Engineering Encyclopedia

Saudi Aramco DeskTop Standards

Control Valve Selection

Chapter : Instrumentation
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CONTENTS **PAGE**

LIST OF FIGURES

CONTROL VALVE DEFINITION, FUNCTION, AND NOMENCLATURE

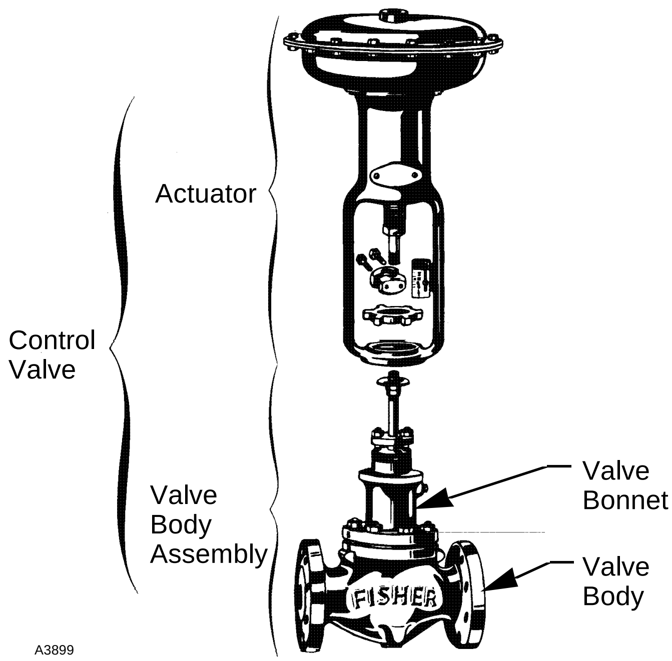
Control Valve Definition

ISA Definition

The ISA (Instrument Society of America) defines a control valve as a power operated device that modulates the fluid flow rate in a process control system. A control valve consists of a valve connected to an actuator mechanism. The actuator, in response to a signal from the controlling system, can change the position of a flow-controlling element in the control valve.

Major Components

The ISA definition implies that a control valve is actually an assembly that includes, at minimum, a valve body assembly and an actuator, as shown in Figure 1. The valve body assembly consists of a valve body and a valve bonnet.



Major Valve Components
Figure 1

Typical Saudi Aramco Applications

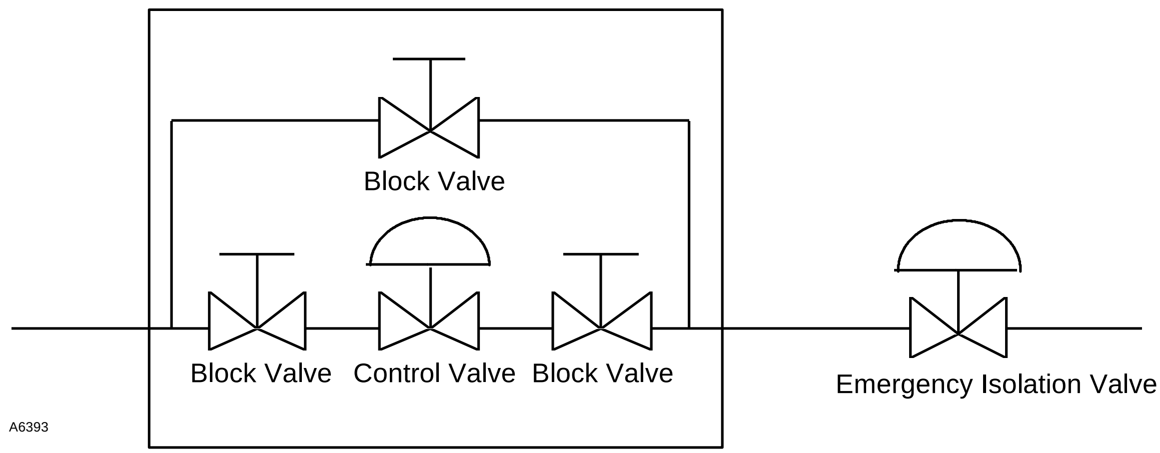
Throughout oil and gas production and processing activities, modulation of fluid flow achieves and maintains desired values for such variables as: flow rate, pressure, liquid level, temperature, and density.

Control Valves Vs. Non-Control Valves

Control Valves

A control valve serves as a variable orifice. The variable orifice includes a port and a closure member such as a plug, disk, or ball. In some applications, the closure member of the control valve is in a constant state of motion, responding to continuous changes in the signal from the control system. To ensure proper operation and long life in a throttling application, a control valve must be ruggedly built. The requirement for constant throttling and the heavy-duty construction that is necessary to withstand the rigors of throttling service distinguish control valves from many other valve types. Refer to Figure 2 and note the distinctions between control valves, block valves, and emergency isolation valves.

Control Valve Bypass Arrangement



Valve Type	Major Function	Major Characteristics	Operation
Control Valve	Modulate flow rate	Operated by an actuator Very rugged May be smaller than line size	Continuous throttling
Block Valve	Fully close or open the pipeline	Full bore Often manually operated	Occasional
Emergency Isolation	Fully close or open the pipeline automatically and quickly	Full bore Typically operated by actuator	Occasional

Comparison Of Valve Types, Functions, Characteristics
Figure 2

Block Valves

The role of a block valve is to fully open or fully close a pipeline. Block valves are not subjected to the rigors of throttling in mid-travel positions, and they are operated only occasionally. The less stringent requirements for block valves are generally visible in terms of design sophistication, materials of construction, and construction details. Block valves do, however, include a sealing method that provides tight shutoff. Section 8.2.2 of Saudi Aramco Engineering Standard J-700 requires the use of full-bore gate, ball, globe, or butterfly valves as block valves. The requirement for a full-bore valve design ensures maximum flow capacity. In contrast, the role of a control valve is to modulate flow; accordingly, very few control valves are of a full-bore design. Block valves, are typically installed in bypass arrangements (refer to Figure 2). A typical bypass arrangement includes valves that direct flow around a control valve or other device to allow removal or repair of the control valve or other device without a shut down of the system. Block valves are often manually operated with handlevers or handwheels.

Emergency Isolation Valves

Emergency isolation valves are distinguished from control valves by function and by performance requirements. Emergency isolation valves are designed to provide tight shutoff when closed, full pipeline capacity when open, and the ability to open or close quickly. Emergency isolation valves are actuated by Emergency Shutdown System commands, which, in the event of fire, vessel rupture, pipe rupture, or other loss of containment, function to isolate process equipment and to stop the release of hydrocarbons or potentially toxic materials. Emergency isolation valves are typically operated by actuators. As with other block valves, there is typically no requirement for throttling, and they are operated only occasionally. Section 4 of SAES-J-700 disallows the use of control valves as emergency isolation valves.

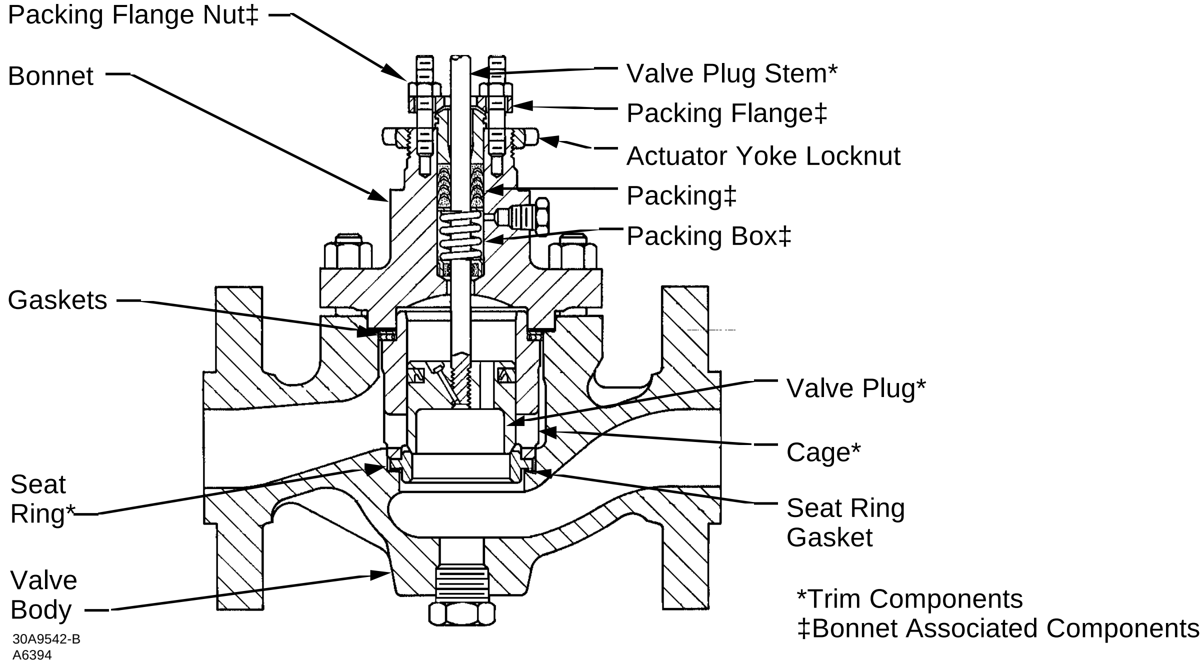
Saudi Aramco Standards

Section 4 of SAES-J-700 allows the specification of any of the following valve types as control valves: globe valves, angle valves, ball valves, butterfly valves, axial flow valves, and rotary-plug valves. Globe valves, angle valves, and axial flow valves are often referred to as sliding-stem valves, while ball valves, butterfly valves, and rotary-plug valves are commonly referred to as rotary-shaft valves.

Standard Nomenclature

Sliding-Stem Valves (Fisher ES)

Sliding-stem valves include globe valves, angle valves, and axial flow valves. Of all the control valve types, the sliding-stem, globe style valve is the most common. As shown in Figure 3, the major components of a sliding-stem, globe style valve include the valve body, bonnet, trim, gaskets, and packing.



Sliding-Stem, Globe Style Valve Nomenclature
Figure 3

Valve Body - The valve body is the main fluid boundary and pressure containing component. The valve body includes provisions for securing internal parts, end connections that allow installation in the pipeline, and a means for attaching the bonnet.

Bonnet - The bonnet is also a major pressure containing component and fluid boundary. In common configurations, the bonnet is bolted or threaded onto the valve body. The bonnet locates and guides the valve stem, and it includes a bore for the packing that is referred to as the packing box. The bonnet also includes a yoke boss or some other means of mounting an actuator. When the valve design includes a yoke boss, an actuator yoke locknut secures the actuator to the bonnet.

Most globe and angle valves are top-entry designs. This means that removal of the bonnet allows access to all internal trim components for maintenance or replacement. The top-entry design allows in-line valve maintenance, provided that the valve is isolated from system pressure prior to bonnet removal.

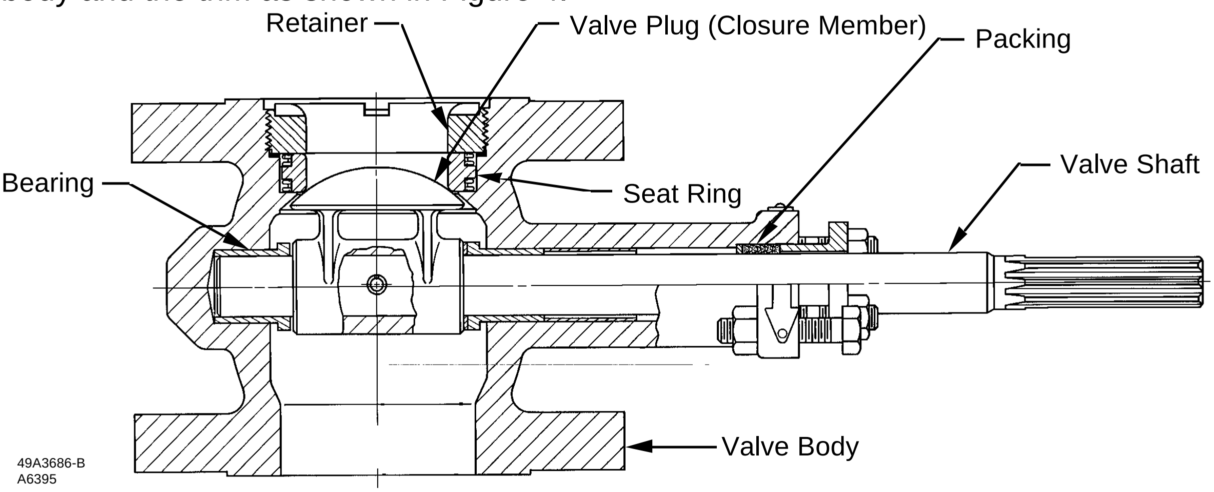
Trim - Trim refers to all internal, process wetted components. Trim includes the valve plug, the valve plug stem, the cage, and the seat ring.

Gaskets - In a typical valve construction, a bonnet gasket provides a seal between the body and bonnet mating surfaces; a cage gasket provides a seal between the bonnet and the cage mating surfaces; and a seat ring gasket provides a seal between the seat ring and body mating surfaces.

Packing - Packing prevents leakage along the valve plug stem. Packing is compressed to form a tight seal between the packing box wall and the valve plug stem by tightening the packing flange nuts. As the nuts are tightened, the packing flange transfers the compressive load to the packing.

Rotary-Shaft Valves (Fisher V500)

Although they are less popular than sliding-stem control valves, a wide range of rotary-shaft control valves, including ball valves, butterfly valves, and rotary-plug valves, are also available. The components of a typical rotary-shaft control valve include the valve body and the trim as shown in Figure 4.



Rotary-Shaft Valve Nomenclature
Figure 4

Valve Body - The valve body is the major fluid boundary and pressure-containing component. The valve body also supports and locates internal parts such as shafts, bushings, and seals. As Figure 4 indicates, many rotary-shaft valve designs do not include a separate bonnet.
Trim refers to all internal, process-wetted parts. Trim includes:

- A closure member in the form of a disk, ball, ball segment, or valve plug.
- A seal or seat ring that mates with the closure member to provide shutoff when the valve is in the closed position.
- A retainer that locates and secures the seal or seat ring in the valve body.
- A valve shaft that transmits torque to the closure member.
- Bearings and/or bushings that locate and support the valve shaft.
- Packing that prevents process fluid leakage along the valve shaft.

specifying required control valve performance attributes

Many different aspects of control valve performance and capability must be considered during the selection of a control valve for a specific application. This section will present a discussion of the performance criteria that apply to all control valves, regardless of valve style, size or manufacturer.

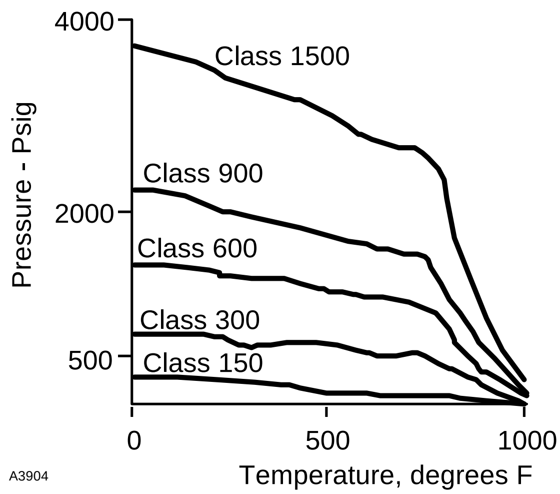
ANSI Class Ratings

Definition

One of the first considerations in valve selection is to ensure that the pressure and temperature ratings of the body and bonnet assembly are adequate for the application. Body and bonnet pressure ratings are typically expressed in terms of ANSI (American National Standards Institute) Class ratings. ANSI Class ratings are determined on the basis of the worst-case conditions of pressure and temperature at the control valve inlet. ANSI Class ratings of 150, 300, 600, 900, 1500, and 2500 are common.

Body And Bonnet Ratings

Tables and charts that list the pressure limits of various materials at different temperatures are located in various standards and references, as well as in manufacturer's literature. The chart in Figure 5 is out of date, but it does illustrate the basic concept that as the application temperature increases, the pressure rating of the material decreases. The current version of the ANSI Standard (ANSI B16.34-1988) is presented in table form. Excerpts from this standard are included in Fisher Bulletin 59.1:021 (refer to Fisher Catalog 71).



ANSI Class Pressure Ratings For WCC Carbon Steel Valve Bodies And Bonnets
Figure 5

Common Body And Bonnet Materials

The selection of a particular material of construction for bodies and bonnets is often based on economics, material strength, erosion resistance, and the compatibility of the selected materials with the process fluid (corrosion resistance). A basic description of some common body and bonnet materials follows. Additional information on material designations, characteristics, and applications is included in Figure 12, page 18.

- Historically, carbon steel has been the standard material for control valve bodies and bonnets. Cast carbon steel welds easily, which allows simple installation and weld repair of damaged bodies. ASME SA216 Grade WCB has been quite popular throughout the valve industry. Many valve manufacturers have switched from WCB to WCC because WCC offers higher strength and increased pressure-temperature ratings. WCC and WCB should not be applied at temperatures below -20 degrees F. LCC and LCB are the standard low-temperature carbon steel grades, and they can be applied at temperatures as low as -50 degrees F.

- Alloy steels (also known as chrome-moly alloy steels) are often specified when the application pressures and/or temperatures exceed the limits for carbon steel. Alloy steels also provide greater erosion resistance than ordinary carbon steels; therefore, alloy steel bodies and bonnets are typically specified for erosion resistance; i.e., for applications where the fluid contains erosive particles or vapor droplets.

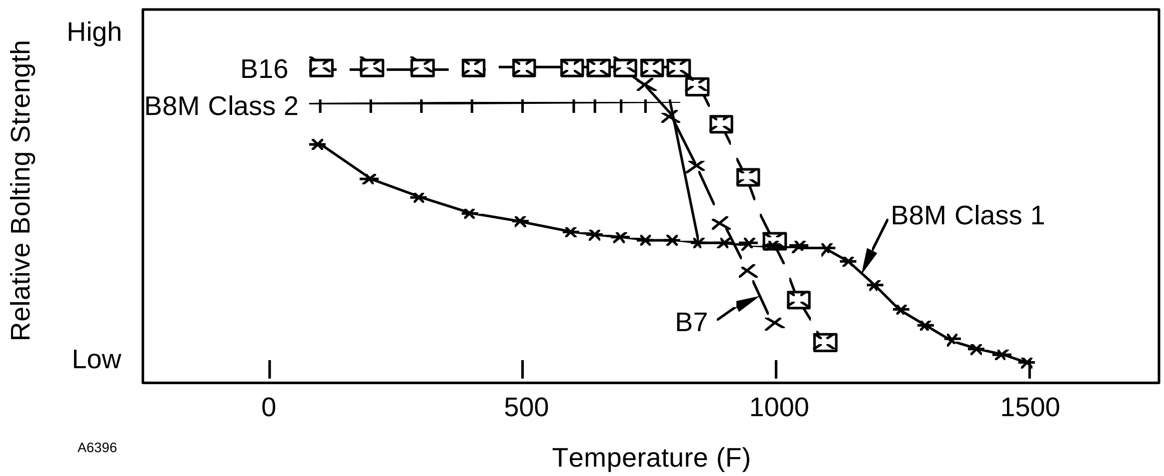
  Historically, ASME SA217 Grade C5 has been very popular; however, C5 tends to form cracks during the casting process and whenever it is welded. WC6 is another alloy that has enjoyed some popularity because its pressure and temperature ratings are somewhat greater than the ratings for C5; however, it has the same tendency to crack as C5. WC9 is another chrome-moly steel that has greater strength than C5 or WC6 under most conditions. WC9 casts well, and it can be weld-repaired if necessary. For these reasons, some manufacturers have standardized on WC9 as a standard chrome-moly body and bonnet material.

- Stainless steels provide excellent high and low temperature performance and corrosion resistance in a wide variety of environments. CF8 (type 304 stainless steel) is preferred for some corrosive fluid applications. CF8M (type 316 stainless steel) offers a good balance of strength, corrosion resistance, and economics. Generally speaking, CF8M bodies have higher pressure-temperature ratings than CF8.

Bolting Considerations

Although the valve body and bonnet are the major pressure-containing components, other components such as the body-to-bonnet bolting can influence the pressure and temperature limits of a control valve assembly.

Characteristics Of Common Bolting Materials - The graph in Figure 6 shows the relative strength vs. temperature of various bolting materials. The table lists key material characteristics and typical applications. Section 10.2.1 of SAES-L-009, Metallic Flanges, Gaskets And Bolts, lists B7 studs (with 2H nuts) as a standard bolting material.



Specification	Material	Key Characteristics	Typical Application
B7 alloy steel	ASME SA 193 Grade B7 (heat treated G41400)	Excellent strength over a broad temperature range	A standard material to approximately 800 degrees F
B16 alloy steel	As above with additional vanadium and molybdenum	Higher temperature limit than B7	Temperatures between 700 degrees F and 1 100 degrees F
B8M (Class 1) Stainless Steel	Annealed S31600 stainless steel	Stronger than B16 above 1 000 degrees F	High temperature applications With stainless steel bodies
B8M (Class 2) Stainless Steel	Strain hardened S31600 stainless steel	High strength up to 800 degrees F	High pressure applications to 800 degrees F. With stainless steel bodies

Common Body-To-Bonnet Bolting Materials
Figure 6

Bolting Materials And Pressure Deratings - Some body-to-bonnet bolting materials that are specified for ANSI Class 600 and above valve bodies have pressure limits that are lower than the normal ANSI Class pressure limits. The reduced pressure limits are referred to as deratings. PS Sheets in Fisher Catalog 71 include tables that list the pressure deratings for different bolting materials at various temperatures. These tables show that the pressure limits are unique for each valve type. Figure 7 is an excerpt from PS Sheet 59.1:031(A)(S1).
For reference, the standard ANSI Class pressure limits are included in the top portion of the table. Under the heading 'Bolting Pressure Limits', the maximum pressure for each bolting material, valve size, and temperature is listed. Note that, in some instances, the bolting pressure limit is greater the standard ANSI Class pressure limit, and, that in some instances, the bolting pressure limit is less than the standard ANSI Class pressure limit.

