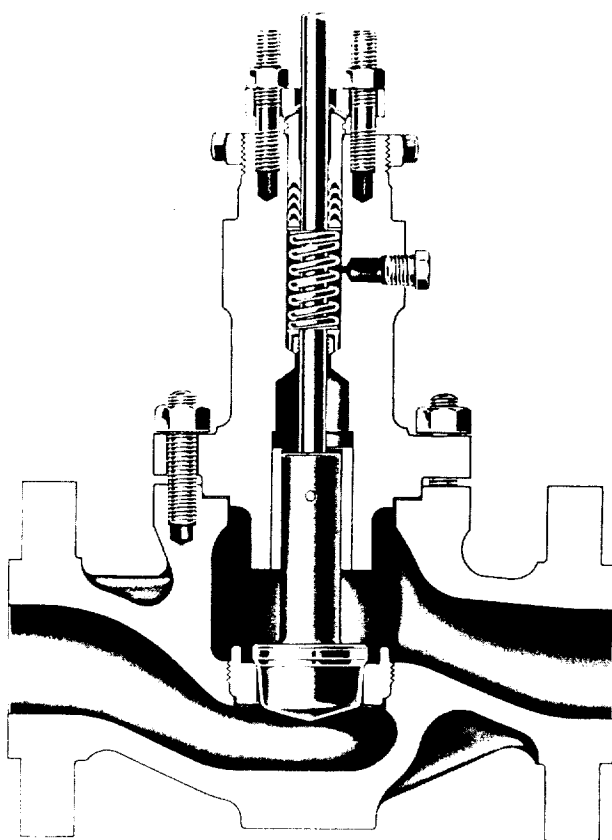


Figure 6-5—Globe Body Valve, Top Guided

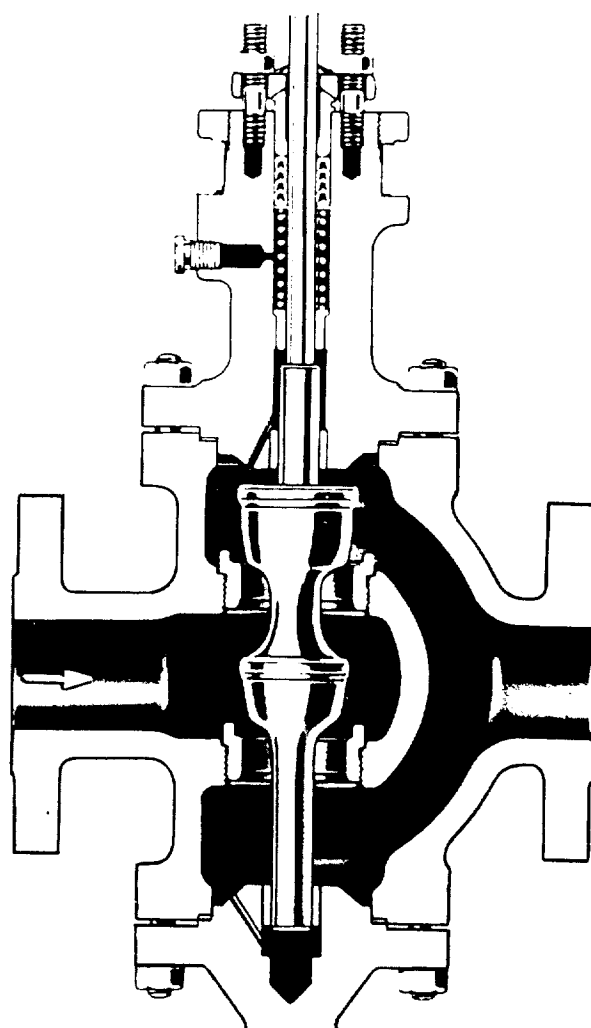


Figure 6-6—Globe Body Valve, Top and Bottom Guided

body sections, which makes it easily removable for replacement. This design is a single-seat type and minimizes leakage in the closed position. However, because of the unbalanced construction, it requires considerable actuator power, particularly in the larger sizes. Guiding is accomplished in the upper portion of the valve body and is known as stem guiding. The split body valve is used extensively in chemical processes because of (1) its availability in alloy materials and (2) its use of separable flanges, which can be manufactured from less expensive materials.