Table 8. B8M, B8, and 660 Bolting Material ANSI Class 1500 Design E Valves

Temperature, °F(1)		−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100
		Standard-Class Pressure Limits, Psig(2,3)															
Valve Body Material and Standard-Class Pressure Limits	CF8M	3600	3905	2795	2570	2390	2255	2220	2460	2110	2075	2030	1970	1930	1820	1800	1610
	CF3M	3600	3095	2795	2570	2390	2255	2220	2160	2110	2075	2030	---	---	---	---	---
	CF8	3600	3000	2640	2350	2185	2075	2040	2015	1990	1970	1945	1920	1870	1610	1545	1285
Bolting Material	Valve Size Inches	Bolting Pressure Limits,Psig(2)															
B8M Class 1	3	3345	3135	2725	2480	2295	2170	2120	2090	2060	2030	2020	2010	2000	1990	1980	1950
	4	3320	3115	2710	2470	2285	2165	2115	2080	2050	2020	2010	2000	1985	1975	1965	1935
	6	3600	3385	2960	2700	2505	2375	2315	2280	2245	2210	2195	2180	2165	2150	2135	2100
B8M Class 2	3	3590	—	—	—	—	—	—	—	—	→	---	---	---	---	---	---
	4	3320	2815	—	—	—	—	—	—	—	→	---	---	---	---	---	---
	6	3600	3070	—	—	—	—	—	—	—	→	---	---	---	---	---	---
B8 Class 2	3	3590	—	—	—	—	—	—	—	—	→	---	---	---	---	---	---
	4	3320	2915	2850	—	—	—	—	—	—	→	---	---	---	---	---	---
	6	3600	3175	3105	—	—	—	—	—	—	→	---	---	---	---	---	---
660	3	3860	3755	3735	—	—	—	—	→	3730	—	—	—	—	→	---	---
	4	3820	3715	3695	3695	3690	—	—	→	3675	—	—	—	—	→	---	---
	6	4120	4005	3980	3970	3960	3950	3950	3945	3930	3930	3920	3920	3910	3910	---	---

Bolting Pressure Limits Versus ANSI Standard Class Pressure Limits
Figure 7

Pressure Drop Ratings

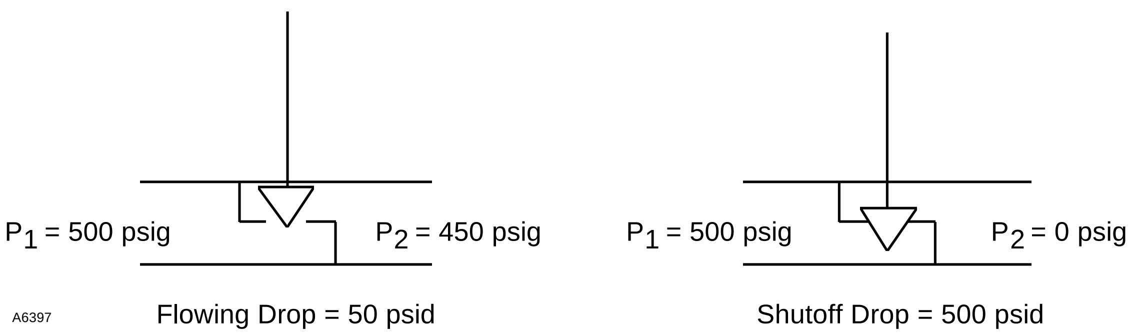
While the ANSI Class rating and bolting pressure limits describe the pressure retaining ability of a control valve, the internal components (trim) typically determine the pressure drop rating of a specific valve construction. Some control valves have pressure drop ratings to the full ANSI Class pressure rating, while other control valves have limited pressure drop capabilities because of the strength limitations of the valve's internal parts.

Flowing Versus Shutoff Pressure Drops

Specifiers need to be aware of two different pressure drop ratings (refer to Figure 8):

- The flowing pressure drop refers to the difference between the upstream pressure (P_1) and the downstream pressure (P_2) while the valve is throttling.
- The shutoff pressure drop is the difference between upstream pressure and downstream pressure when the valve is fully closed.

The shutoff pressure drop is generally higher than the flowing pressure drop; therefore, the pressure drop rating that is listed for most valves refers to the shutoff pressure drop, unless otherwise specified.

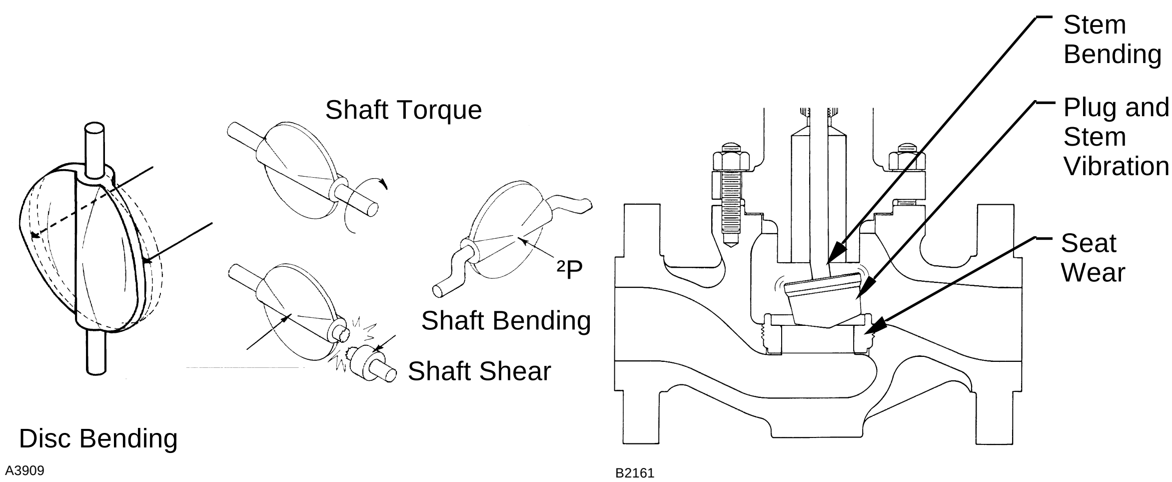


Flowing Versus Shutoff Pressure Drop
Figure 8

Sliding-Stem and Rotary-Shaft Pressure Drop Capabilities

In rotary-shaft valves, the surface area of the closure member is generally quite large as compared to the surface area of the bearings and bushings that guide the closure member. Because of the relatively small guiding surfaces, the pressure drop ratings are often lower than the ANSI Class inlet pressure ratings. Manufacturers publish pressure drop limits that must be observed in order to prevent disk bending, excessive torque on the shaft, shaft bending, and shaft shearing as shown in Figure 9.

In most sliding-stem valves, the ratio of the guiding surface area to the surface area of the valve plug is quite high; accordingly, sliding stem valves are typically rated for higher pressure drops than rotary-shaft control valves. If the pressure drop exceeds the manufacturer's published rating, the fluid forces that act on the valve plug can result in stem bending, plug and stem vibration, and seat wear as shown in Figure 9.

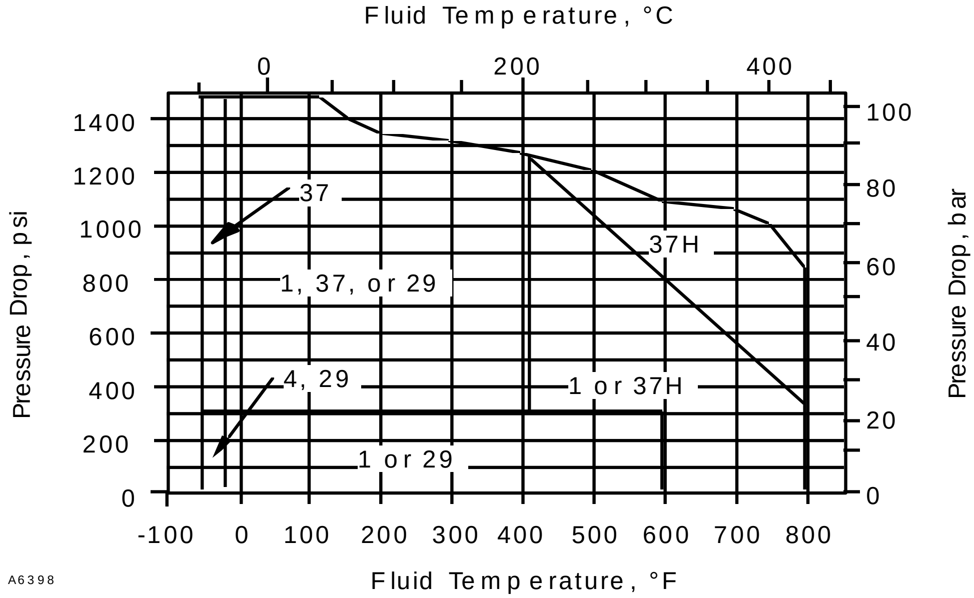


The Effects Of Pressure Drop On Valve Components
Figure 9

Individual Trim Component Ratings

Pressure drop ratings are typically a function of the valve type, trim style, materials of construction, and fluid temperature. Manufacturers may publish maximum pressure drop ratings for a complete valve assembly, or they may publish ratings for individual trim components.

Pressure Drop Charts - Figure 10 includes a chart that shows, in relation to temperature limits, the maximum pressure drop ratings of various trim options for a typical Fisher control valve. The numbers designate specific trim material options. The materials that are used in each option are listed in a corresponding table. For a complete list of standard trim options for a typical control valve, refer to Figure 7 and Table 2 of Fisher Specification Bulletin 51.1:ED (Fisher Catalog 71).



Pressure Drop And Temperature Limits Of Various Trim Options
Figure 10

Selection Guidelines - The lowest available trim number designates a standard trim. Trim options with higher numbers may provide increased pressure drop or temperature ratings, corrosion resistance to certain fluids, and/or increased erosion resistance. Generally speaking, the lowest trim number that satisfies all requirements is the trim option that should be selected. Note that the charts provide selection guidance with respect to pressure drop and temperature limits only.

Pressure Drop Tables - Pressure drop ratings may also be published in tabular form. The pressure drop table that is shown in Figure 11 lists the pressure drop ratings for a Fisher V-200 rotary-shaft control valve. Note that the pressure drop rating depends on the materials of construction, the seal type, the operating temperature, and the valve size.

***Table 8.** Maximum Allowable Shutoff Pressure Drops(1) for Steel and Stainless Steel Valves with Silver-Plated Alloy 6B Bearings*

BODY AND BEARING MATERIAL	BALL SEAL	TEMPERATURE RANGE	VALVE SIZE, INCHES 1	1-1/2	2	3	4	6	8	10
Steel or Stainless Steel Body with Silver-Plated Alloy 6B Bearings		°F	Psi							
	HD Metal(2)	− 50(3) to 450	750	750	750	350	307	344	343	189
	Flat Metal (Lubricated-Service)	− 50 to 500	---	---	---	300	287	218	300	150
		600	---	---	---	300	287	218	300	140
		650	---	---	---	300	287	218	300	125
		700	---	---	---	300	287	218	300	110
		750	---	---	---	300	287	218	300	95
		800	---	---	---	300	287	218	300	80
		°C	Bar							
	HD Metal(2)	− 46 to 232	51.7	51.7	51.7	24.1	21.2	23.7	23.6	13.0
	Flat Metal (Lubricated-Service)	− 46 to 260	---	---	---	20.7	19.8	15.0	20.7	10.3
		316	---	---	---	20.7	19.8	15.0	20.7	9.6
		343	---	---	---	20.7	19.8	15.0	20.7	8.6
		371	---	---	---	20.7	19.8	15.0	20.7	7.6
		399	---	---	---	20.7	19.8	15.0	20.7	6.5
		427	---	---	---	20.7	19.8	15.0	20.7	5.5

Pressure Drop Ratings For A Typical Rotary-Shaft Control Valve

Figure 11

Material Selection

Major Selection Considerations

Previous sections have shown how the construction materials influence the pressure, pressure drop, and temperature ratings of a particular valve type. Material selection is also guided by other requirements, including the material properties and characteristics that are required to ensure compliance with good valve design standards, and the material properties and characteristics that are required to ensure valve compatibility with a specific control valve application. Some of the material selection relate directly to overall valve design include:

- Material strength; i.e., the ability to retain pressure and to withstand considerable pressure drops.
- The thermal expansion coefficients of all valve components (which must be matched in order to prevent dimensional distortions that could result in gasket leaks and excessive stresses on valve components).
- Wear properties; e.g., resistance to wear, such as sliding wear and oxidative wear.
- Wear-couple compatibility; i.e., resistance to galling. Galling is a unique form of wear that results when two incompatible materials that are in sliding contact with each other become welded together, and are then torn apart.

The above grouping of parameters is generally addressed by valve manufacturers who establish 'standard' options for materials and material combinations that will provide satisfactory valve performance in a wide range of applications. Because material options are pre-engineered, valve specifiers can focus on specific application requirements and select material options that are compatible in terms of:

- Corrosion resistance
- Erosion resistance
- Temperature ratings

General Properties Of Materials

Following is a list of materials that are commonly specified for control valves:

- Cast iron is a low cost, non-ductile (brittle) material that is typically specified only for low pressure steam, water, gas, and non-corrosive fluids. Cast iron is brittle, is easily fractured, and cannot be weld repaired. These are some of the reasons that Section 4.1.3 of SAES-J-700 disallows the use of cast or ductile iron for control valve bodies.

- Cast carbon steels (WCC, WCB) are popular body and bonnet materials because of their low cost and good strength over a wide range of temperature conditions.

- Cast alloy steels or chrome moly steels (C5, WC9) are also standard body and bonnet materials. Cast alloy steels are typically specified for applications that require more erosion resistance and/or higher pressure and temperature ratings than can be obtained with cast carbon steel.

- Various grades of cast stainless steel (CF8, CF8M) are typically specified for bodies and bonnets that are applied in high and low temperature applications and in corrosive applications. Stainless steel in several different grades (410, 416, 316) is also the industry standard trim material for mild to moderately corrosive and erosive applications. Increased durability and erosion resistance is achieved through hardening of the material (either by heat treating or cold work), through the application of coatings (such as electroless nickel coating, or ENC), or through the application of hardfacings such as Stellite (CoCr-A) or other erosion resistant materials.

- High nickel content alloys (including Monel, Inconel, Hastelloy, and others) are often selected for valve bodies and trim components that are applied in extremely corrosive or caustic applications.

- Cobalt alloys such as Alloy 6 (Stellite, or CoCr-A) are hard and tough materials that are commonly specified because of their superior erosion resistance. Critical surfaces of trim and bodies may be hardfaced with cobalt materials (by weld depositing the material), or trim components may be machined from wrought and cast forms of the material.

- Other hard and tough materials such as tungsten carbide and ceramics (also referred to as cermets, or ceramics/metals), are sometimes specified to provide erosion resistance in exceptionally erosive applications.

Figure 12 includes a chart of popular materials, their primary characteristics, and their typical applications.

Material Family	Example Materials	Primary Characteristics	Typical Applications
Cast Iron	Cast iron	Low cost Brittle Non-weldable	Limited to low pressure water, steam, and gas Disallowed for many control applications
Cast carbon steel	LCC, WCC, WCB	High strength; ductile Weldable Limited to 800 degrees F	A standard material for control bodies
Alloy Steel	C5, WC9, LC3	Temperature ratings above 800 degrees F and to -150 degrees F Better erosion resistance than carbon steel	Valve bodies for high and low temperature applications, and for moderately erosive applications
300 Series Stainless Steels	304, 316, 316L stainless steels	Good balance of corrosion resistance, strength, and cost Higher temperature ratings than carbon steel Poor wear couple with itself and not particularly tough; therefore is often ENC coated or hardfaced. Coated or hardfaced materials are resistant to corrosion and erosion	Valve bodies for corrosive, erosive, and high temperature applications A standard material for valve trim (when ENC coated or hardfaced with CoCr-A)
400 Series Stainless Steels	410, 416, stainless steels	Higher hardenability than 300 series Less corrosion resistance than 300 series Extremely difficult to hardface for erosion resistance	Seat rings, valve plugs, and other trim components that require hardness and erosion resistance
Precipitation Hardened Stainless Steel	17-4 PH stainless steel	Excellent hardness and strength Excellent corrosion resistance	Valve shafts, stems, and cages that require strength and erosion resistance
Nickel Alloys	Hastelloy, Inconel, Monel	Excellent resistance to corrosion Expensive	Bodies and trim in highly corrosive environments
Cobalt Alloys	Alloy 6 (Stellite)	Very tough Excellent resistance to erosion Corrosion resistance equal to 300 series stainless	As a hardfacing applied to trims In cast form, as seat rings and other erosion resistant trim
Ceramics	Partially Stabilized Zirconia	Extreme toughness, erosion resistance Good corrosion resistance	Seat rings and plugs for highly erosive and/or corrosive applications
Cermets	Tungsten Carbide	Extreme toughness, erosion resistance Poor corrosion resistance	Seat rings and plugs for highly erosive applications

Common Control Valve Materials, Characteristics and Applications

Figure 12

Classification Systems For Metals And Alloys

For each basic type of material, many different grades are available. In an effort to describe all the various material types and grades, materials have been given many different designations. For example, these designations include:

- Popular trade names; e.g., Inconel, Monel, and Alloy 6.
- American Iron and Steel Institute (AISI) designations; e.g., AISI 316 stainless steel.
- UNS (Unified Numbering System) designations; e.g., S31600.
- American Society for Testing and Materials (ASTM) designations; e.g., ASTM WCB carbon steel.
- ACI (American Casting Institute) designations; e.g., CF8M.

Current Trends

A survey of codes and standards that are commonly referenced in the process control industry indicates that no single designation system is preferred for metallic materials. For the most part, materials are designated according to the following:

- UNS numbers are favored over other systems for nearly all wrought products, including: AISI carbon and alloy steels, stainless steels, nickel alloys, copper alloys, and aluminum alloys. UNS numbers are favored also for cast aluminum and copper alloys. As a rule of thumb with notable exceptions, valve trim materials are specified with UNS designations.
- ACI designations are preferred for all cast stainless steels, cast heat resistant steels, and cast nickel-base alloys.
- ASTM/ASME designations have been retained for many special carbon steel products and alloy steel products.

A brief explanation of each of these systems follows.

Unified Numbering System (UNS) - UNS designations have been jointly developed by the Society of Automotive Engineers (SAE) and the American Society for Testing and Materials (ASTM). This system provides a uniform method of designating metallic materials by dividing metals and alloys into eighteen categories as shown in Figure 13. A UNS material designation starts with a single alpha character, which in many cases is suggestive of the family of metals it identifies; e.g., "A" indicates aluminum, "C" indicates copper, "N" indicates nickel, and "S" indicates stainless steel. Following the alpha character are five numeric digits, which likewise often suggest alloys within the family of metals; e.g., A92024 designates 2024 aluminum, C36000 designates copper alloy 360, S31600 designates type 316 stainless steel, and N04400 designates nickel alloy 400.

UNS Prefix	Alloy Series	UNS Prefix	Alloy Series
A	Aluminum and aluminum alloys	L	Cast steels (except tool steels)
C	Copper and copper alloys	M	Miscellaneous non-ferrous metals and alloys
D	Steels with specified mechanical properties	N	Nickel and nickel alloys
E	Rare earths and rare earth-like metals and alloys	P	Precious metals and alloys
F	Cast irons	R	Reactive and refractory metals and alloys
G	AISI and SAE carbon steels and alloys (except H-steels and tool steels)	S	Heat and corrosion resistant (stainless) steels
H	AISI H-steels (hardenability controlled)	T	Tool steels
J	Cast steels (except tool steels)	W	Welding filler materials classified by weld deposit composition
K	Miscellaneous steels and ferrous alloys	Z	Zinc and zinc alloys

Examples:

S31600 = 316 stainless steel
N04400 = nickel alloy 400 (Monel K400)
N10276 = nickel alloy C276 (Hastelloy 276)

UNS Numbering System Prefixes
Figure 13

ACI Designations - The Alloy Casting Institute (ACI) has developed a system for designating stainless and heat resistant casting alloys. As Figure 14 shows, casting designations begin with either a "C" for corrosion resistant materials, or an "H" for heat resistant materials. The second letter in the designation ranges from "A" to "Z" depending upon the nickel content and, to a lesser degree, the chromium content. For example, a corrosion resistant material with no nickel and 12% chromium begins with "CA" (refer to CA15 in the Figure 14). For another example, an alloy with 100% nickel and no chromium begins with "CZ" (refer to material CZ100 in Figure 14). Following the letter designators are numeric digits that indicate the maximum carbon content. Additional letters following the numeric digits indicate the presence of supplementary alloying elements.

Cast Material Designa-tion	Nickel	Chrom-ium	Maxi-mum Carbon	Other Alloying Elements	Common Name
CA15	----	12	0.15	----	Cast 410
CD4MCu	6	25	0.04	3.0 Mo, 3.0 Cu	Cast duplex
CF8M	10	19	0.08	2.5 Mo	Cast 316
CF3M	10	19	0.03	2.5 Mo	Cast 316L
CN7M	29	21	0.07	2.5 Mo	Cast Nickel Alloy
CW2M	68	16	0.02	16 Mo	Hastelloy 276
CZ100	100	0	1.00	----	Alloy 200
HK40	20	25	0.40	----	

Typical ACI Material Designations

Figure 14

Although ACI no longer exists, the system has been adopted by ASTM, and designations for new alloys are being assigned. UNS numbers have also been assigned to many of these alloys; however, the ACI designations are easier to interpret than the UNS designations, which explains the continued popularity of the ACI system.

ASTM Designations - ASTM/ASME designations have been retained for many carbon steel and alloy steel products. Examples of ASTM/ASME designations and common names are shown in Figure 15.

ASTM/ASME Designation	Common Name	UNS Number
WCB, WCC	WCB casting	J03002, J02503
LCB	LCB casting	J03003
C5	5 Cr-1/2 Mo Steel Casting	J42045
WC6	1 1/4 Cr-1/2 Mo Steel Casting	J12072
WC9	2 1/2 Cr-1 Mo Steel Casting	J21890

ASTM/ASME Designations For Common Valve Materials

Figure 15

Fluid Compatibility Guidelines For Valve Bodies And Trim

One of the first objectives in material selection is to identify materials that are compatible with the process fluid in terms of corrosion resistance. In Saudi Aramco operations, corrosive applications range from those involving sea water and brine to those that involve caustics and acids.

Saudi Aramco Engineering Standard SAES-L-008 is titled Selection of Valves. Table I of this standard includes fluid and material compatibility guidelines. An excerpt from Table I is shown in Figure 16. Note that for each different environment, the table lists the recommended valve body and trim materials. SAES-L-008 provides general guidance for material selection; however, the following should also be considered:

- Section 1 of SAES-L-008 limits the applicability of the standard to several types of on-off valves, block valves, and check valves; however, in most applications, the material recommendations that are included in SAES-L-008 do apply reasonably well to control valves.
- Table I of SAES-L-008 addresses corrosion concerns only, without regard for other requirements such as erosion resistance, strength, and other material properties.
- The standard occasionally recommends materials that are not available in the preferred valve constructions; therefore, available materials that are equivalent to the recommended materials must be identified. For example, SAES-L-008 typically lists the standard trim material as 410 stainless steel, while 416 is a standard trim material that is used by Fisher Controls. 416 is the free-machining equivalent to 410; i.e., sulfur is added for better machinability and finer finishes.

SERVICE & APPLICATION REQUIREMENTS
VALVE BODY AND TRIM MATERIALS

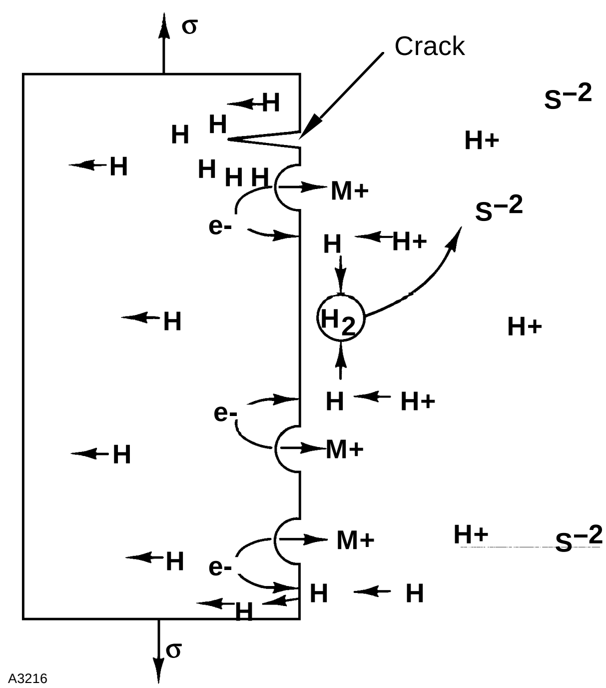
ENVIRONMENT	CONDITIONS		VALVE MATERIALS (9)		REMARKS
	Conc. % (19)	Temp. deg C	Body	Trim	
Acid, Hydrochloric	LT 37	5 - 50	PVC B-2	PVC B-2	No ferric ions or other oxidants for B-2
Acid, Hydrofluoric non oxidizing	1 - 70	5 - 50	M400	C	No glass or glass reinforced plastics; no titanium, zirconium or tantalum
	GT 65	5 - 40	PTFE	PTFE	
Acid, Hydrofluoric	All conc.	to 50	20	20	

Excerpt From Table I Of SAES-L-008
Figure 16

H_2S and SSC - A form of corrosion that is routinely encountered in oil and gas production applications is sulfide stress cracking, or SSC. SSC occurs in sour gas and oil environments. In this context, the term 'sour' means that sulfur and hydrogen sulfide (H_2S) are present.

SSC is a function of the interaction between hydrogen molecules and a base metal. Hydrogen ions are a product of many corrosion processes. Refer to Figure 17. These ions pick up electrons from the base material and produce hydrogen atoms. Two hydrogen atoms may combine to form a hydrogen molecule. Most molecules will eventually collect, form hydrogen bubbles, and float harmlessly away; however, some percentage of the hydrogen molecules will diffuse into the base metal and embrittle the crystalline structure (a process that is referred to as hydrogen embrittlement). If a certain critical concentration of hydrogen is reached, and if a susceptible material is subjected to tensile stress, SSC will occur.

In many instances (particularly with low carbon and low alloy steels), the cracking will initiate and propagate along the grain boundaries (referred to as intergranular stress cracking). In other materials, the cracking will propagate through the grains (referred to as transgranular cracking).



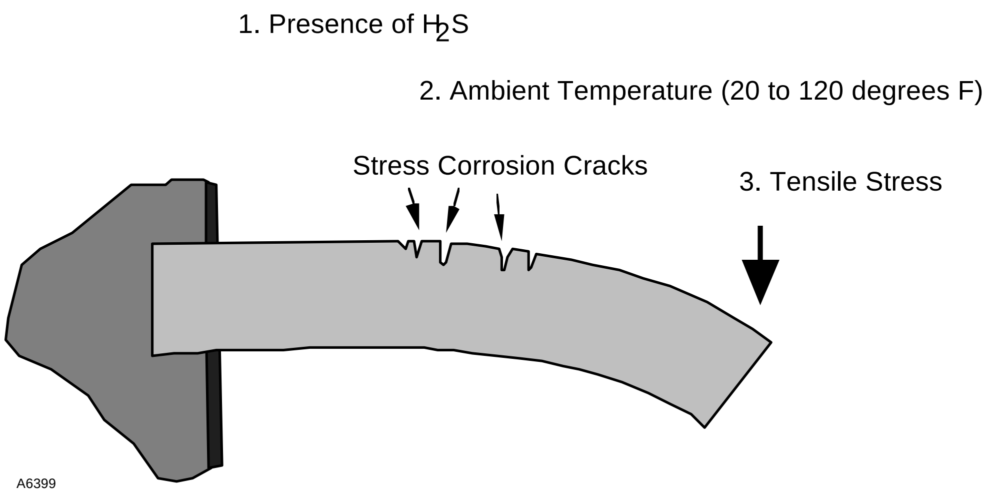
Mechanics Of Sulfide Stress Cracking
Figure 17

The precipitating conditions for SSC are described below and they are shown in Figure 18.

- Concentration of H_2S - While the intensity of SSC increases as the concentration of H_2S increases (refer to Figure 18), many users select corrosion resistant materials whenever any measurable amount of H_2S is present.

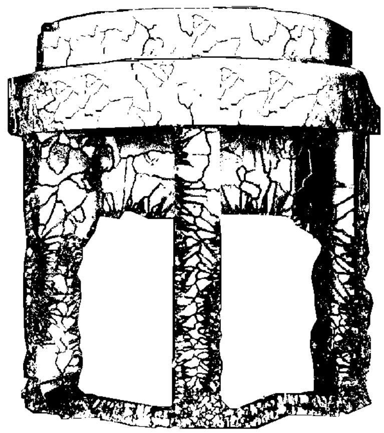
- Fluid temperature - SSC is most severe at temperatures between 20 and 120 degrees F. Below this temperature range, the hydrogen diffusion rate is slow enough that the critical concentration is never reached. Above this temperature range, the diffusion rate is fast enough that the hydrogen passes through the material quickly and the critical concentration is never reached. The occurrence of stress corrosion cracking above 120 degrees F is still likely, but it will generally be of another form such as chloride stress cracking. As mentioned, many users select corrosion resistant materials whenever any measurable amount of H_2S is present, regardless of the temperature.

- Tensile stress - A susceptible component must be placed under tensile stress for SSC damage to occur; however, virtually all valve components are stressed. Tensile stress may result from process pressure that acts on valve components, from misalignment of piping, from thermal expansion, and from the residual stress of cold work, welding, or heat treatments.



Precipitating Conditions For Sulfide Stress Cracking
Figure 18

Figure 19 is an illustration of a valve plug guide that has been severely damaged by sulfide stress cracking. The valve body from which the component was removed was so severely damaged that it would not hold line pressure; i.e., the process fluid seeped through the body wall.

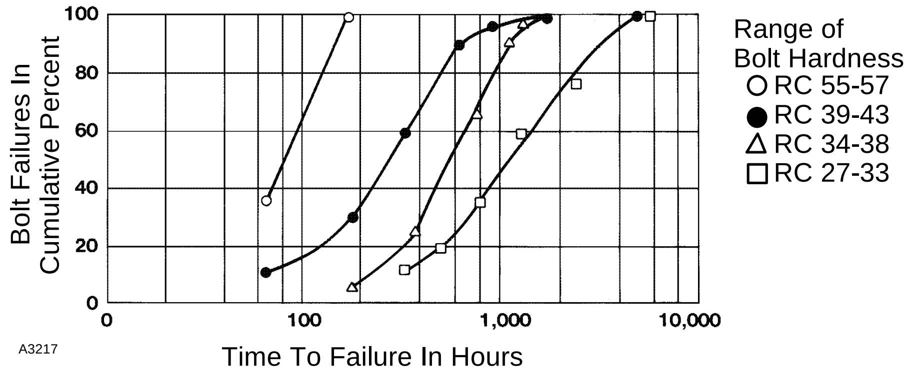


A6400

Valve Plug Guide That Has Been Damaged By SSC
Figure 19

The susceptibility of a material to SSC is related to its hardness level. Hardness is a physical property that relates the resistance of a material to penetration or indentation. In metals, hardness is usually measured in the laboratory by loading an indenter into a material and measuring either the depth or the surface area of the indentation. Several test procedures and scales of hardness have been established. A popular scale is the Rockwell C scale, which is abbreviated as HRC (Hardness Rockwell C).
The range for the Rockwell C scale is from HRC 20 to HRC 60. Generally speaking, most trim materials for general service applications have a minimum hardness in the range of 25 to 35 HRC. For example, untreated 316 stainless steel bar stock has a hardness of approximately HRC 20, although this material may be hardened through various treatments. Harder trims that are designed for erosive applications commonly have a hardness of 38 to 45 HRC. For example, 17-4 stainless steel that is treated to the H1075 condition has a hardness of 35-40, and Alloy 6 hardfacing has a hardness of approximately 43. Trim for extremely erosive applications may require material hardness of up to 50 to 60 HRC. 440 C stainless steel in the fully hardened condition has a hardness of 55-60 HRC.

When control valve trim components are heat treated to progressively higher hardness levels, the time to SSC induced failure decreases dramatically. Figure 20 illustrates the relative time to failure (in hours) of bolting materials with varying hardness levels. Because of the relationship of hardness levels and SSC, the hardness of valve construction materials must be less than allowable hardness levels that have been determined by test and evaluation.



Material Hardness Related To Time To Failure
Figure 20

NACE MR0175 - The National Association of Corrosion Engineers (NACE) has issued Standard MR0175 that specifies proper materials, heat-treating conditions, and strength levels that are required to provide good service life in sour gas and oil environments. NACE Standard MR0175 also provides material recommendations and guidelines for specific components including bolting and springs.

Figure 21 lists some of the NACE approved materials, hardness information, and pertinent remarks. Note that the maximum hardness that is allowed under the NACE guidelines depends on the material type.

Figure 21 shows, under the heading Remarks/Applications, that there are two NACE classes for bolting materials. Class III bolting allows more-or-less standard bolting materials (B7) provided the bolting is exposed to atmosphere. Class II bolting must be specified whenever the bolting will be in direct contact with a sour environment; i.e., if the valve is insulated or buried.

Component	Material	Maximum Hardness, HRC	Remarks/Applications
Valve Bodies	WCC, WCB, C5, WC9	22	Requires stress relieving and post-weld heat treatment
	CA6NM (modified version of cast S41600)	23	Requires post-weld heat treatment
	CF8M	22	Post-weld heat treatment not required
	Wrought S32550 (Ferralium)	28	Cast form is *not* NACE approved; therefore, bodies must be forged
Valve Trim (cages, plugs, and seat rings)	S31600 (and many other 300 series stainless steels)	22	May be hardfaced with Alloy 6 for increased durability Excellent resistance to H_2S and general corrosion
	S41000	25	Moderate increase in hardness over 316, but less resistant to general corrosion. S41600 is the free machining equivalent to 410, but free machining materials are not allowed per NACE
	Solid R30006		Highly erosion resistant seat rings
Stems and Shafts	S31600	22	NACE approved but low strength may require larger stem diameter.
	S20910 (XM-19 or Nitronic 50)	35	Much stronger than 316
	Wrought 17-4 PH1150	33	Not NACE approved, but has an excellent history of performance; NACE approval is pending
Body-to-bonnet and packing flange bolting	B7 and other standard bolting	NA	<u>NACE Class III</u> - Bolting is exposed to atmosphere and therefore not subject to SSC unless leaks are present
	B7M	22	<u>NACE Class II</u> - Bolting is exposed to H_2S because of insulation, burial, etc. Class II bolting may require pressure derating of the valve body assembly
Springs	N07750 (Inconel X750)	50	Common material for pressure regulator springs
	N07718 (Inconel 718)	40	Belleville springs in externally loaded packing designs

Common NACE Approved Materials
Figure 21

NACE MR0175 does not address elastomer and polymer materials. However, the importance of these materials for critical sealing must be considered. User experience has shown that nitrile, neoprene, and PTFE can be applied within their normal respective temperature ranges.

Some valve manufacturers have established standard policies and practices that ensure compliance with NACE guidelines whenever a valve is specified for sour service. For example, the following summarizes the procedures that are followed by Fisher Controls.

- Carbon steel bodies and bonnets are heat treated to 22 HRC maximum, and they are post-weld heat-treated.
- Martensitic and cast precipitation hardened stainless steels are not used.
- Control valve packing sets are jam style only (springless or externally live-loaded).
- Valve stems are made from Nitronic 50 when strength is required.
- Primary trim materials are S31600 and Alloy 6.
- No machining operations that cause work hardening of the materials are performed in the manufacturing process.
- Platings and coatings are applied over NACE approved base metals, and the coatings are not intended to provide corrosion protection.
- Bolting in Class III material is standard when the bolting is exposed to atmosphere. Bolting in Class II material is available when bolting is buried, insulated, or otherwise exposed to H_2S.

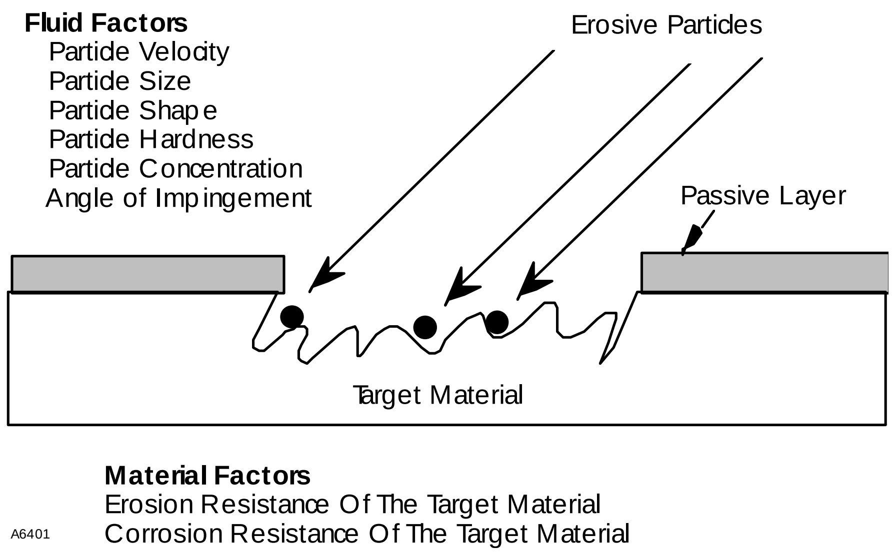
Most valve manufacturers offer specific construction options that comply with the NACE guidelines. Refer to Table 7 in Bulletin 51.1:ES (Fisher Catalog 71) and note the standard trim options that are NACE approved.

Erosion

Erosion concerns deal with the ability of a selected material to resist the wear that results from the impingement of dirt, scale, sand, vapor droplets, or other small particles on critical valve surfaces.

Conditions For Erosion - Erosion is the result of many factors. Figure 22 illustrates the major factors that influence the potential for erosion damage.

Erosion And Corrosion - Erosion and corrosion often occur simultaneously. Many materials gain corrosion resistance from a passive layer of oxides that form on the material surface. If this layer is damaged or removed by erosion, then corrosion and erosion work together to remove material from the surface of the affected component.



Factors That Influence The Potential For Erosion
Figure 22

Erosive Applications - The potential for erosion damage is generally greatest in applications that are near the wellhead because the fluids typically carry sand, dirt, gravel, and scale; however, it is common for fine grit and other particulates to remain in the fluid stream even in intermediate refinery and gas plant processes. Vapor droplets can also result in erosion damage. Vapor droplets are common in steam applications, and in flashing liquids.

Evaluating The Potential For Erosion Damage - Unfortunately, there is no standard scale on which the potential for erosion damage can be empirically measured, and there is no absolute guideline for material selection. Experience and professional engineering judgment must be applied when selecting materials for erosive applications.

Material Selection - Figure 23 lists some of the materials that are commonly specified for erosive applications. In general, the materials are listed in the order of increasing erosion resistance. In addition to erosion resistance, specifiers must also evaluate materials in terms of their corrosion resistance, strength, temperature limits, and other material properties.

Material	Typical Application	Remarks
Valve Bodies		
Carbon Steel (WCC, WCB)	Bodies and bonnets	A standard material. May be selected for mildly erosive applications
Alloy steel, or chrome moly steel (C5, WC9)	Bodies and bonnets	Much greater erosion resistance than carbon steel
Stainless Steel (CF8M)	Bodies and bonnets	Erosion and corrosion resistance (corrosion often accompanies erosion)
Valve Trim		
S31600	Plugs, cages, stems	Material is not particularly erosion resistant and it is a poor wear couple with itself; therefore, components are typically ENC (electroless nickel coating) coated for wear resistance
S41000/S41600	Plugs, cages	Typically heat-treated to HRC 38. Good erosion resistance but lacks general corrosion resistance
S17400 PH1150	Plugs, cages	Typically heat-treated to HRC 40
S31600 with CoCr-A (alloy 6, R30006) hardfacing	Plugs, cages, seat rings	Hardfacing on plug tips, plug guiding surfaces, and seat rings improves resistance to erosion
Solid R30006 (alloy 6)	Seat rings	Very tough material; excellent erosion resistance
Tungsten Carbide	Plugs, seat rings	Excellent erosion and wear resistance; however, the binders that hold the tungsten carbide are susceptible to corrosion in some applications
Ceramics (Partially Stabilized Zirconia - PSZ)	Plugs, seat rings	Exceptional wear resistance and corrosion resistance; applied in extremely erosive applications

Common Erosion Resistant Materials
Figure 23

Temperature Concerns And Gasket Material Selection

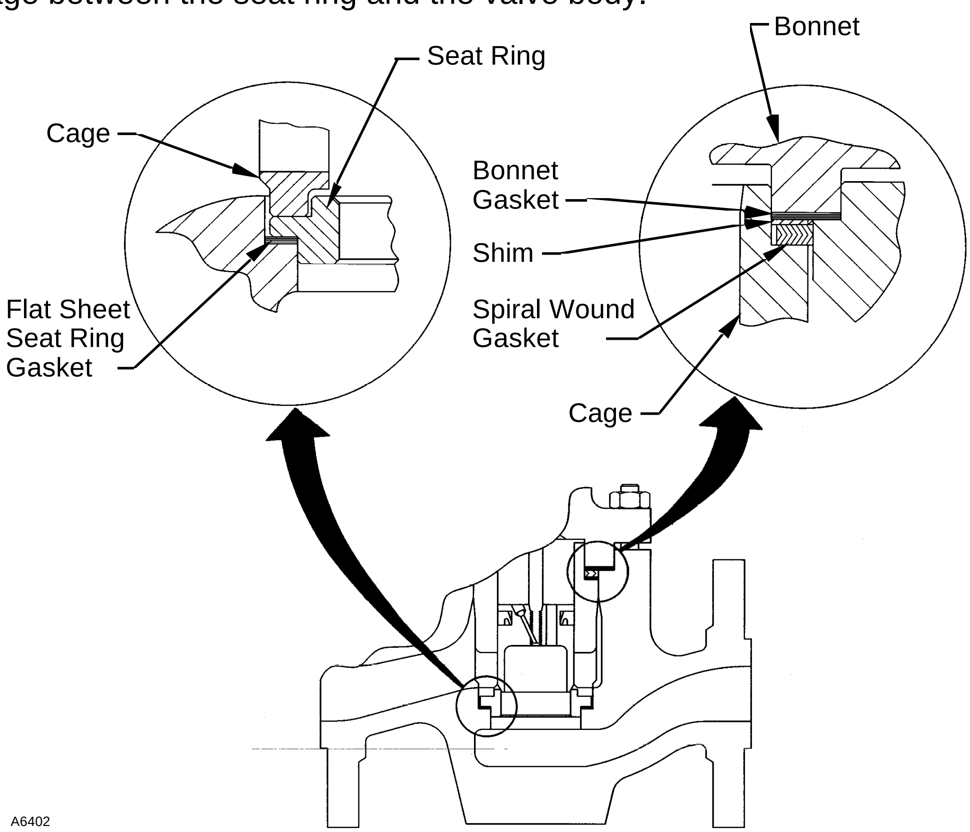
Figure 24 shows the gaskets that are included in a standard cage-guided valve.

Spiral-Wound Gasket - Temperature gradients can cause the combined height of the seat ring and the cage to change because of thermal expansion and contraction. For this reason, a spiral wound gasket is included in many valve designs. The spiral wound gasket is actually a spring that can absorb a slight amount of cage expansion while maintaining a tight seal. The spiral wound gasket is a coil of a metal alloy that has been formed into a V-shape. Each V-shape in the finished gasket is separated from the next V-shape by a filler material.

Bonnet Gasket - The bonnet gasket is a flat sheet gasket that creates a tight seal between the bonnet gasket surface and the valve body gasket surface.

Shim - The shim prevents the sharp edge of the spiral wound gasket from cutting the flat sheet bonnet gasket.

Seat Ring Gasket - The seat ring gasket is a flat sheet gasket that prevents leakage between the seat ring and the valve body.



Typical Gaskets
Figure 24

Gasket Options - The selection of a particular gasket material is determined by the temperature limits of the application and by the corrosion resistance that is required. Various options are described in Figure 25.

- Spiral Wound Gasket Options - A standard spiral wound gasket is made of stainless steel that is filled with a composition material. As indicated in Figure 25, the standard gasket material is limited to 450 degrees F and it must be derated to 300 degrees F if the temperature cycles repeatedly. For high temperature (up to 1 100 degrees F) and for temperature cycling applications, an Inconel or other alloy that is filled with a graphite material is specified.

- Flat Sheet Gasket Options - A common standard for flat sheet gaskets is a composition material. Manufacturers may use proprietary materials such as Fisher Controls' FGM (Fisher Gasket Material). Most composition materials are suitable for temperatures up to 1 100 degrees F; however, they may not provide the required corrosion resistance. Options such as PTFE coated Monel provide corrosion resistance, but at reduced temperature ratings, as shown in the table below.

Gasket Type	Standard Material		Optional Materials	
	Material	**Application**	**Material**	**Application**
Spiral Wound	316L, composition	Limited to 450 degrees F for constant temperature, and to 300 degrees F for temperature cycling	Inconel, Graphite	High and low temperature: Rated at -325 degrees F to 1 100 degrees F
			Monel, Composition	Corrosion resistance to 450 degrees F
			Monel PTFE	Corrosion resistance to 300 degrees F
Flat Sheet	Composition (e.g., Fisher FGM)	High temperature: (to 1 100 degrees F) and temperature cycling services	PTFE Coated Monel	Corrosion resistance to 300 degrees F

Gasket Material Options And Applications
Figure 25

Temperature And Pressure Concerns And Packing Material Selection

The purpose of packing is to create a tight seal between the packing bore and the valve stem to prevent fluid leakage to atmosphere. Design and selection criteria for packing includes:

- Low friction so that the actuator can stroke the valve.
- Compatibility of packing components with the process fluid.
- Compatibility of packing parts with the service temperature.

Spring-Loaded PTFE Packing Arrangements - Spring-loaded PTFE packing arrangements are very common. A spring loaded PTFE arrangement is illustrated in Figure 26.

The packing box rings sits at the bottom of the packing bore and provides a replaceable seat for the spring. The spring transmits force to the packing rings through a washer. Male and female adapters form flat surfaces on the top and bottom ends of the packing ring stack so that the packing mates squarely with other components. The packing follower compresses (loads) the entire packing arrangement as the packing gland nuts are tightened.

Because the packing rings are "V" shaped, the spring load forces the edges of the rings against the stem and the packing box bore to form a seal. The concave surfaces of the packing rings always face high pressure; therefore, process pressure also pushes the edges of the rings against the valve stem and the packing box bore. The orientation of the packing rings results in a pressure-assisted seal.

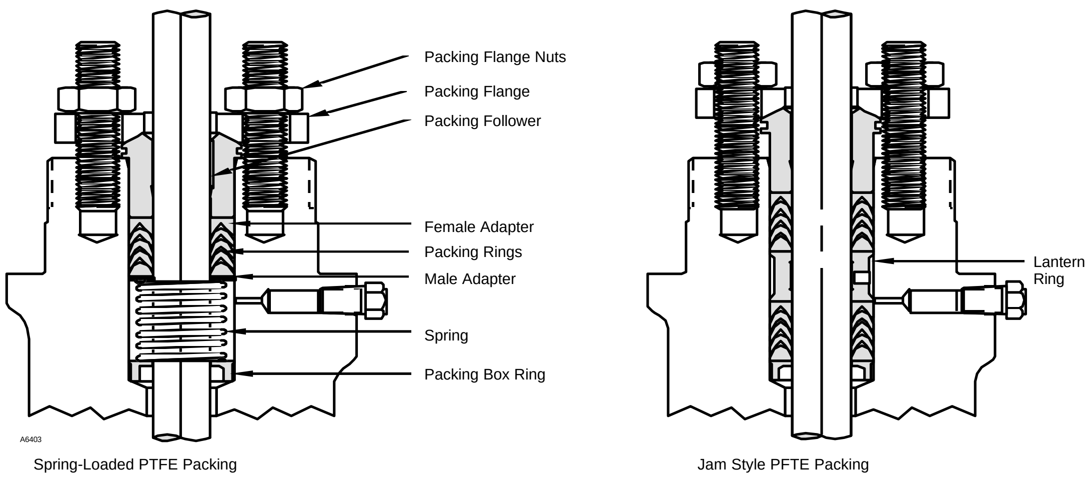
Spring-loaded PTFE packing arrangements are popular because:

- They have low friction.
- They are chemically compatible with a broad range of fluids.
- They provide a tight seal.
- They have a long cycle life.
- They provide constant loading because of the spring; therefore, they require minimal maintenance.

Jam Style PTFE Packing Arrangements - In some applications, a jam style packing arrangement is preferred to the spring-loaded design. A double, jam style, PTFE packing arrangement is shown in Figure 26. Note that the two sets of packing are separated by a lantern ring.