6.4.3 BUTTERFLY VALVE

The butterfly valve shown in Figure 6-8 is a rotating-vane valve characterized by high pressure-recovery (see 6.5.4) and used in applications where high capacity and low pressure

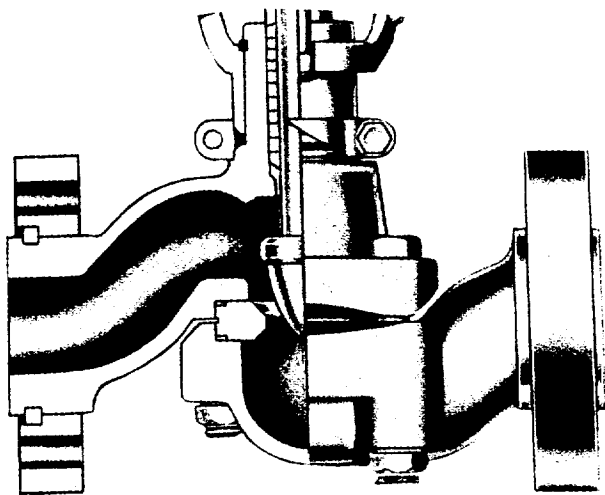


Figure 6-7—Split Body Valve, Stem Guided

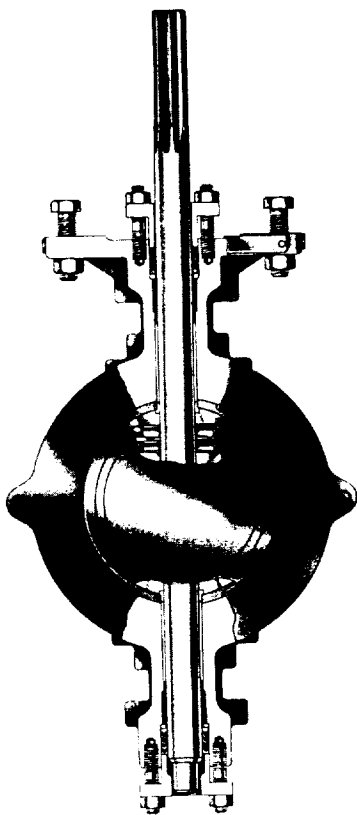


Figure 6-8—Butterfly Valve

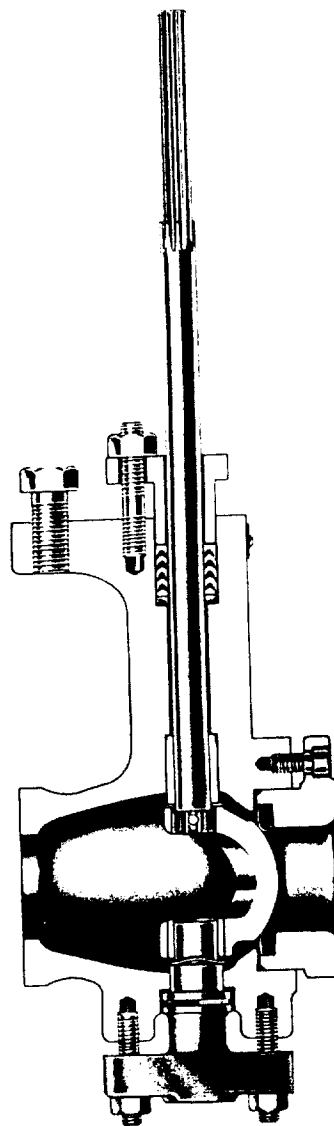


Figure 6-9—Ball Valve

drop are required. Although not normally used in minimum leakage applications, it is available with piston ring, pressurized seat, or various types of elastomer seating surfaces if minimum leakage is required.

6.4.4 BALL VALVE

The ball control valve shown in Figure 6-9 is a rotating-stem, high pressure-recovery type of valve in which the flow of fluid is restricted by using a full- or partial-type ball in the valve body. This valve has a high flow coefficient and