Jam style packing is commonly specified for sour hydrocarbon services and other applications that must conform to NACE guidelines. Because the NACE guidelines limit material hardness, and because material hardness is a required property for a good spring material, suitable springs are simply not available for spring-loaded packing.

The major disadvantage of the jam style packing is the requirement for periodic adjustment of the packing flange nuts to ensure that sufficient loading is applied to create a tight seal.

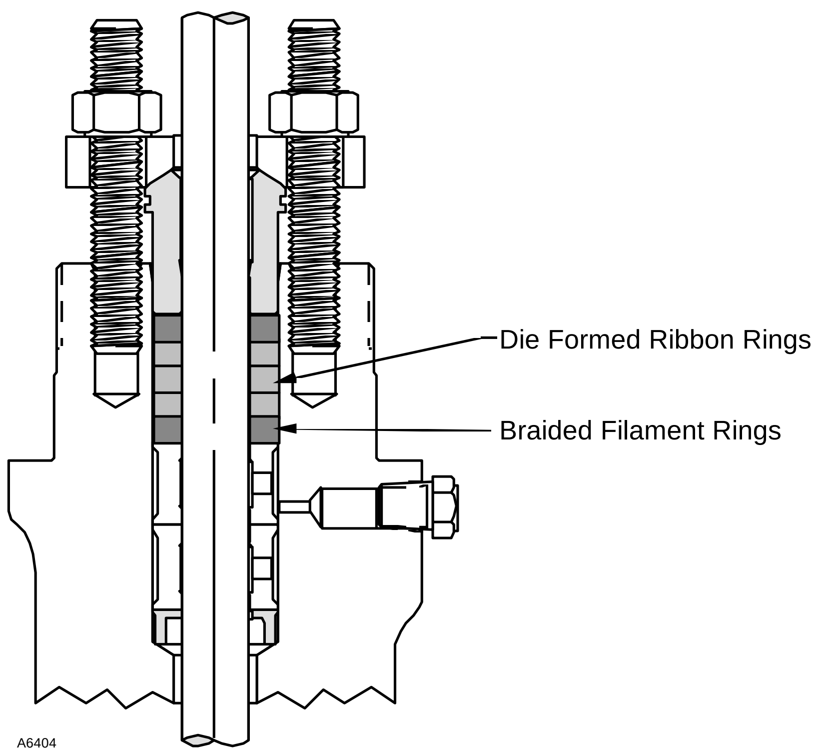


Spring-Loaded Single And Jam Style Double PTFE Packing Arrangements
Figure 26

Jam Style Graphite Packing Arrangements - Graphite packing arrangements are commonly specified in applications where high temperatures (temperatures above 450 degrees F) disallow the use of PTFE materials, or in applications where it is necessary to limit leakage through the packing bore in the event of a fire.

A typical graphite packing arrangement (refer to Figure 27) includes die formed ribbon rings and braided filament rings. Although graphite is well suited to high temperature applications, graphite has several negative characteristics, including the following:

- Graphite is a high-friction material, and high friction can cause jerky valve stem movement. If overtightened, graphite packing may totally seize the valve stem.
- Graphite tends to consolidate (compress) over time; therefore, frequent packing adjustments are required.
- Graphite tends to corrode. To prevent valve and packing damage, sacrificial zinc washers are often included in the packing arrangement.



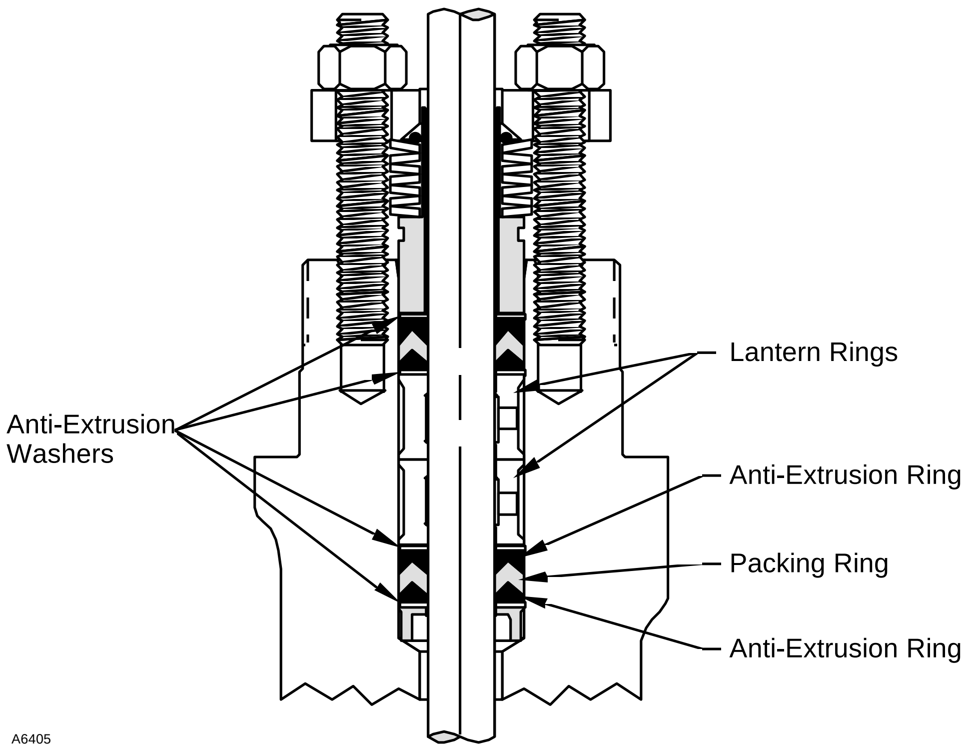
Jam Style Graphite Packing Arrangement
Figure 27

Low Leakage Packing - In North America, the Environmental Protection Agency (EPA) has recently enacted strict guidelines for the maximum allowable leakage of specific pollutants to the atmosphere. For many fluids and applications, the maximum allowable leakage from gasketed joints and stem packing is 500 ppm (parts per million). This low leakage requirement has led to the development of several new packing designs.

Figures 28 and 29 illustrate PTFE and graphite based, low leakage packing arrangements that are suitable for use in ANSI Class 125 through ANSI Class 600 valve bodies. Note the following general design features that have been developed to improve stem sealing:

- Low leakage packing arrangements include fewer packing rings than standard packings. The inclusion of fewer packing rings results in a higher stress on each ring (more force in terms of psi). The higher stress results in tighter sealing.
- A smaller packing surface results in less stem and packing wear, and improved packing life.
- The packing is live-loaded through the use of externally located Belleville springs. Live loading places a constant load on the packing. Live-loaded packings require less maintenance than jam style packings.
- Massive guiding prevents lateral stem movement that can result in packing damage.

Low-Leakage PTFE Packing - PTFE cold forms easily and it does not have good memory; i.e., after PTFE becomes deformed, it does not return to its original shape. When PTFE is used as a packing ring material, a major concern is the extrusion of the packing rings and the resulting loss of sealing integrity. Refer to Figure 28 and note the anti-extrusion rings and anti-extrusion washers that prevent packing ring extrusion. Because only a few packing rings are included in the arrangement, there is extra space in the packing bore. Lantern rings are included to fill the empty space. The packing arrangement that is shown in Figure 28 is designed to meet the 500 ppm leakage requirement at temperatures up to 450 degrees F and at pressures up to 750 psig.



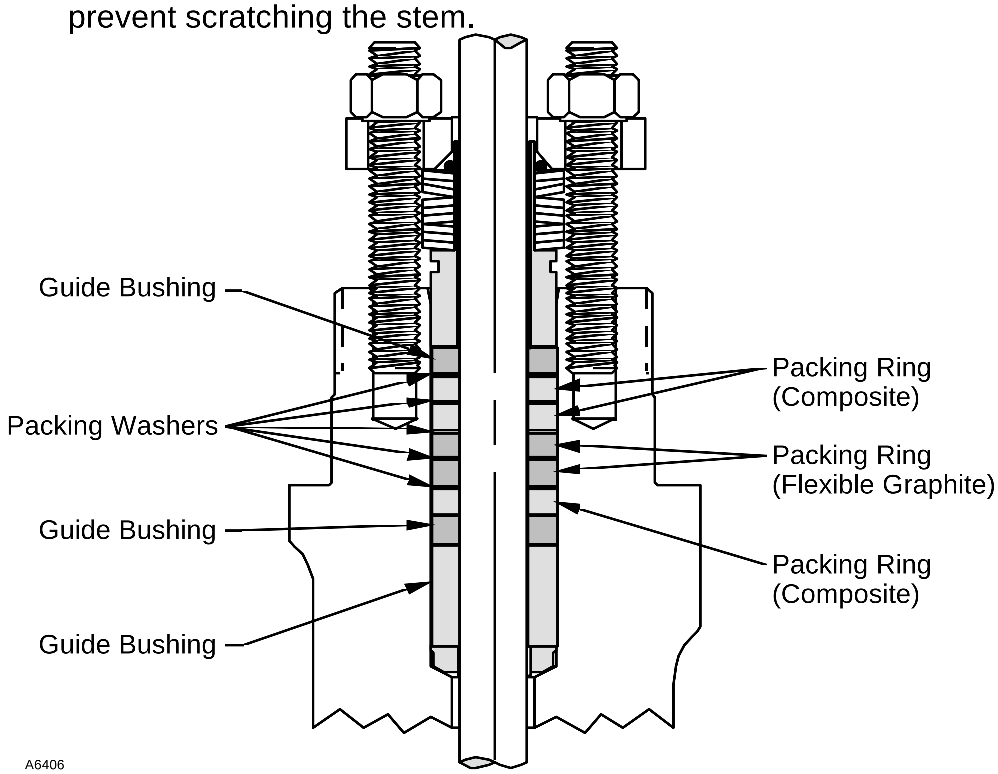
Low Leakage PTFE Packing Arrangement
Figure 28

Low Leakage Graphite Packing - When low leakage is required at higher temperatures and pressures, graphite packing rings are included in the packing arrangement. Refer to Figure 29 and note the following:

- The packing arrangement includes graphite rings and composite rings. The major role of the composite rings is to transmit the loading force to the graphite rings. The graphite rings perform the primary sealing function.

- To create a tight seal, PTFE packing washers are included between the packing rings. PTFE is typically limited to 400 to 450 degrees F to prevent extrusion. In this application, however, extrusion of the PTFE actually helps produce and maintain a tight seal. For this reason, the packing arrangement that is shown in Figure 29 is designed to meet the 500 ppm leakage requirement at a maximum temperature of 600 degrees F.

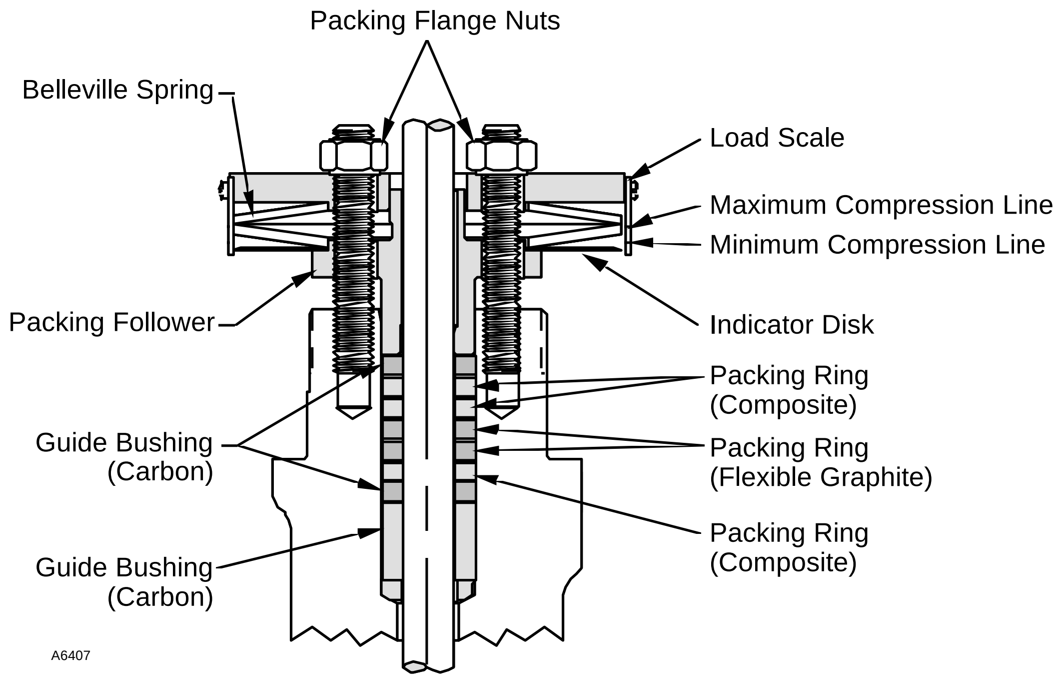
- Graphite packing is not as resilient as PTFE packing and any lateral movement of the stem will enlarge the packing bore, leading to leakage. To prevent packing damage and subsequent leakage, carbon guide bushings are located above and below the packing rings to provide stem guiding. The guide bushings are made of a non-metallic material to prevent scratching the stem.



Low Leakage Graphite Packing Arrangement
Figure 29

Live-Loaded Packing With Load Scale - For extremely high temperature and high pressure applications, a graphite packing arrangement that does not include PTFE packing washers may be specified. The graphite packing arrangement that is illustrated in Figure 30 is rated to 1 200 degrees F. However, the stem friction is extremely high and packing loads must be carefully managed to prevent stem seizure. An adjustable Belleville spring arrangement allows precise adjustment of the packing loading.

As the Belleville springs are compressed (by tightening the packing flange nuts), the load scale moves down relative to the position of a fixed indicator disk. The position of the indicator disk relative to the load scale provides a visual indication of the amount of loading force that is applied to the packing by the packing follower.



Live-Loaded Packing With Load Scale
Figure 30

Adjustable Belleville Spring Operation - During installation, the Belleville springs are compressed until the indicator disk aligns with the maximum (MAX) compression line on the load scale. As the packing consolidates over time, the indicator disk moves toward the minimum (MIN) compression line on the load scale. When the indicator disk aligns with the MIN marking, the packing nuts must be tightened to restore the proper loading.

Basic Packing Selection Considerations - The general rule for packing material selection that is suggested by most valve manufacturers is as follows:

- If the packing temperature is below 450 degrees F, select PTFE packing.
- If the packing temperature is above 450 degrees F, or if minimum leakage after a fire is required, select graphite packing.

Section 4.1.5 of SAES-J-700 is consistent with the above guideline except that it limits PTFE to a maximum temperature of 400 degrees F.

In addition to the above guidelines, packing selection criteria may include the following:

- Line pressure.
- Packing material compatibility with the process fluid.
- Compliance with NACE guidelines, if pertinent.
- Leakage requirements (environmental concerns, plant policies, etc.).
- Maintenance schedules and costs.
- Friction and valve performance (good process control).

Low Leakage Packing And Nonenvironmental Applications - Even when the 500 ppm emission requirement does not apply to a specific application, low-leakage packings may be considered for purposes of conserving the process fluid, controlling the fugitive emission (unwanted leakage) of toxic or polluting fluids, or minimizing packing maintenance and extending packing life.

Externally Loaded Packing And NACE Guidelines - Because of the material hardness limits that are imposed by the NACE guidelines, conventional spring-loaded packing arrangements are not generally available for sour applications; however, the Belleville springs that are included in externally loaded packing arrangements are typically made of an Inconel alloy that does conform to the NACE material guidelines. As a result, externally loaded packing arrangements expand the packing options that are available for sour applications.

Packing Specifications - Charts that illustrate the pressure and temperature limits of the packing arrangements that have been discussed in this section are included in Fisher Specification Bulletin 59.1:062. Pressure and temperature limits are listed for two types of applications: (1) for environmental applications (when the 500 ppm standard must be met), and (2) for nonenvironmental applications.

Temperature Rating Information

The previous discussions of gasket and packing material selection underscore the importance of the temperature ratings of all the control valve components. The temperature limits of the body and the bonnet are considered during the assessment of ANSI Class pressure and temperature ratings. Trim material temperature limits are considered when a specific trim option is selected. The material temperature capabilities of all other components are generally listed in specification bulletins as shown in Figure 31.

Materials and Temperature Limits for All Other Parts

PART		MATERIAL	MATERIAL TEMPERATURE CAPABILITIES			
			°F		°C	
			Min	Max	Min	Max
Optional disk		PTFE	– 100	400	– 73	204
Bonnet gasket		S31600 (316 stainless steel/graphite)	– 325	1100 except 800 on oxidizing service	198	593 except 427 on oxidizing service
Packing flange studs and nuts when used with plain bonnet		Steel	– 20	800	– 29	427
		S31600 (316 stainless steel)	– 325	800	– 198	427
Packing (temperatures shown are material temperature capabilities)		PTFE V-ring	– 40(1)	450	– 40(1)	232
		PTFE/composition	– 100	450	– 73	232
		Graphite ribbon/filament	425	1100(2)	– 254	593(2)
Enviro-Seal Packing System		PTFE V-ring	Please refer to Enviro-Seal and High-Seal Packing Systems bulletin 59.1:061 for temperature capabilities of packing.			
		Graphite ring				
ANSI(3) body/bolting combination limitations	WCC steel body	SA-193-B7 steel studs	– 20	800	– 29	427
		SA-194-2H steel nuts				
	CF3M (316L stainless steel) body	SA-193-B8M (strain hardened) stainless steel studs	– 325	800	– 198	427
		SA-194-8M stainless steel nuts				
		SA-193-B7 steel studs	– 50	800	46	427
		SA-194-2H steel nuts				

1. Bonnet temperature guidelines provide for using a plain bonnet with PTFE packing for 0 to 450°F (18°C to 232°C) in-body process temperatures. The in-body process temperatures assume an ambient outside temperature of 70°F (21°C).
2. Except 700°F (371°C) on oxidizing service.
3. Lubricated nuts are offered to maximize ease of maintenance and minimize gauling potential for temperatures above 450°F (232°C).

Material Temperature Capabilities For Components
Other Than Bodies And Trim
Figure 31

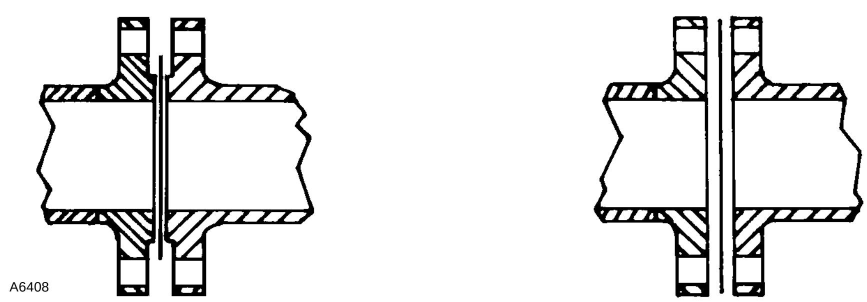
End Connections

End connections provide the means for installation of control valves in pipelines. Popular end connections include several types of screwed pipe threads, bolted and gasketed flanges, and welded-end connections.

Common Flange Connections

Raised-Face Flange - The raised-face flange (see Figure 32) is the most common end connection. These flanges have circular, raised faces with concentric, circular grooves for good gasket sealing and resistance to gasket blowout. The line gasket only covers the raised-face portion of the flange. As the line bolting is tightened, high stresses are produced at the perimeter of each flange; therefore, raised-face flanges are available only for strong, ductile (non-brittle) materials such as carbon steel and stainless steel.

Flat-Face Flange - The flat-face flange (see Figure 32) allows full-face contact, with the gasket clamped between the flanges. Full-face contact has the advantage of minimizing flange stresses that are caused by the force of line bolting. Flat-face flanges are common with cast iron bodies, which are brittle and would crack if raised-face flanges were used. Flat-face flanges are also common with brass and aluminum bodies, which are soft and would bend if raised-face flanges were used. Flat-face flanges are generally limited to low pressure applications.



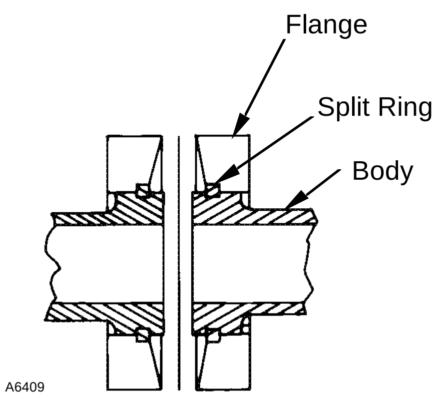
Raised-Face Flange Flat-Face Flange

Raised-Face And Flat-Face Flanges
Figure 32

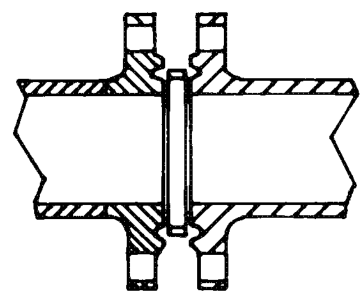
Other Flanged End Connections

Separable Flange - The separable flange (see Figure 33) is another variation of a raised-face flange. In this construction, the flange is manufactured independently of the valve body. Split rings are required to secure the flange to the body and to transmit the bolting force to the gasket and the mating connection. When an expensive body material is specified, separable flanges may result in some economy, because the flanges can be made of a more economical material such as carbon steel. Some companies prefer separable flanges because a standing inventory of control valves can be adapted to several different piping configurations by simply installing the appropriate flange.

Ring-Type Joint - Also known as RTJ, this flange design (see Figure 33) is well suited for extremely high pressure applications. Matching grooves in the body and pipe flanges retain a solid metal seal ring. As the line bolting is tightened, the ring deforms and conforms to the grooves. This seal is pressure-assisted because, as the pressure increases, the ring pushes against the groove, making the seal tighter.



Separable Flanges

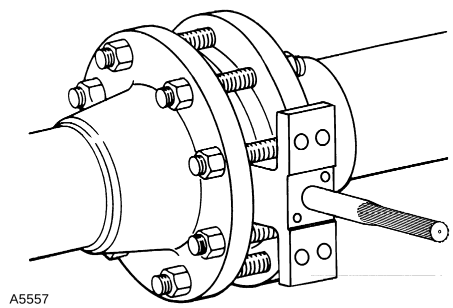


Ring-Type Joint (RTJ)

Separable Flanges And Ring Type Joints
Figure 33

Wafer Style

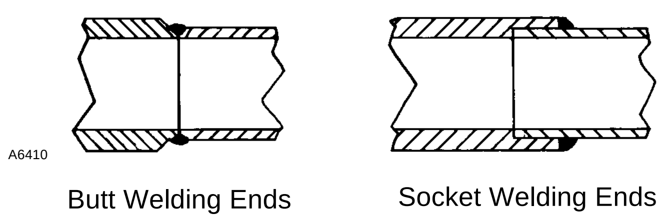
A wafer-style valve body (see Figure 34) includes a raised-face contact surface in the body casting. The faces conform to standard raised-face flange dimensions, and they include concentric grooves just like a standard raised-face flange. The long line bolting sandwiches the wafer body and gaskets between the pipe flanges. Ball and butterfly valves are commonly available with this body style.



Wafer Style Valve Body
Figure 34

Welded End Connections

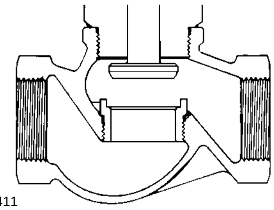
In many high pressure and high temperature applications, the valve body is welded directly into the pipeline. Welded end connections (see Figure 35) are leak-tight at all pressures and temperatures. Welded end connections are economical in first cost; however, valves with welded ends are difficult to remove from the pipeline for service. Socket-weld ends are common for smaller valve sizes (through 2-inch) and butt-weld ends are standard for 2-1/2 inch and larger valve bodies.



Welded End Connections
Figure 35

Threaded End Connections

Threaded-end connections (see Figure 36) are popular for small control valves because of their economy and ease of installation. Threaded end connections are generally not available for valve bodies that are larger than 2 inches.



Threaded End Connections
Figure 36

Saudi Aramco Standards

Section 4.1.2 of SAES-J-700 Control Valves provides some guidance for the selection of end connections. This standard:

- Disallows threaded ends on valve sizes 2-inch and larger.
- Requires a minimum flange rating of ANSI Class 300 (according to ANSI B16.5) for carbon steel valve bodies up to 16 inches.

Section 6 of SAES-L-009 Metallic Flanges, Gaskets, And Bolts also provides guidance for the selection of flange facings. Specifically:

- Section 6.1 specifies flat-face flanges when one or both of the mating flanges is ANSI Class 125 iron, aluminum, plastic, or other material that could be overstressed by the bolt load of a raised-face flange.
- Section 6.2 states that the raised face is the Saudi Aramco standard for steel flanges through ANSI Class 600 and up to a design temperature of 900 degrees F, except for underwater service.
- Section 6.3 requires ring type joints for steel flanges in ratings of ANSI Class 900 and higher, for temperature above 900 degrees F, and for underwater applications in ANSI Class 300 and higher.

Face-to-Face Dimensions

Standards

Several standards organizations issue and maintain standards for face-to-face and end-to-end dimensions of control valves. (Face-to-face dimensions are listed for flanged valve bodies, while end-to-end dimensions are given for welded-end and screwed-end connections). Following is an overview of standards organizations and popular standards that address face-to-face and end-to-end dimensions.

ISA - Instrument Society of America. ISA Standard S75.03 specifies face-to-face dimensions for flanged, globe style valves through ANSI Class 600, and S75.16 lists dimensions for globe valves in ANSI Classes 900 through 2500. ISA Standard S75.04 specifies face-to-face dimensions for many flangeless, rotary-shaft valves. ISA Standard S75.12 lists end-to-end dimensions for socket weld and screwed end connections, and ISA Standard S75.15 lists end-to-end dimensions for ANSI Class 150 through Class 2500 butt-weld ends. The ISA standards are the most popular for control valves.

ANSI - American National Standards Institute. In the past, ANSI B16.10 was the primary standard for face-to-face and end-to-end dimensions for all control valve end connections; however, ANSI has relinquished responsibility for these dimensions to the ISA. Fewer and fewer references to ANSI B16.10 should be observed now that the transfer of dimensional standards to the ISA is complete.

MSS - Manufacturers Standardization Society of the Valves and Fittings Industry, Inc. MSS SP-67 lists face-to-face dimensions for conventional butterfly valve constructions while MSS SP-68 lists face-to-face dimensions for high performance (offset) butterfly valve constructions.

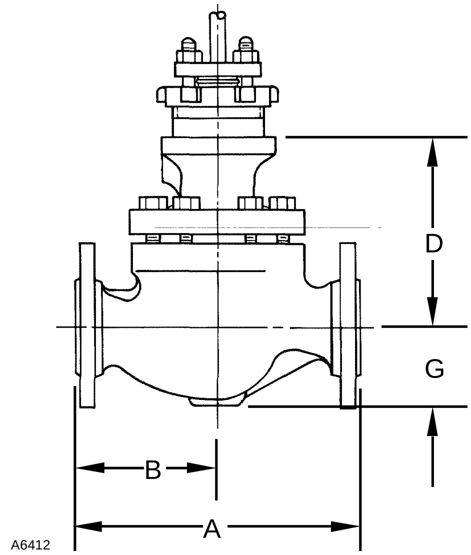
DIN - Deutsche Industrie Norme is a West German national standards organization. DIN face-to-face dimensions are unique.

IEC - International ElectroTechnical Commission. IEC Standard EC534-3-1 is taken directly from ISA S75.03, and IEC Standard EC534-3-2 is taken from ISA S75.04.

API - American Petroleum Institute. API standards relate primarily to pipeline equipment other than control valves; however, the face-to-face dimensions that are included in API-609 are identical to the dimensions in MSS SP-68.

Valve Specification Bulletins

Specification bulletins typically include dimensional drawings (see Figure 37) and tables that list face-to-face (or end-to-end) and other critical dimensions.



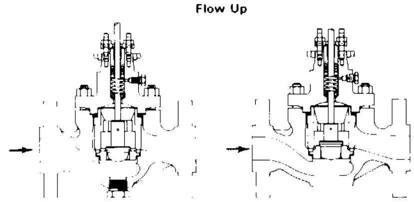
Typical Dimension Drawing
Figure 37

Flow Capacity

Flow Coefficient (C_V) Definition

The relative flow capacity of a control valve is indicated by its flow coefficient. The flow coefficient C_V refers to the number of U.S. gallons water at 60 degrees F that will pass through the valve with a 1 psid pressure drop across the valve.

Valve manufacturers determine flow coefficients by test and by calculation according to ANSI and Fluid Controls Institute (FCI) standards. Manufacturers typically publish the C_V ratings in tabular formats as shown in Figure 38. Note that the table includes C_V ratings at different percentages of travel for different valve sizes and port sizes. For rotary-shaft control valves, capacities are published for different degrees of rotation.



Design EZ

Equal Percentage Valve Plug

FLOW COEFFICIENTS

For additional information see *Bulletin 51.1:EZ(10)*

Equal Percentage — Equal Percentage Characteristic

Coefficient	Body Size, In.	Port Diameter, In.	Total Travel, In.	Valve Opening—Percent of Total Travel: 10	20	30	40	50	60	70	80	90	100	K_m* and C_1
C_v (Liquid)	1	1	3/4	.79	1.25	1.80	2.53	4.16	5.52	7.59	10.7	12.7	13.2	.93
	1-1/2	1-1/2	3/4	.795	1.23	1.91	2.95	4.30	6.46	9.84	16.4	22.2	28.1	.94
	2	2	1-1/8	1.65	2.61	4.30	6.62	11.1	20.7	32.8	44.7	50.0	53.8	.91
	3	3	1-1/2	3.11	5.77	9.12	13.7	21.7	36.0	60.4	86.4	104	114	.84
	4	4	2	4.90	8.19	13.5	20.1	31.2	52.6	96.7	140	170	190	.81
	1-1/2	1	3/4	.770	1.23	1.78	2.58	3.67	5.54	8.30	12.0	15.1	17.3	.95
	2	1	3/4	1.02	1.50	2.05	2.78	3.90	5.57	8.16	11.8	14.5	15.9	.85
	3	2	1-1/8	2.11	3.11	4.58	6.76	10.7	20.7	34.3	48.3	61.5	71.5	.85
	4	2	1-1/8	1.96	3.05	4.43	6.98	11.9	22.3	36.7	50.9	61.8	72.7	.84
			3/4	[illegible]	[illegible]	55.7				[illegible]	353	442	497	37.7
												[illegible]	1030	36.7

C_V = GPM Of Water At 60 degrees F At 1 psid ÆP

Typical Table Of Flow Coefficients

Figure 38

Basic Liquid Flow Equation

The rated C_V of a particular style can be included in the basic liquid flow equation to calculate flow (Q). When the flow rate and pressure conditions are known, the equation can be arranged to solve for the required C_V. Calculating the required C_V and selecting an appropriate valve is the essence of valve sizing.

To Solve For Flow: $Q = Cv\sqrt{\frac{\Delta P}{G}}$ To Solve For C_V: $Cv = Q\sqrt{\frac{G}{\Delta P}}$

Where:

Q is the liquid flow rate in GPM (gallons per minute).

c_V is the flow coefficient that describes the flow capacity of a valve.

ÆP is the pressure drop (P_1-P_2) across the valve in psid.

G is the specific gravity of the fluid at the valve inlet.

Determinants Of C_V

Although control valve sizing is the subject of another Module in this Course, the specifier should be generally aware of the following factors, which combine to influence the rated flow capacity (flow coefficient) of a control valve:

- The port size is obviously a major contributor to the flow coefficient.
- Flow capacity is directly related to the percentage of valve travel or valve opening. To prevent excessive fluid velocity at low flow, control valves are sized to pass the minimum required flow at 10-20 percent travel. To ensure reserve capacity, valves are sized to pass the maximum required flow at 80-90 percent travel.
- The flow geometry of a valve greatly influences its liquid flow capacity. The tortuous flow path of the globe valve limits liquid flow capacity, while the streamlined, flow paths of most rotary-shaft valves results in greater relative capacity for similarly sized valves. Refer to Figure 39. For gasses, flow is a function of the port area alone, and flow geometry has little impact on flow.

Valve Size	**Travel, Percent**	**Rated Cv**	
		Sliding-Stem Tortuous Path	**Rotary-Shaft Streamlined Flow Path**
1 inch	90	20	29
	10	3	0.5
8 inch	90	500	1180
	10	20	5

Relative Liquid Capacity Of Sliding-Stem And Rotary-Shaft Control Valves
Figure 39

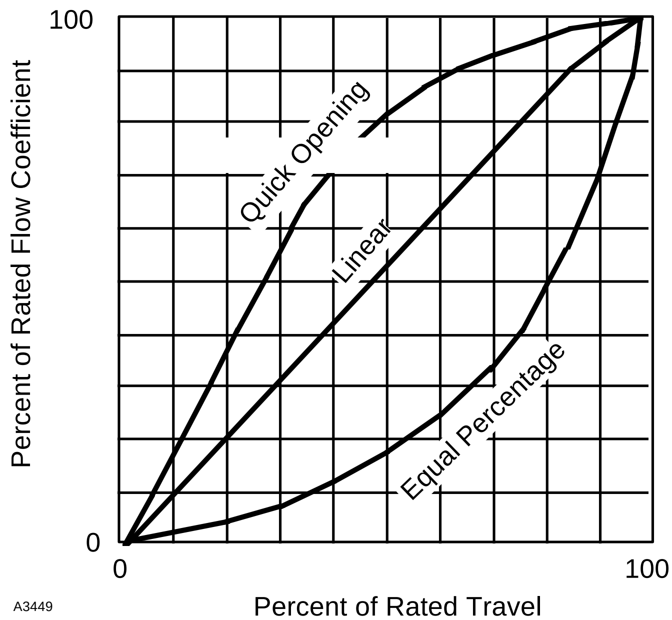
Flow Characteristics

Definition

The flow characteristic of a control valve is defined as the relationship between the flow coefficient and valve travel as the valve travels from 0 to 100 percent open. The purpose of characterizing a control valve is to provide uniform control loop stability over the expected range of operating conditions; i.e., to match the valve gain to the system gain for optimum performance.

Common Characteristics

The three most common flow characteristics are illustrated in Figure 40 and they are described below. Variations of these characteristics may also be encountered.



Valve Characteristics
Figure 40

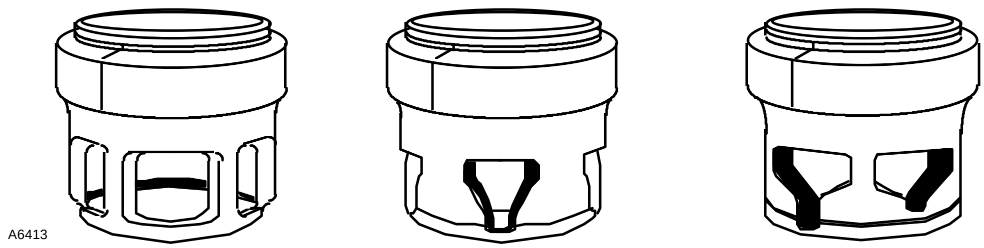
Quick Opening - Throughout the first 60 percent of the rated valve travel, the quick-opening characteristic provides a very large change in C_V for every incremental change in travel. Above 60 percent of the rated travel, each incremental change in valve position results in smaller and smaller changes in C_V. Another way to describe this characteristic is that it provides high valve gain at low percentages of valve travel, and it provides low valve gain at high percentages of valve travel. This characteristic is appropriate for on-off applications, for emergency relief applications, or when high, linear valve gain at low percentages of travel is desired.

Linear - When a linear flow characteristic is specified, the control valve C_V is directly proportional to valve travel. In other words, valve gain is constant over travel. This characteristic is commonly selected when the pressure drop remains constant over the entire operating range of the system.

Equal Percentage - With an equal percentage characteristic, equal increments of change in valve travel produce equal percentage changes in the *existing* flow coefficient. Refer to Figure 41 and note that between 0 and 50 percent valve travel, each 10 percent increase in travel produces a relatively small increase in C_V. Beyond 50 percent travel, each 10 percent increase in valve travel results in larger and larger changes in C_V. In other words, this characteristic provides low valve gain at low percentages of valve travel, and high valve gain at higher percentages of valve travel.

Characterizing Valves

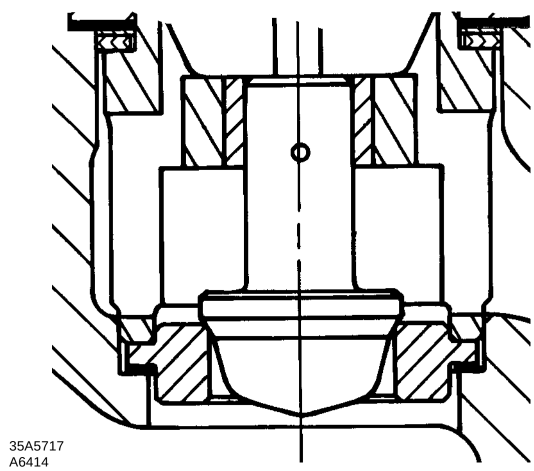
Cage-Guided Valves - In a cage-guided valve, the flow characteristic is determined by the shape of the cage windows, or openings. Figure 41 illustrates the cage window shapes for the three flow characteristics that were previously described.



Quick Opening Linear Equal Percentage

Characterized Cages
Figure 41

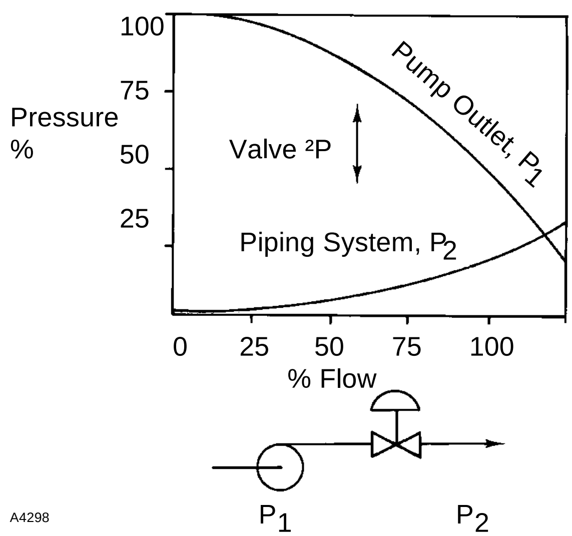
Post-Guided Valves - For post-guided valves, flow characteristics are determined by the contours of the valve plug, as shown in Figure 42.



Characterized Valve Plug
Figure 42

System Characteristics

Typical Pump And Piping System - The objective of flow characterization is to select a valve gain curve that will match with, or compensate for, the gain of the process system. To illustrate, consider the typical pump and piping system that is shown in Figure 43. This system includes a fixed-speed, centrifugal pump. A primary characteristic of a centrifugal pump is that the pressure at the pump outlet (P_1) decreases as the flow rate increases. Because of piping friction, the downstream pressure (P_2) increases as the flow rate increases. The combined effect of the pump curve and the system curve is that as flow increases, the pressure drop across the valve decreases.



Pressure Profile Of A Typical Centrifugal Pump System
Figure 43

Combined Process And Valve Gain - For the purpose of selecting an appropriate valve characteristic, the system characteristics, or process gain, can be analyzed. The process gain will be defined in terms of the change in flow, or GPM (the process output) relative to the change in valve capacity, (the process input). Figure 44 shows a plot of the process gain.

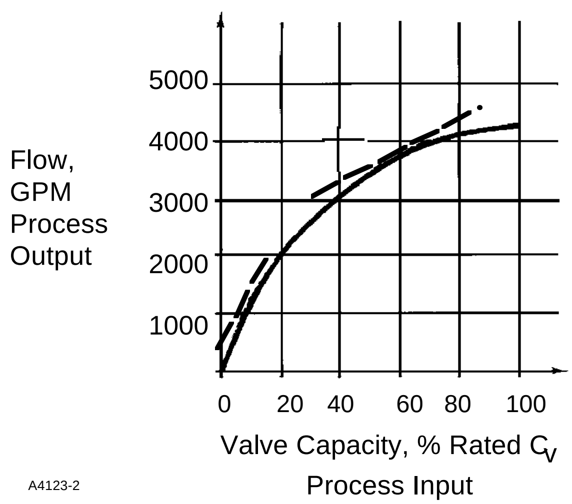
Calculating Gain - Refer to Figure 44 and note that the process gain is defined by the slope of the curve at any operating point. For purposes of illustration, the process gain will be calculated at 10 percent travel and at 60 percent travel.

At 10% valve travel, the process gain is:

$$\text{Gain} = \frac{\Delta\,\text{Output},\%}{\Delta\text{Input},\%} = \frac{\Delta\,\text{Flow, Percent}}{\Delta\text{Valve Travel, Percent}} = \frac{[(2000-250)/4200]\%}{(18-0)\%} = \frac{42\%}{18\%} = 2.3$$

At 60% valve travel, the process gain is:

$$\text{Gain} = \frac{\Delta\,\text{Output},\%}{\Delta\text{Input},\%} = \frac{[(4200-3200)/4200]\%}{(80-40)\%} = \frac{24\%}{40\%} = 0.6$$



Non Linear Process Gain
Figure 44

Non-Linear Gain - The plot and the calculations above illustrate a process that is non-linear. If this system were to be operated over a broad range of flow conditions, the following would occur:

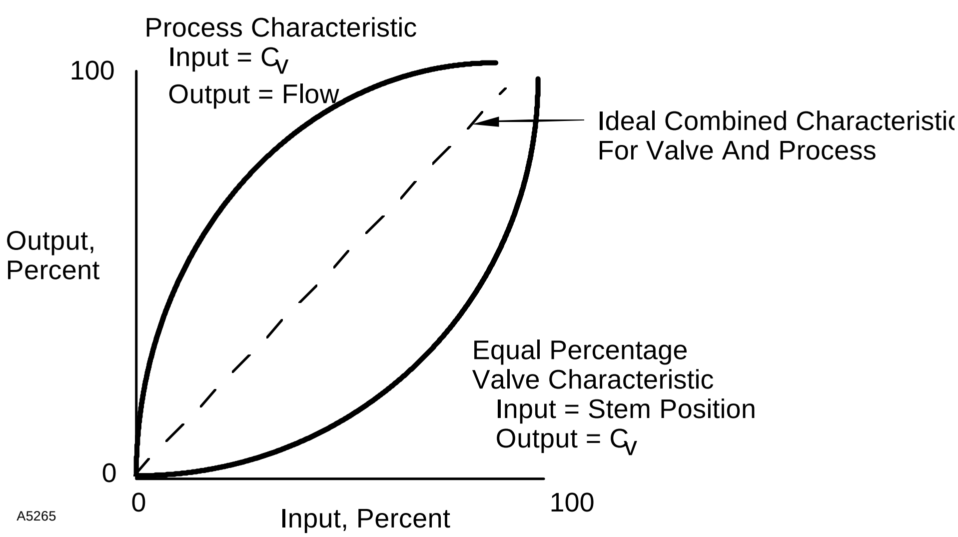
- At low flow rates, a given change in the input signal (controller output to the actuator) will cause a large change in flow.
- At high flow rates, the same amount of change in the input signal (controller output to the actuator) will cause a very small change in flow rate.

Controllability And Operating Range - Non-linear process gain can make it difficult or impossible to tune the controller for stable control, unless the system will be operated over a fairly narrow range of conditions.

Non-Linear Process Gain And Pressure Drop - As is often the case, the non-linear process gain that has been demonstrated in this example is the result of a decreasing pressure drop with increasing flow rate.

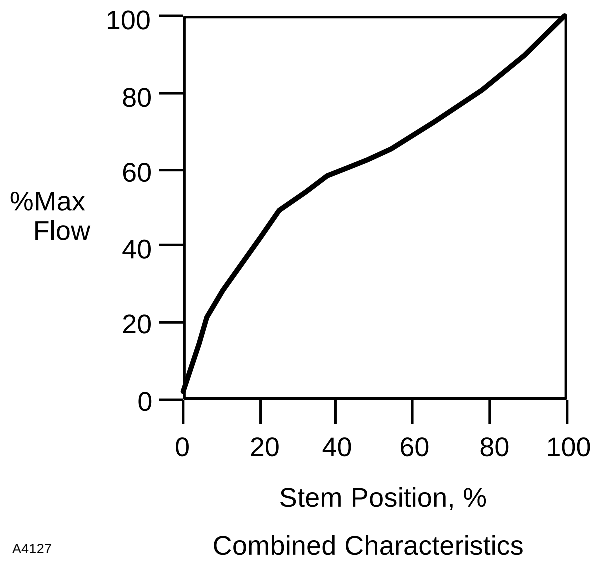
Compensation For Non-Linear Process Gain

Selecting A Characteristic - To provide linear system gain over the entire operating range of the system, an equal percentage valve characteristic is selected. This valve characteristic compensates for the characteristics of the process. Figure 45 illustrates the concept of compensation. Note that the valve characteristic, or gain, is defined by the percent change in output (C_V) for a given change in input (stem position). Note also that the process characteristic, or gain, is defined by the percent change in output (flow) for a given change in input (control valve C_V). Theoretically, the combination of the valve and process characteristics would result in a linear characteristic, which is ideal for many applications.



Process And Valve Characteristics
Figure 45

Combined Gain - In reality, the combined gain is not perfectly linear (refer to Figure 46); however, the combined gain more nearly approximates a linear characteristic and the system will be much easier to control.



Actual Combined Valve And Process Gain
Figure 46

Additional Considerations - Even though flow characterization results in more linear gain, note that the gain is still quite high at low percentages of valve travel. The high gain at low percentages of valve travel is a common occurrence, and it explains why many loops become unstable at low flows.

Gain And Sizing Issues - The high valve gain that is experienced at low percentages of valve travel is one reason why valves should not be allowed to throttle below specific travel limits. As a general guideline, most valves should not be allowed to throttle below 10 percent travel. Throttling below 10 percent travel can result in control instability. In addition, seat wear can result from high velocity flow, and from the plug bouncing in and out of the valve seat.

Selection Guidelines

While a thorough dynamic analysis of the system can be performed to guide the selection of a particular valve characteristic, the use of established rules of thumb generally results in effective control and satisfactory performance. Refer to the guidelines that are included in Work Aid 1G.

Pressure - The guidelines for pressure applications are based on the assumption that in most pressure processes, the valve pressure drop decreases as the flow rate increases; therefore, an equal-percentage characteristic is generally appropriate. An exception is a large-volume application in which the ratio of the maximum to minimum pressure drop is less than approximately 5:1. In this application, a linear characteristic is recommended.

Temperature - Most temperature processes perform well with an equal-percentage characteristic.

Flow - The majority of flow loops work well with equal percentage valve characteristics. One exception is a liquid process with a wide range of setpoints.

Liquid level - The guidelines for liquid level systems are based on the assumption that, in most applications, the pressure drop decreases with increasing load or flow. Again, the exception to the equal percentage guideline is when the ratio of the maximum to minimum pressure drop is less than approximately 5:1. For such applications, a linear characteristic is recommended.

Rangeability

Control valve *rangeability* is a specification that is closely associated with the concept of flow characterization. Unfortunately, the term rangeability is often misused.

Definitions

Classical - A common definition of the term rangeability (also referred to as 'turndown') is the ratio of the maximum to the minimum flow rate; however, the maximum and minimum flow rates are impossible for a valve manufacturer to specify because flow rates are a function of the pressure conditions of a specific application.

ISA Definition - The ISA definition of rangeability is more precise because it defines rangeability as "the ratio of the maximum control valve C_V to the minimum control valve C_V".

$$\text{Rangeability} = \frac{\text{Maximum Flow Coefficient}}{\text{Minimum Flow Coefficient}}$$

By defining rangeability in terms of C_V, manufacturers can develop a rangeability specification, and users can evaluate that specification with respect to specific application requirements.

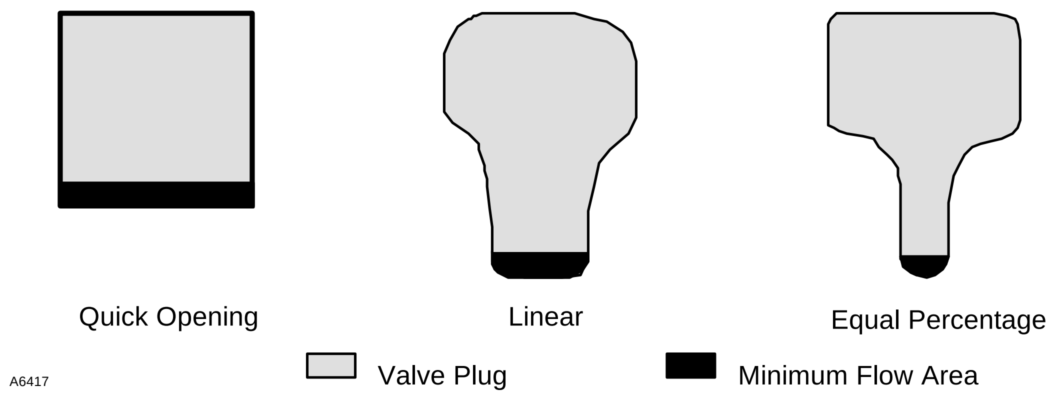
Practical Definition - A more precise and practical definition is "the ratio of the maximum control valve C_V to the minimum *usable* control valve C_V".

$$\text{Rangeability} = \frac{\text{Maximum Flow Coefficient}}{\text{Minimum Usable Flow Coefficient}}$$

The term *usable* is significant because, while some valves may have very low C_V ratings, sustained throttling at low travels may lead to accelerated erosion damage or to valve plug instability and plug slamming.

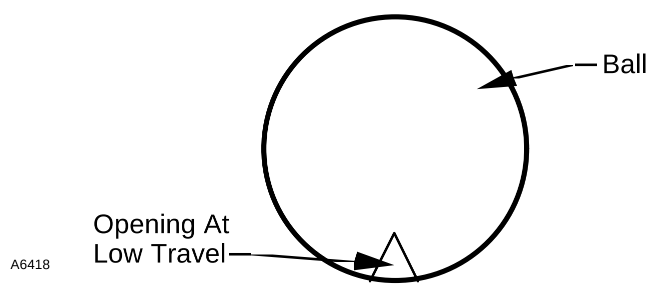
Valve Selection And Rangeability

Sliding-Stem - For sliding-stem valves, the ratio of the maximum to the minimum usable C_V is highly variable, but is generally between 20:1 and 100:1. The minimum usable flow coefficient is determined by the size and shape of the cage openings when the valve plug is near the closed position. Refer to Figure 47 and note that the equal-percentage characteristic will result in the smallest controllable C_V.



Cage Window Shapes And Rangeability
Figure 47

Rotary-Shaft Valves - Rotary-shaft control valves typically provide wider rangeability than globe style valves because of their full bore design. Rangeability from 100:1 to 300:1 is common. V-notch ball valves provide exceptionally wide rangeability because of the shape of the V-notch when the ball is near the closed position. Refer to Figure 48.



V-Notch Ball Segment
Figure 48

Shutoff Classifications

Definition

While many control valves throttle in mid-travel positions throughout their operating lives, some applications include a requirement for the control valve to stop, or nearly stop, fluid flow through the valve. The term that describes the ability of a control valve to stop flow is *shutoff*.

To provide varying degrees of shutoff, sliding stem valves are available with several different types of plug and seat constructions. In rotary-shaft valves, seals of various configurations and materials provide a range of shutoff options.

Importance

There are several conditions under which it may be important for a control valve to either partially or fully shut off flow.

Process - A requirement for full or partial shutoff may be related to the proper operation of a process or system; for example, if a control valve in a blending operation leaks excessively in the closed position, the leakage may make it impossible to maintain the desired ratio of blended ingredients.

Seat Life - Potential damage to the valve is another reason why shutoff may be desirable; for example, if a valve in a boiler feedwater application leaks, the high velocity streams that leak across the seat can result in rapid erosion of critical seating surfaces.

ANSI Test Criteria B16.104 And Section 4.1.7 Of SAES-J-700

Shutoff is ordinarily stated in terms of classes of seat leakage as defined in the American National Standard for Control Valve Seat Leakage (ANSI B16.104). Section 4.1.7 of SAES-J-700 states that all seat leakage classifications shall be specified in accordance with ANSI B16.104.

The ANSI standard defines leakage test setups and test procedures, and it lists the allowable leakage rates for several classes of seat leakage.

ANSI Seat Leakage Classifications

The table that is included in Figure 49 lists the maximum allowable seat leakage and the testing parameters for each of the ANSI Seat Leakage Classifications.

<table>
<tr><th>ANSI Class</th><th colspan="4">Maximum Leakage</th><th>Medium</th><th>Pressure And Temperature</th></tr>
<tr><td>Class II</td><td colspan="4">0.5% valve capacity at full travel</td><td>Air or water</td><td>Lower of service ÆP or 50 psid at 50 to 125 degrees F</td></tr>
<tr><td>Class III</td><td colspan="4">0.1% valve capacity at full travel</td><td>Air or water</td><td>Lower of service ÆP or 50 psid at 50 to 125 degrees F</td></tr>
<tr><td>Class IV</td><td colspan="4">0.01% valve capacity at full travel</td><td>Air or water</td><td>Lower of service ÆP or 50 psid at 50 to 125 degrees F</td></tr>
<tr><td>Class V</td><td colspan="4">5x10^{-4} mL/minute/psid/inch port diameter (5x10^{-12} m^3/second/bar differential/mm port diameter)</td><td>Water</td><td>Service ÆP at 50 to 125 degrees F</td></tr>
<tr><td rowspan="10">Class VI</td><th colspan="2">Port Diameter</th><th rowspan="2">Bubbles per minute</th><th rowspan="2">mL per minute</th><td rowspan="10">Air</td><td rowspan="10">Lower of service ÆP or 50 psid at 50-125 degrees F</td></tr>
<tr><th>In</th><th>mm</th></tr>
<tr><td>1</td><td>25</td><td>1</td><td>0.15</td></tr>
<tr><td>1 1/2</td><td>38</td><td>2</td><td>0.30</td></tr>
<tr><td>2</td><td>51</td><td>3</td><td>0.45</td></tr>
<tr><td>2 1/2</td><td>64</td><td>4</td><td>0.60</td></tr>
<tr><td>3</td><td>76</td><td>6</td><td>0.90</td></tr>
<tr><td>4</td><td>102</td><td>11</td><td>1.70</td></tr>
<tr><td>6</td><td>152</td><td>27</td><td>4.00</td></tr>
<tr><td>8</td><td>203</td><td>45</td><td>6.75</td></tr>
<tr><td colspan="7">Extracted from American National Standard for Control Valve Seat Leakage, ANSI B16.104-1985 with the permission of the publisher, Fluid Controls Institute, Inc.</td></tr>
</table>

ANSI Class Shutoff Ratings, Leak Rates, And Test Conditions
Figure 49

Test Conditions Versus Installed Conditions

ANSI Class II , III, And IV - For ANSI Classes II through IV, the test pressure drop is limited to 50 psid and the test fluid is air. In most applications, the test conditions do not replicate actual service conditions; therefore, these shutoff classes only provide an indicator of relative shutoff ability.

ANSI Class V - The test conditions for ANSI Class V shutoff do duplicate service conditions; therefore, the actual seat leakage can be predicted, provided that the process fluid is a liquid.

ANSI Class VI - For ANSI Class VI, the test pressure drop is limited to 50 psid. If the actual shutoff pressure drop is larger, it is difficult to predict the installed leak rate.

Shutoff Classification And Expected Installed Seat Leakage

To illustrate the relative seat leakage of the various shutoff classes, the maximum allowable seat leakage for ANSI Class II through ANSI Class VI shutoff will be calculated for a globe valve with the following specifications:

- Maximum rated C_V = 140
- Port diameter = 2.5 inch
- Service ÆP = 100 psid
- Fluid = water

Seat leakage will be calculated with the basic liquid flow equation, $Q = C_v\sqrt{\Delta P}$, where:

- The C_V is the shutoff C_V. The shutoff C_V is calculated by multiplying the maximum rated C_V of the valve times the percentages that are included in the standard (see Figure 49).
- The ÆP is the test ÆP that is specified for each shutoff class (see Figure 49).

Class II - ANSI Class II shutoff class allows seat leakage of up to 0.5 percent of the rated capacity of the valve; therefore, the shutoff C_V is 0.005 x 140 = 0.7. The test ÆP is 50 psid.

$$Q_{shutoff} = 0.7\sqrt{50} = 4.95\,\text{gpm}$$

Class III - ANSI Class III allows seat leakage of up to 0.1 percent of the rated valve capacity; therefore, the calculated shutoff C_V is 0.001 x 140 = 0.14. The test ÆP is 50 psid.

$$Q_{shutoff} = 0.14\sqrt{50} = .99\ \text{gpm}$$

Class IV - ANSI Class IV allows leakage of up to 0.01 percent (0.0001) of the rated valve capacity; therefore, the calculated shutoff C_V is 0.0001 x 140 = 0.014. The test ÆP is 50 psid.

$$Q_{shutoff} = 0.014\sqrt{50} = .099\ \text{gpm}$$

Class V - The standard for ANSI Class V shutoff allows seat leakage to a maximum that is calculated with the following:

$$Q_{shutoff} = 5x10^{-4} mL/minute \text{ per psid per inch of port diameter}$$

The test ÆP is the service drop (100 psid). Therefore, the allowable seat leakage for the sample application is calculated by:

$$Q_{shutoff} = 0.0005\ mL/minute/100/2.5$$
$$Q_{shutoff} = 0.125\ mL/minute$$
$$1\ mL = 0.000264\ gallon;\ therefore$$
$$Q_{shutoff} = 0.000033\ gpm$$

Class VI - ANSI Standard B16.104 lists the allowable leakage for port diameters through 8-inches, as shown in Figure 49. The allowable leakage is expressed in both milliliters per minute and in bubbles per minute. This leak class provides very tight shutoff.

Other Considerations

Test Vs. Installed Seat Leakage - It must be emphasized that seat leakage that is allowed for a certain ANSI Class shutoff rating is substantially different from the seat leakage of an installed valve, because the actual shutoff pressure drop is generally much larger than the test pressure drop.

Service Conditions - An approximation of the installed seat leakage of valves with ANSI Class II, III, and IV shutoff can be calculated with the use of the liquid flow equation and the actual shutoff ÆP (instead of the test P). The table in Figure 50 compares the maximum allowable leakage that was calculated previously (with the use of test ÆP of 50 psid) to the estimated leakage when the shutoff ÆP is 600 psid.

ANSI Class Rating	Seat Leakage At Test Conditions, GPM	Seat Leakage At 600 psid (Actual Conditions), GPM
I I	4.95	17.1
III	0.99	3.42
IV	0.099	0.342
V	0.000198	0.000198

Allowable ANSI Class Seat Leakage Versus Estimated Actual Seat Leakage
Figure 50

Shutoff And Valve Condition - Seat leakage ratings are based on new valves in good condition and with actuators that can produce the appropriate shutoff force. The actual seat leakage may be greater than the rated seat leakage if valve seals and seats are damaged, or if the actuator does not provide sufficient force for shutoff.

Need - Not all throttling valves need to provide tight shutoff. Quite often, block valves placed around the control valve to provide the tight shutoff function. Over-specifying control valve shutoff has been identified as one of the greatest unnecessary costs incurred during control valve selection.

On the other hand, there are many applications in which tight shutoff is required. For example, tight shutoff may be required to isolate a system in an emergency situation. In severe services involving erosive fluids, high pressure drops, or cavitation (discussed later), tight shutoff may be specified to reduce the erosion of closure members and seats that can result from high velocity clearance flow (seat leakage).

selecting control valve types for specific service conditions

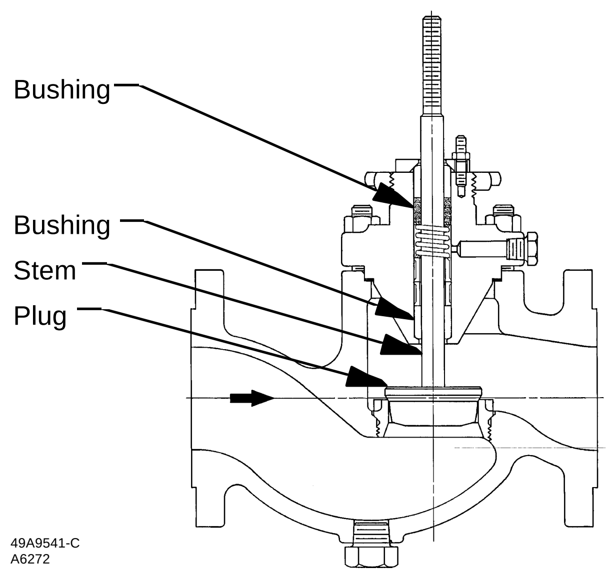
Sliding-Stem Valve Construction Options

Guiding Methods

One of the most basic distinctions that can be made among the broad range of sliding-stem valve types is the method of locating and guiding the valve plug and stem. The two basic approaches are stem or post guiding, and cage guiding.

Stem Guided (Fisher GL) and Post Guided Valves - *Stem-guided* valves (refer to Figure 51) are those in which the valve plug is guided by a bushing or bushings that surround the valve stem. *Post-guided* valves are those in which the diameter of the guided portion of the stem is enlarged to provide a larger guiding area. Post-guided valves typically have larger pressure drop ratings because of the increased guiding surface.

A major advantage of stem and post-guiding is that the guiding surfaces can be located out of the fluid stream. As a result, they are less susceptible to erosion damage from gritty fluids and to clogging by viscous or dirty fluids. Stem and post-guided valves have a smaller guiding area than some other valve designs, and the smaller guiding area can result in reduced friction. This feature is also attractive in applications that involve dirty fluids.

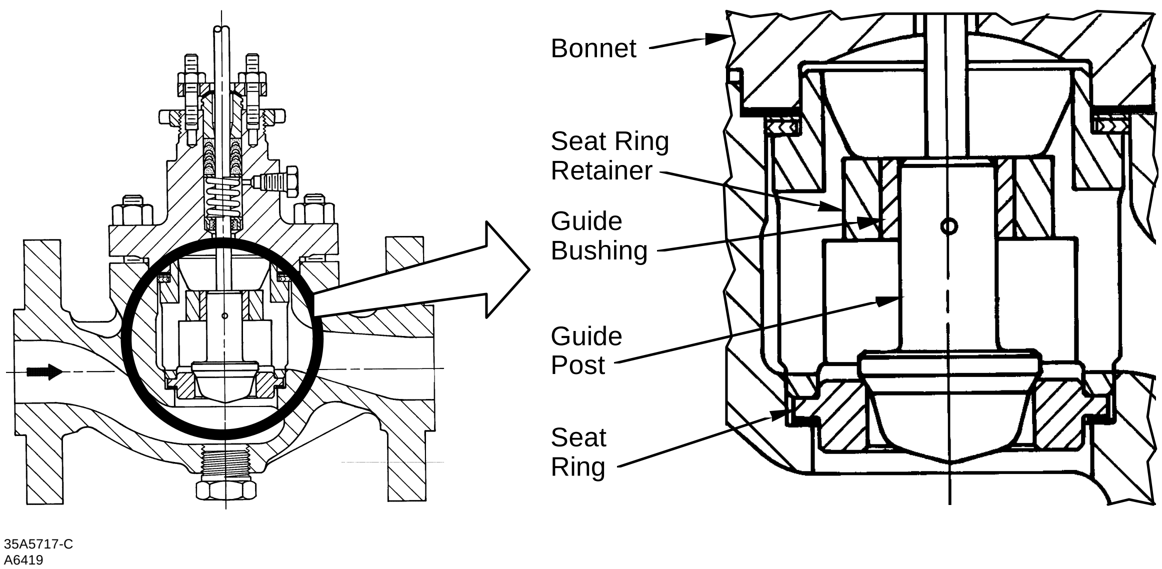


Stem Guiding
Figure 51

Post-Guided Design (Fisher EZ) - Some post-guided valves make include a cage-like component that is referred to as a seat ring retainer. Refer to Figure 52. The seat ring retainer serves the following roles:

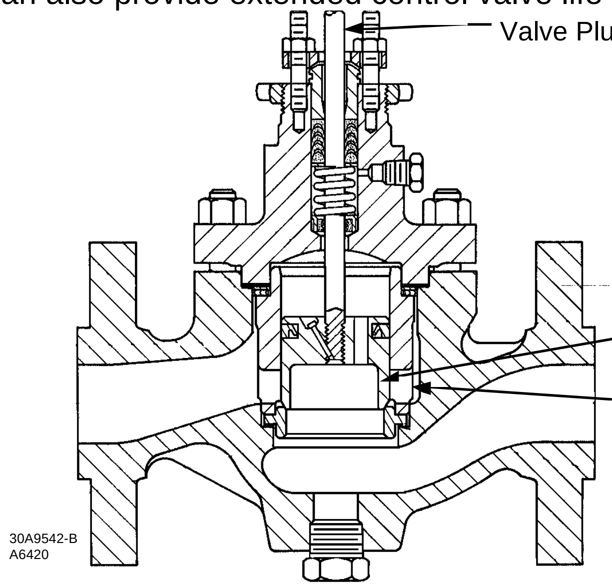
- holds the guide bushing that guides the valve plug
- retains the seat ring
- transmits the bonnet bolting forces to the seat ring for purposes of seat ring retention and gasket compression

This guiding method results in excellent valve plug stability and a flow geometry that is compatible with thick, erosive, or sticky fluids. Note that the seat ring retainer does not characterize flow.



Post-Guided Construction
Figure 52

Cage-Guided Valves (Fisher ES) - Figure 53 illustrates the construction of a typical cage-guided valve. The cage provides a massive guiding area that aligns and controls the valve plug throughout the entire travel range. Cage guiding results in even flow distribution around the valve plug, which balances side loads and helps keep the plug in alignment throughout its range of travel. Because the valve plug is rigidly guided, the plug seals against the seat ring without damaging sideways dislocation, chattering or vibration. Massive guiding often results in pressure drop ratings to the full ANSI Class inlet pressure. Cage guiding can also provide extended control valve life in many applications.



Cage Guiding
Figure 53

Guiding Selection Table

Figure 54 includes a table that can provide assistance in selecting the proper type of guiding for various process fluids.

Fluid Properties	Cage Guided	Post Guided
Clean	A	A
Erosive/Dirty/Non-Lubricating	B	A
Viscous Fluid	B	A
Fibrous Slurry	C	C

A = Best choice. Highly suited to this type of service.

B = Good Choice. May Require the use of options for enhanced performance.

C = Not typically recommended.

Selection Guidelines For Guiding Methods
Figure 54

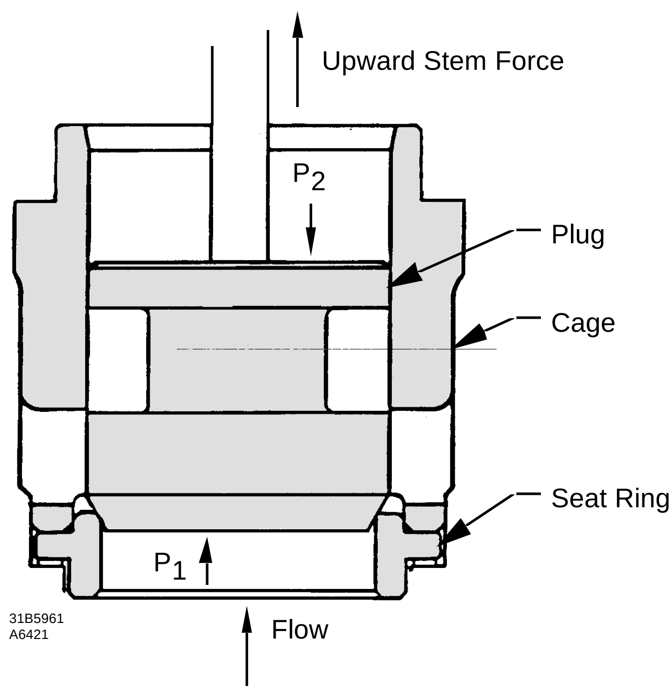
Plug Balancing

Valve designs are also distinguished by whether they use balanced or unbalanced valve plugs.

Unbalanced (Fisher ES) - In unbalanced valve designs, (refer to Figure 55), there is a pressure unbalance across the valve plug. The higher upstream pressure (P_1) registers on the bottom of the plug and the lower downstream pressure (P_2) registers on the top of the plug. The pressure unbalance results in an upward stem force that must be overcome by the actuator. The magnitude of the stem force is a function of the pressure drop.

When unbalanced valve plugs are selected for high pressure drop applications, considerable actuator force may be required to move the valve plug and to seat the valve plug with sufficient force to achieve the rated shutoff.

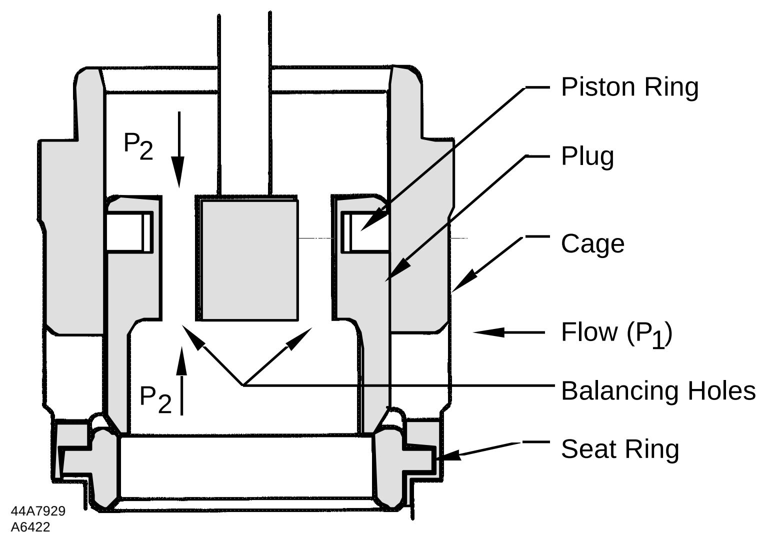
The primary advantages of unbalanced trim are tight shutoff (because there is only one leakpath when the valve is closed), and suitability for high temperature applications (when metal-to-metal seating is specified). However, because of the large stem forces that can result from pressure unbalance, unbalanced plugs are typically available only in smaller valve sizes (through 6 to 10 inch).



Unbalanced Valve Plug
Figure 55

Balanced (Fisher ED) - The valve plug instability that can result from unbalanced plugs is minimized by balanced plug designs. A balanced plug includes holes or ports through the valve plug that allow the pressures that register on both sides of the plug to equalize. Refer to Figure 56.

For balanced plug constructions, the normal flow direction is flow-down, meaning that fluid flows through the cage windows toward the plug. Upstream pressure P_1 registers on the sides of the valve plug, and, because of the balancing ports, downstream pressure P_2 registers on the top and bottom of the valve plug. The result is reduced pressure unbalance across the plug and a minimal stem force; therefore, less actuator force is required to stroke the valve. The disadvantage of balanced valve plugs is that the balancing ports introduce a second leak path between the plug and the cage wall when the valve is closed. This leakpath is sealed by one of several different types of seal rings, or piston rings.



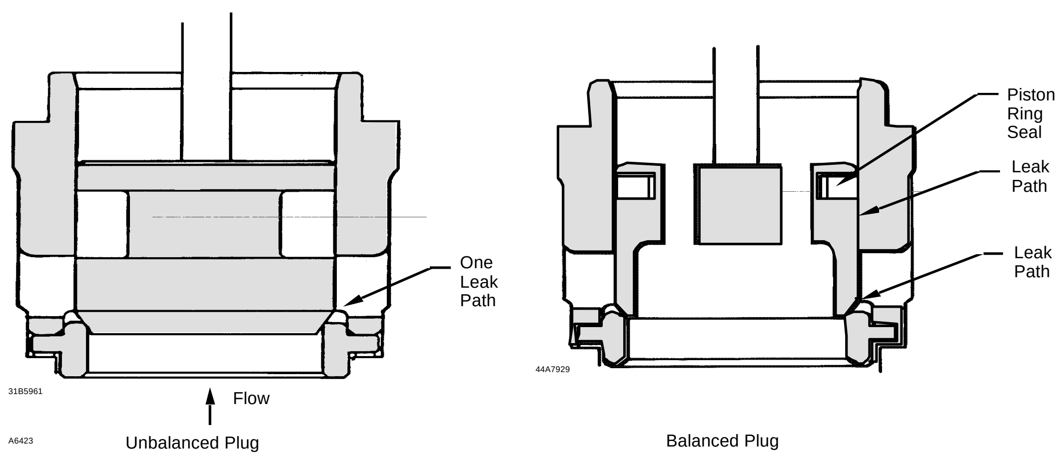
Balanced Valve Plug
Figure 56

Seating Methods And Shutoff

The selection of a particular type of valve seat depends upon the ANSI Class shutoff that is required and the nature and temperature of the process fluid. The common tradeoff is tighter shutoff at the expense of lower temperature ratings.

Metal Seats - Unbalanced valves with metal-to-metal seats (refer to Figure 57) can provide very tight shutoff because there is only one leak path. Valve constructions with metal-to-metal seats can be applied at high temperatures that are greater than 450 degrees F because there are no elastomer temperature limits to consider. Depending on the specific valve construction and the service conditions, shutoff to ANSI Class IV or V is typical.

There are two leakpaths in a balanced plug valve construction. Therefore, the ANSI Class shutoff is determined not only by the seating configuration but also by the piston ring seal type and material. Depending on the piston ring seal type and material, shutoff to ANSI Class II, III, or IV is common.



Metal-To-Metal Seats
Figure 57

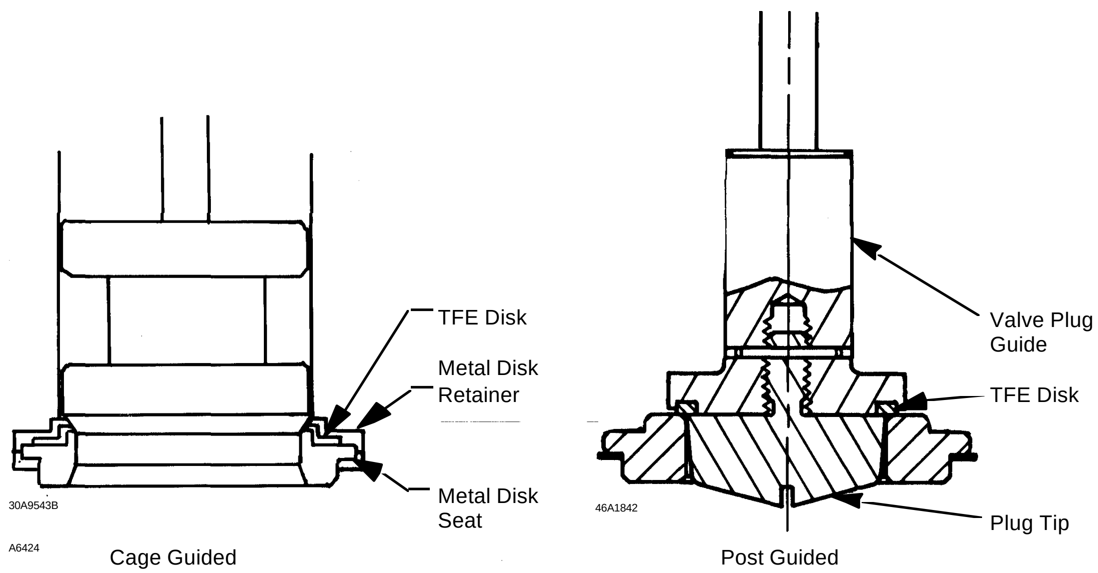
Soft Seats - Soft seats are often specified when very tight shutoff (ANSI Class VI) is required.

With cage guided valves (see Figure 58), a common approach is to sandwich a PTFE disk between a metal disk seat and a metal disk retainer. This assembly replaces the standard seat ring.

For stem or post-guided valves, the PTFE disk is sometimes located in the valve plug assembly. In the design that is shown in Figure 58, the PTFE disk is clamped between the plug tip and the valve plug guide.

Soft-seated, unbalanced valves will usually result in ANSI Class VI shutoff. Balanced valves with soft seats will generally provide shutoff to ANSI Class V or better.

Soft-seated designs often use PTFE seals. As previously described, Section 4.1.5 of SAES-J-700 limits the use of PTFE to temperatures below 400 degrees F.



Soft Seat Constructions
Figure 58

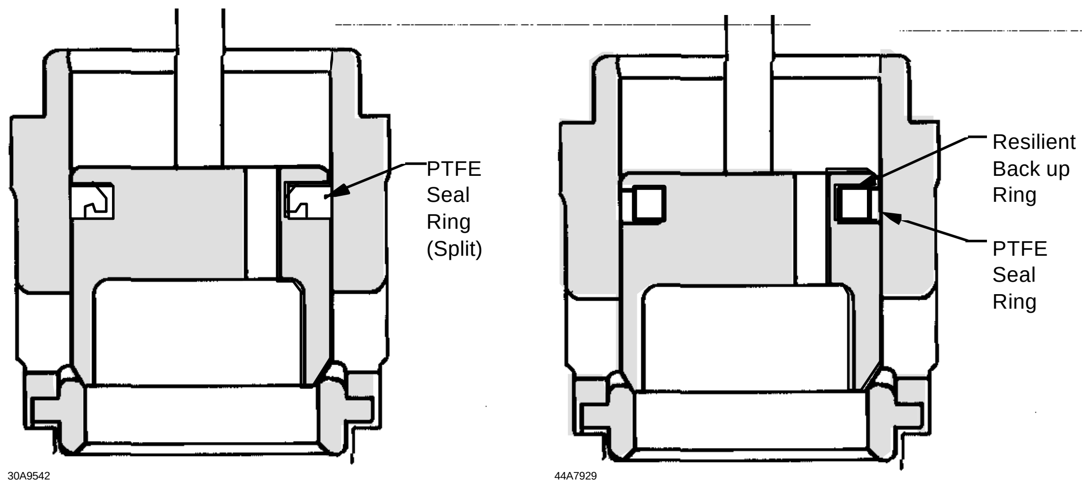
Balanced Plug Seals

As noted previously, balanced valve plugs introduce a second leak path that is blocked by one of several different types of seal rings, or piston rings. Seal ring selection is based on service conditions and the required shutoff.

Low Temperature - Several PTFE seal-ring options are available for low temperature applications. Vendors typically rate PTFE for a maximum temperature of 450 deg F; however, sections 4.1.4 and 4.1.5 of SAES-J-700 limits PTFE to a maximum temperature of 400 degrees F.

- The PTFE Alloy Seal Ring (see Figure 59) is somewhat pressure-assisted to achieve a tight seal. This seal includes a single cut to simplify seal installation. The gap at the cut does allow some leakage, and the result is a maximum shutoff rating of ANSI Class II.

- The PTFE-with-backup-ring seal (see Figure 59) is a two-piece seal in which the PTFE ring performs the actual sealing. Because PTFE does not have "memory," a resilient back up ring is required to provide sufficient force for the seal. There is no cut in this assembly to provide a leak path. The PTFE-with-backup-ring seal, in conjunction with soft seats, can provide ANSI Class IV or V shutoff. Specifiers must determine that the back up ring material is compatible with the process fluid.



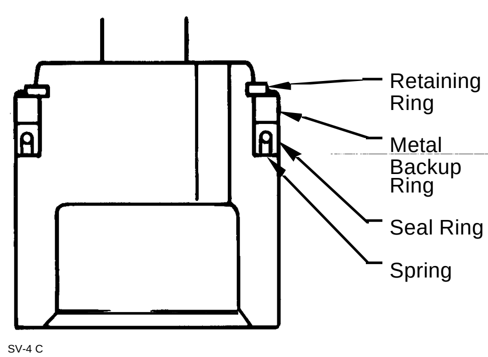
A6425 PTFE Alloy Seal Ring   PTFE With Backup Ring

Standard PTFE Seal Rings
Figure 59

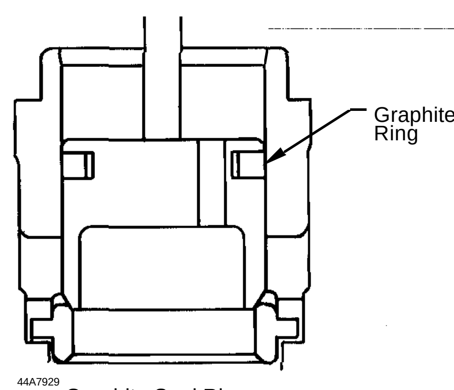
- A spring-loaded, pressure-assisted PTFE seal assembly (see Figure 60) may be specified if a resilient back up ring that is compatible with the process fluid is not available. This seal assembly consists of three pieces. The PTFE seal ring is in the form of a cup that forms two legs that expand when the seal is exposed to process pressure. A spring that is located inside the cup helps the seal to keep its shape. The spring also provides the outward force that is necessary for tight sealing. Because there is no cut or split in the seal, leakage is reduced. To allow installation and replacement, a metal back-up ring and a retaining ring are included in the arrangement. This type of seal is specified for special applications that require an extremely tight plug seal. In combination with soft seats, ANSI Class V shutoff is possible.

  A special version of this seal (not shown) includes an anti-extrusion ring that increases the temperature limit of the PTFE material to 600 degrees F.

High Temperature - Graphite seal rings are designed to provide the plug sealing function at temperatures above the limits of PTFE (450 degrees F). Graphite rings (see Figure 60) are manufactured as a complete, circular ring that must be broken into two pieces to accommodate installation. Graphite rings provide a reasonably tight seal as long as the broken surfaces are closely mated. Graphite rings typically provide shutoff to ANSI Class II. The use of multiple rings may improve the shutoff rating.



A6426 Spring Loaded TFE Seal



Graphite Seal Ring

Spring-Loaded Seal Ring And Graphite Seal Ring
Figure 60

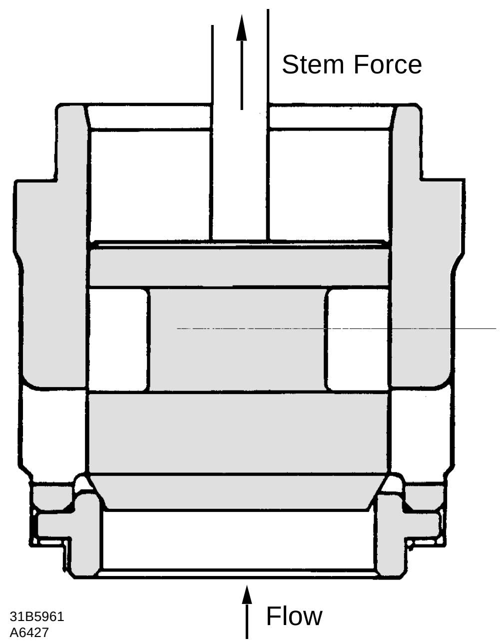
Flow Direction

The selection of a balanced or unbalanced plug also includes the consideration of the preferred flow direction through the valve - flow-up or flow-down. The preferred flow direction is established after considering the effect of pressure on the valve plug when the valve is in the closed position. The two effects are:

- PTTO - pressure-tends-to-open
- PTTC - pressure-tends-to-close

The normal recommendation is PTTO. The PTTO configuration prevents the valve plug from slamming into the seat as the valve plug nears the closed position.

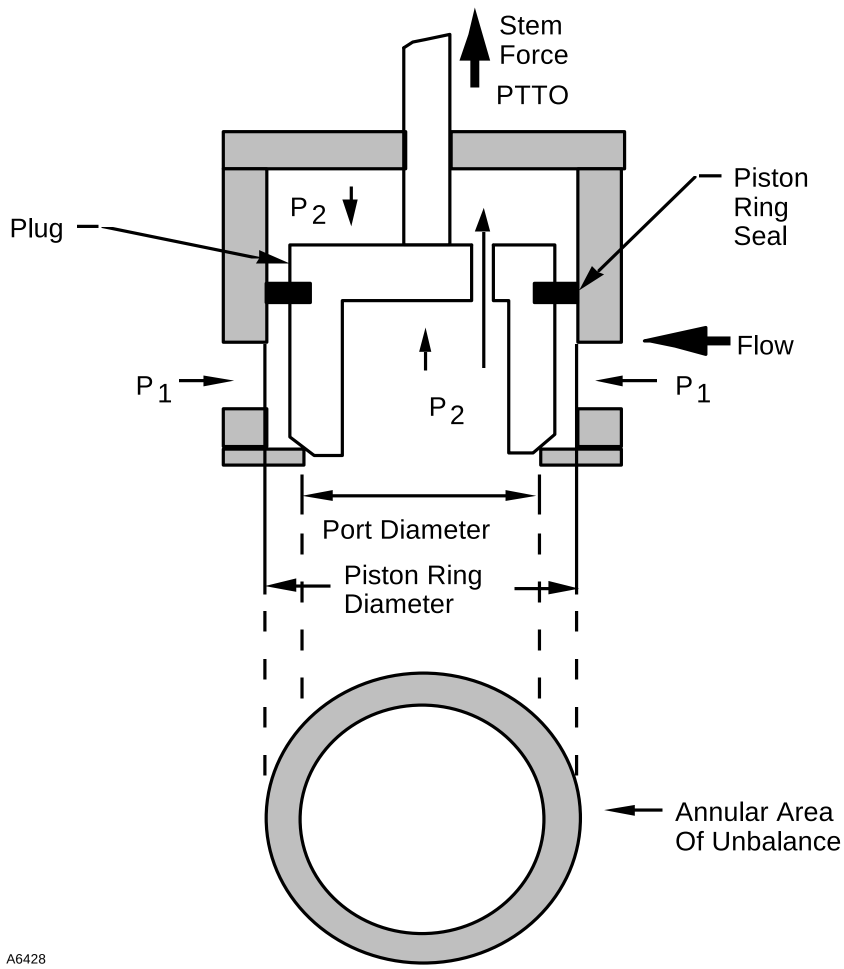
Unbalanced Valves - In unbalanced valves, the PTTO condition is achieved when the valve is installed in a flow-up configuration as shown in Figure 61.



Flow Direction To Achieve PTTO In Unbalanced Valves
Figure 61

Balanced Valves - In balanced valves, the PTTO condition is achieved when the valve is installed in a flow-down configuration as shown in Figure 62. The flow down orientation results in a PTTO condition because:

- The effects of P_2 are nearly balanced.
- High pressure (P_1) registers on an annular area where the inside diameter is defined by the port diameter, and where the outside diameter is defined by outside diameter of the piston ring seal. To achieve a PTTO condition, high pressure P_1 must register on the bottom surface of the annular area that was just described, and this requires a flow down orientation.



Flow Direction To Achieve PTTO In Balanced Valves
Figure 62

Review of Shutoff Capabilities - The table that is shown in Figure 63 summarizes the ANSI Class shutoff for most common valve constructions. Note that the 450 degree F limit is based on manufacturer's recommendations, while Section 4.1.5 of SAES-J-700 limits the use of PTFE to 400 degrees F.

ANSI Class Shutoff Rating	**Unbalanced Plug**	**Balanced Plug**	
		Below 450 Degrees F	Above 450 Degrees F
II		Metal Seat, PTFE Plug Seal (Split)	Metal Seat, Graphite Plug Seal
III			3" & Larger Metal Seat, Graphite Plug Seal
IV	Metal Seat	Metal Seat, PTFE Plug Seal (2 Piece)	4 inch And Larger - Metal Seat, And Multiple Graphite Plug Seals
V	Metal Seat, Larger Actuator, And Custom Lapping Of Plug To Seat	Metal or PTFE Seat With Spring-Loaded PTFE Seal Ring	
VI	PTFE Seat		

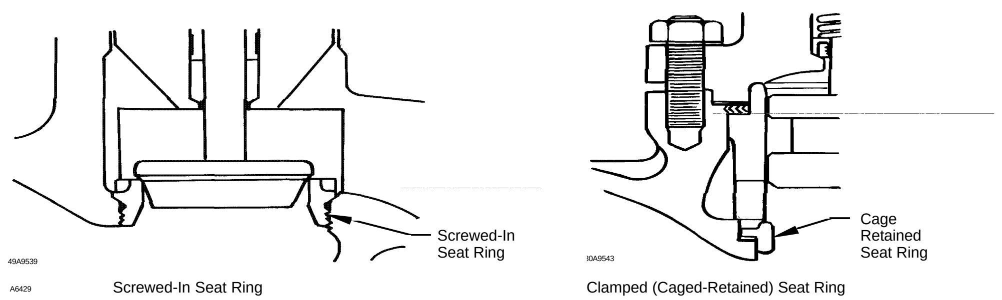
Plug Style Versus Shutoff And Temperature Ratings
Figure 63

Seat-Ring Retention

Seat rings are retained in several different ways. The preferred method depends on the special requirements that are imposed by the pressure drop, fluid temperature, and whether the fluid is corrosive or erosive.

Screwed-In Seat Rings - Screwed-in seat ring designs (see Figure 64) are the most economical; however, they have some history of problems in high temperature applications. When subjected to high temperatures or to large temperature changes, screwed-in seat rings tend to work loose. Leakage between the seat ring and the valve body results in high velocity streams that can quickly erode the seat ring and the body. In corrosive applications, screwed-in seat rings have been known to seize in the body, making removal difficult or impossible.

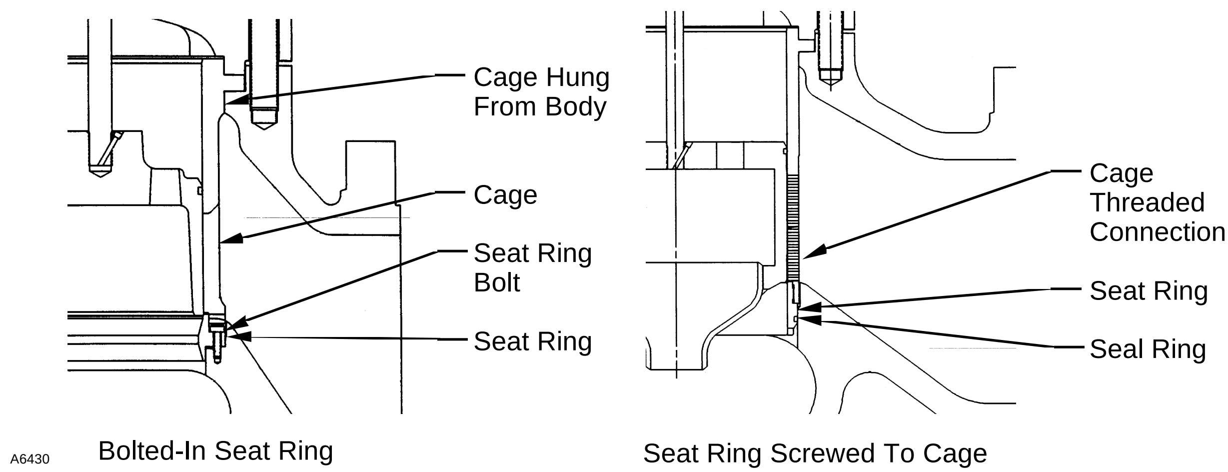
Cage-Retained (Or Clamped) Seat Rings - A cage retained seat ring (see Figure 64) solves many of the problems that are associated with threaded seat rings. The force to retain the seat ring comes from the bonnet bolting. This loading force is transmitted through the bonnet gaskets and cage to the seat ring and seat ring gasket. At higher temperatures, the seat ring will not work loose, and at higher pressure drops, the seat ring gasket should not leak. Because the seat ring is a "drop-in" design, it should not seize in most applications. Gasket loading and seat ring retention is a function of bonnet bolting stresses; therefore, attention to bonnet bolting torque values is a key concern for maintenance personnel.



Screwed-In And Clamped Seat Ring Constructions
Figure 64

Bolted-In Seat Rings - Bolted-in seat ring designs (refer to Figure 65) are most commonly available for large valves and for high temperature services. If the seat ring were cage retained in a high temperature service, the thermal expansion and contraction of large and long components could cause gasket unloading, cage crushing, and damage to the seat ring. One solution is to bolt the seat ring in place and hang the cage from the top of the body. In some designs, a flexible seal between the cage and the seat ring maintains a tight seal as components expand and contract. Bolted-in seat rings are easily removed with common tools.

Seat-Ring Screwed To Cage Constructions - For some special applications, the seat ring is screwed onto the bottom of the cage. Refer to Figure 65. A seal ring prevents leakage between the seat ring and the valve body. With this construction, maintenance is simplified because the cage and seat ring are removed as a single component. A common application for this construction is for large valves that are installed in remote areas where maintenance must be easy to perform, and where maintenance must be performed quickly. Pipeline valves are an example application. The construction has an upper temperature limit of approximately 450 degrees F because of the cage-to-body seal ring.



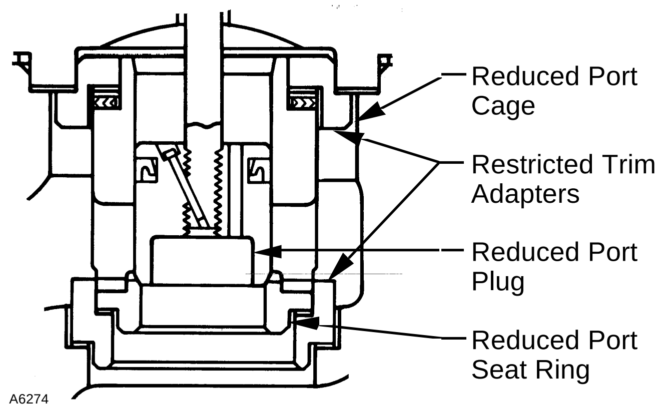
Bolted-In And Screwed-To-Cage Seat Ring Constructions
Figure 65

Reduced Capacity Trim

Reduced Capacity Applications - Reduced capacity trim is available for many types of control valves. Reduced capacity trim may be desirable for the following reasons:

- To permit installation of a valve body that is large enough to meet future needs in a system that is not yet operating at full capacity.
- To avoid installation of pipeline reducers.
- To correct over-sizing errors.

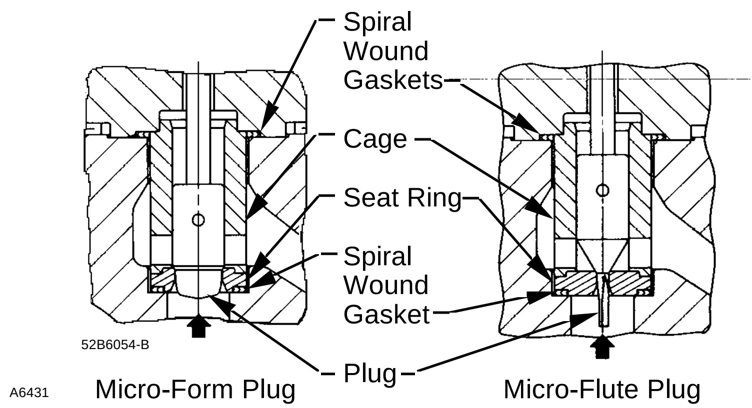
Reduced Capacity, Cage Characterized Trim - Reduced capacity trim (refer to Figure 66) consists of a reduced port cage, plug, and seat ring. The reduced port cage and seat ring are installed through the use of restricted trim adapters.



Restricted Trim
Figure 66

Reduced-Capacity, Plug Characterized Trims - Formed and fluted trims (refer to Figure 67) include reduced port sizes and specially contoured plug tips that are designed to produce a very low flow coefficient and the desired flow characteristic. Fluted plugs are often used in boiler feedwater applications, metering applications, and other high pressure or high pressure drop applications that require extremely low flow rates.

The upward direction of flow, however, exerts a considerable force on the lower side of the seat ring. When an unbalanced plug design is used, this force is increased to an extent that could unload seat ring gaskets. In valves that use reduced capacity trim, the pressure drop limits are reduced to an extent that minimizes unloading of seat ring gaskets. An alternative way of minimizing such unloading is to include a spiral wound gasket between the seat ring and the valve body.



Formed And Fluted Plugs
Figure 67

Relative Capacity Of Standard, Formed, And Fluted Plugs - To achieve a better understanding of the relative capacity of various trim types, the table in Figure 68 lists the minimum and maximum C_V's of various trim options that are installed in a 2-inch valve body.

Trim Option	Body Size, Inches	Port Diameter, Inches	Minimum Cv	Maximum Cv
Standard Equal Percentage Trim	2	1 1/2	1.06	25.3
Micro-Form Trim	2	7/8	.43	21.5
		1/4	.07	1.58
Micro-Flute Trim	2	1/2	.099	4.21
		1/4	.013	.342

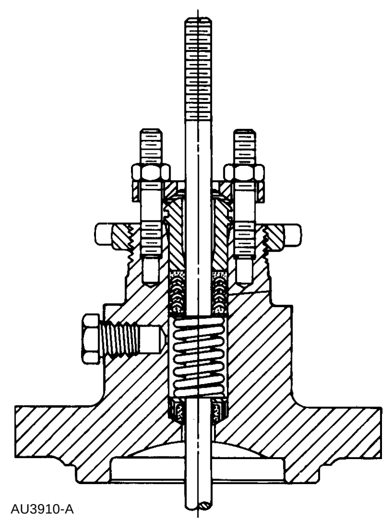
Flow Coefficient Comparison For Standard, Formed, And Fluted Plugs
Figure 68

Bonnets

Most control valves are available with a number of different bonnet options. A standard bonnet and an extended bonnet are shown in Figure 69.

Standard Bonnets - Standard bonnets satisfy a majority of service conditions. Section 4.1.5 of SAES J-700 specifies standard bonnets for applications in which fluid temperatures range from 32 to 450 degrees F.

Extended Bonnets - An extended bonnet locates the packing away from the process fluid, thereby reducing the severity of temperature extremes on the packing. As a result, PTFE packings may be selected even though the process fluid temperature is above
400 degrees F. Section 4.1.5 of SAES J-700 requires extended bonnets or special packing materials for applications in which the fluid temperature is above 450 degrees F or below 32 degrees F.



Standard Bonnet

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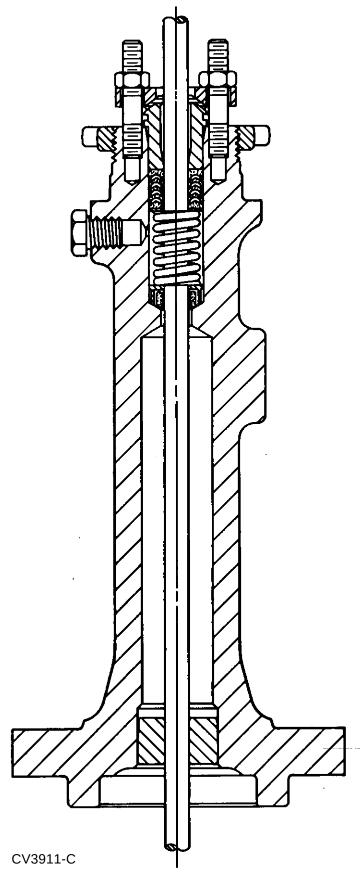
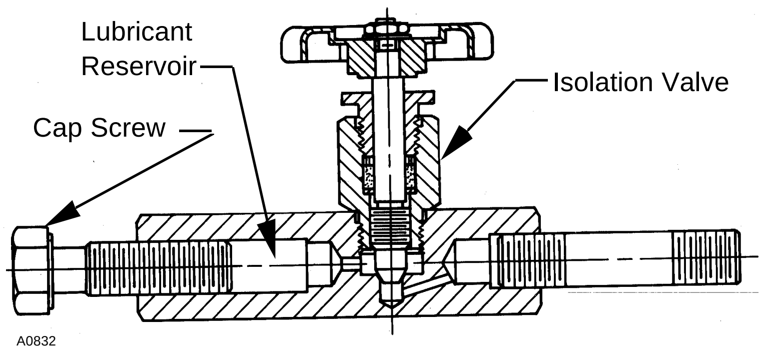


Extended Bonnet

Standard And Extended Bonnets
Figure 69

Lubricator/Isolation Valve - Lubricators and isolating valves are available when it is necessary to lubricate the packing per customer specifications. A typical lubricator and isolating valve is shown in Figure 70. The lubricator assembly is threaded into a tapped hole in the side of the bonnet, generally adjacent to a lantern ring. A reservoir of lubricant is included beneath the cap screw. To lubricate the packing, the isolation valve is opened, and the cap screw is turned to force the lubricant into the packing bore. The isolating valve is then closed to isolate the lubricator from the bonnet.

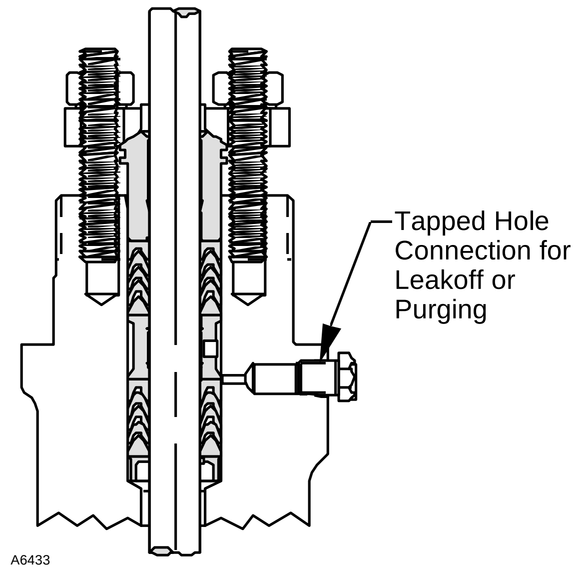
Section 4.1.5 of SAES J-700 requires the use of lubricators with graphite asbestos packings, except in steam, feedwater, and condensate systems; however, the use of asbestos in packing (and other seals) has been generally abandoned because of health concerns. In addition, most modern packings do not require lubrication, and some packings must *not* be lubricated in order to function properly. As a result, lubrication of packing is not as common as it was in the past. Some companies continue to specify lubricators for the purpose of temporarily stopping packing leakage.



Lubricator/Isolating Valve
Figure 70

Leakoffs - A leakoff (refer to Figure 71) is simply a tube or pipe that is threaded into a tapped hole in the side of the bonnet. Leakoffs allow an operator or technician to visually monitor any packing leakage. Leakoffs are generally specified in conjunction with double packing arrangements, and the leakoff tap is located adjacent to the lantern ring.

Purging - Packing boxes are sometimes purged to ensure zero leakage to atmosphere, or to drive any damaging materials out of the packing bore. Purging involves piping an inert or compatible fluid into the packing bore through a tapped hole in the bonnet wall. Packing is typically purged only when fluids are extremely corrosive, hazardous, or erosive.

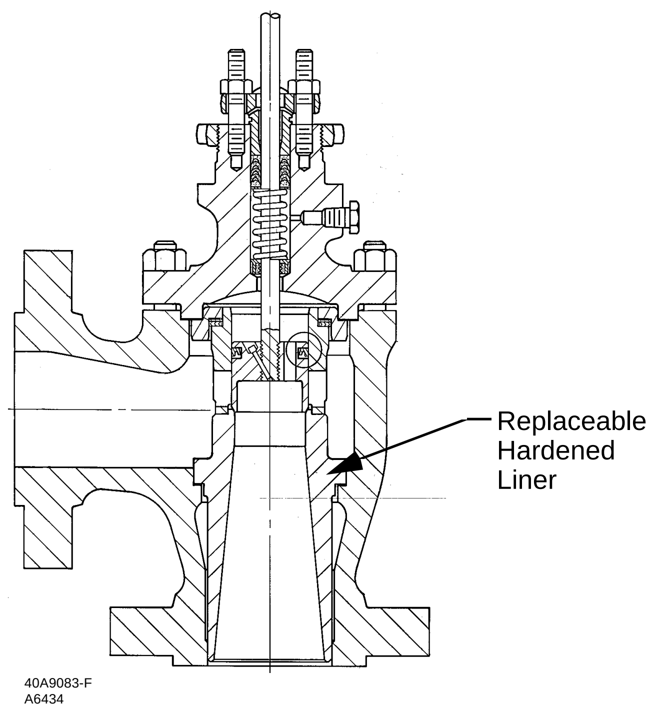


Connection For Leakoffs And Purging
Figure 71

Valve Body Styles

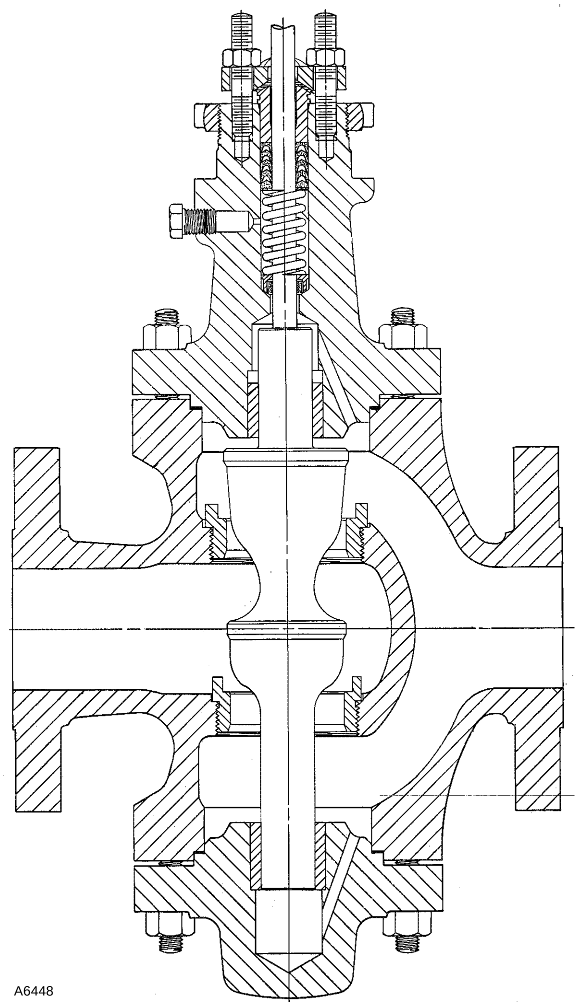
Most of the valve design options that have been presented in this section can be incorporated in different body styles to better satisfy unique application requirements. Some of the popular body styles are explained below.

Angle Bodies - In an angle body construction (see Figure 72), the flow direction changes only once. The streamlined flowpath results in a flushing action and minimizes the accumulation of solids within the valve. Angle valves are commonly used in boiler feedwater, heater drain, and many flashing applications. Angle valves may also be applied in applications where space is at a premium and the valve can also serve as an elbow. Angle valves are commonly available with replaceable, hardened liners in the outlet area to help combat erosion and flashing damage.



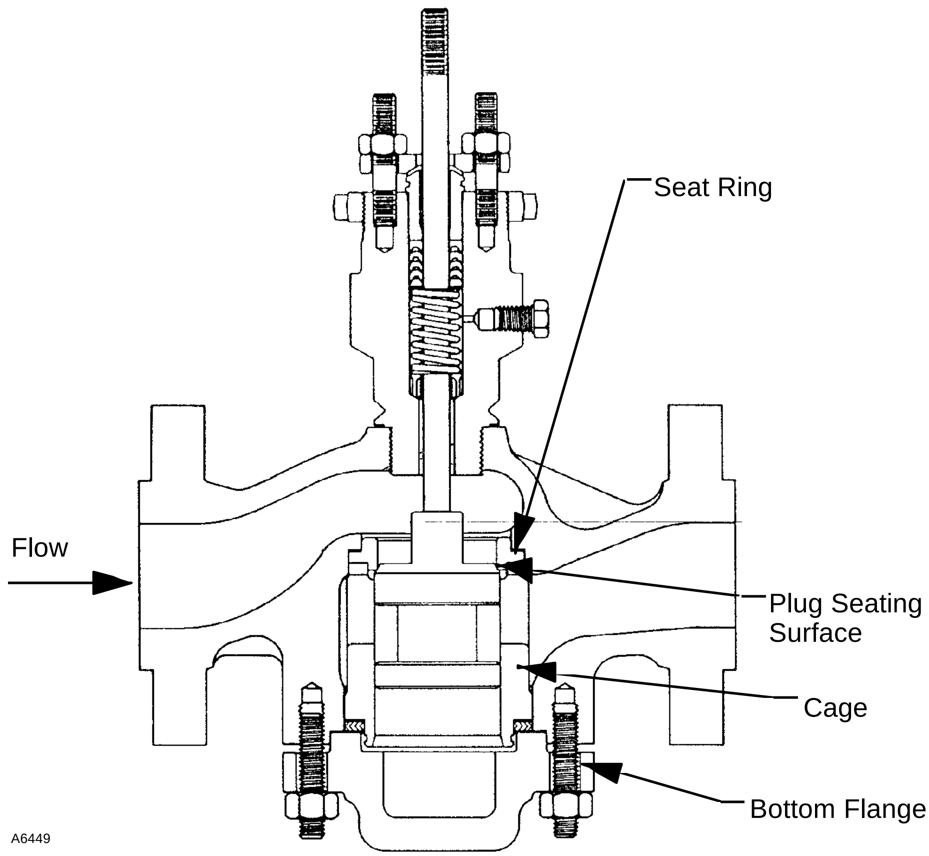
Angle Body With Outlet Liner
Figure 72

Double-Port Design - The double-ported valve (see Figure 73) has two ports, two plugs, and two seat rings. This valve design is generally post guided. The main application advantages are the balanced design (that allows the selection of smaller actuators), and the relatively small and protected guiding surfaces, which make this valve type compatible with dirty fluids.



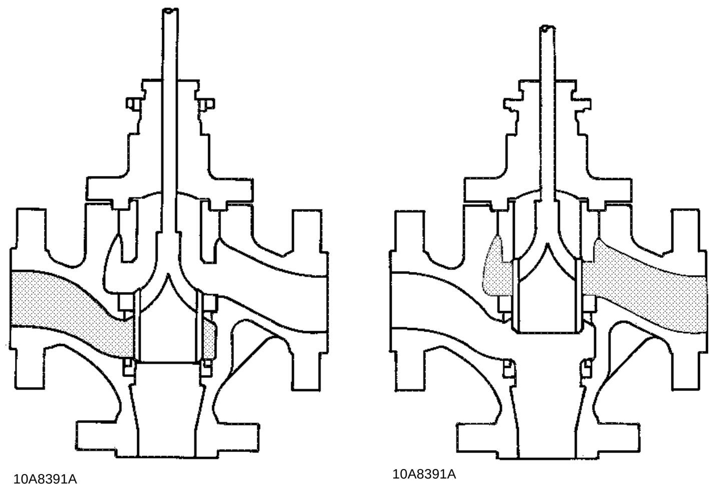
Double-Port Valve Design
Figure 73

Push-Down-to-Open Valves - Although the valves that have been described to this point have all been of a push-down-to-close (PDTC) construction, some valve types are available in a push-down-to-open (PDTO) construction (refer to Figure 74). In most PDTO valves, a bottom flange allows access to trim and other internal parts. PDTO are fairly rare, and they are generally selected only for applications in which the valve is line powered; i.e., the pneumatic power that operates the actuator is taken from the pipeline.

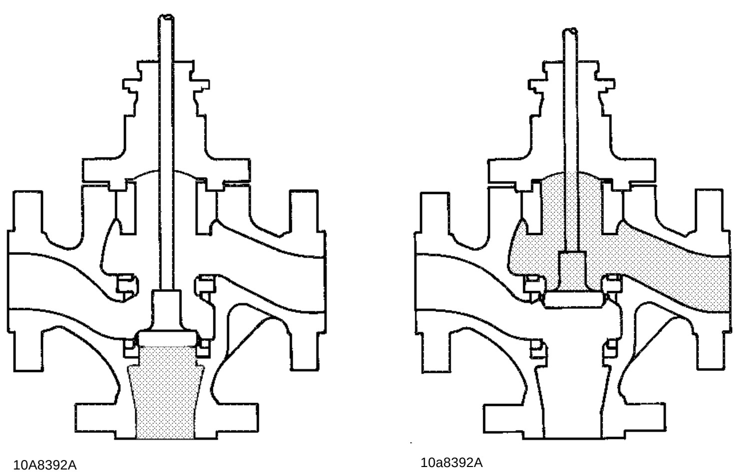


Push-Down-To-Open Globe Valve Construction
Figure 74

3-Way Bodies - 3-way valve bodies are useful for converging (flow mixing) and diverging (flow splitting) services. Refer to Figure 75 and note that for diverging applications, fluid flows toward the common port. For diverging applications, fluid flows away from the common port.



Balanced Valve Construction



Unbalanced Valve Construction

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3-Way Valve Construction
Figure 75

Typical Valve Configurations

Previous sections have reviewed the many design features and options of sliding-stem valves. This section will provide an overview of general service valve constructions that are typically available from valve manufacturers. For purposes of identification and to facilitate the selection and sizing exercises that follow, a manufacturer's type number will be included along with the generic description of each valve configuration.

Light Duty, Stem-Guided Valve (Fisher GL)

Specification Bulletin - For illustrations and specifications that relate to this valve type, refer to Fisher Specification Bulletin 51.1:GL.

Construction Features - Light duty, general service valves are typically available with ANSI Class 150 and 300 flanged end connections, in sizes from 1/2 through 4-inches, and in a variety of different materials to provide compatibility with the process fluid. Two widely spaced bushings guide the valve plug. The screwed-in seat ring has a tapered lip that permits tight sealing of the ring in the body to help prevent leakage between the seat and the body.

Options - All popular flow characteristics are possible by selecting the appropriate plug, and reduced capacity trim is available. Alloy and hardened trims provide erosion and corrosion control. Both metal and soft seats are available.

Features - In this design, the guide bushings are located out of the flow path. This feature allows application with dirty fluid, viscous fluids, and fluids with entrained solids.

Limitations - Because it is a light-duty design, this valve type has limited pressure, temperature, and pressure drop ratings.

Typical Applications - Common applications are in chemical process operations, utilities (fuel gas, water, and steam) and other light to moderate duty applications.

Self-Flushing Post-Guided Valve (Fisher EZ)

Specification Bulletin - For illustrations and specifications that relate to this valve type, refer to Fisher Specification Bulletin 51.1:EZ.

Construction Features - This valve incorporates post guiding. The guide bushing is located in a cage-like component. In addition to holding the guide bushing, the cage clamps the seat ring in place. This approach minimizes seat leakage and erosion problems that can accompany screwed-in seat rings. The heavy body and bonnet pattern provide pressure and temperature ratings through ANSI Class 600. Pressure drop ratings to the full ANSI Class are possible.

Options - Options include soft seats for tight shutoff, hard trims (Stellite) for erosive and coking applications, and the availability of trim in many different alloys for corrosion protection. Trim that complies with NACE guidelines is also available.

Features - A primary feature of this valve design is the massive guiding mechanism that results in higher pressure drop ratings than most stem-guided valves. The self-flushing feature makes the valve compatible with fluids that include gritty fines and coking particles.

Limitations - The unbalanced design of this valve may require large actuator forces for operation and tight shutoff, especially in high pressure drop applications.

Typical Applications - These valves are commonly specified for a broad range of hydrocarbon applications because of their compatibility with viscous and non-lubricating fluids, their self-flushing action, and their compatibility with coking fluids when hard trims are specified. Example applications include separator dump valves and many refinery operations.

Erosive Service Post-Guided Valve (Fisher D)

Specification Bulletin - For illustrations and specifications that relate to this valve type, refer to Fisher Specification Bulletin 51.2:D.

Construction Features - This valve, which is available in small (1 and 2 inch) sizes, is a high pressure, heavy-duty, low volume valve with pressure-temperature ratings to ANSI Class 2500. Post-guiding and options for hard trim make this a very rugged, erosion resistant, high pressure valve.

Options - Options include carbide and ceramic trim for extremely erosive applications, formed and fluted trim, flanged and threaded end connections, NACE trim. Angle body constructions provide increased erosion resistance.

Features - The primary feature is the capability to provide good throttling control with high pressure, erosive fluids. ANSI Class IV shutoff is standard with an option for ANSI Class V shutoff (which is achieved by precision lapping of seats during manufacture). The higher shutoff rating may also require extra seat loading force (a larger actuator).

Limitations - Limitations include the large unbalance forces that accompany high pressure drops in any unbalanced valve, and a relatively limited flow capacity.

Typical Applications - This valve type has been applied extensively in wellhead services in North America because of its rugged construction and erosion resistance, and because of the lower wellhead pressures that are used there. In Mid-East production, it may be used in any low volume, erosive, high-pressure-drop application, such as a low-volume, separator-dump (liquid level control) valve. This valve is also specified for the control of high pressure hydraulic oils.

Sweep Flow, Expanded Outlet Valve (Fisher Type 461)

Specification Bulletin - For illustrations and specifications that relate to this valve type, refer to Fisher Specification Bulletin 51.2:461.

Construction Features - This is a self-cleaning, angle body that is designed specifically to combat flashing and erosion damage and buildup of coking fluids. The shape of the cavity around the valve plug helps prevent accumulation of solids and coking materials on the plug and stem. The expanded outlet helps reduce outlet velocity, thus reducing damaging effects of flashing fluids. A hardened outlet liner is easily replaced to help extend valve life in severe applications. This valve is available in ANSI Classes 150 through 1500, and to ANSI Class 2500 in smaller (2x3 and 3x4 inch) sizes.

Options - Options include extension bonnets for use with extremely high temperature fluids, connections to recirculate fluid to warm up the valve prior to startup, and connections for introducing a flushing oil to prevent coke build up within the body. Trim materials are also available in carbide and ceramics for extremely erosive applications.

Features - The primary feature of this valve is its ability to withstand erosive and flashing services through brute strength. The plug is guided and protected by a massive, cylinder-like bushing that is designed to provide positive plug alignment under high pressure drop conditions. When all other solutions fail because of pressure drop, erosion, and flashing, this valve style is often successful.

Limitations - Limitations of this valve style include the large actuator forces that are required (because of the unbalanced design) and the relatively high cost compared to other valve styles.

Typical Applications - Because of its self-flushing, angle body design, this valve is commonly used in flash-to-tank, choke, and other highly erosive services. It is compatible with viscous fluids, dirty fluids, and coking fluids.

Double Ported Sliding-Stem Valves (Fisher Type A)

Specification Bulletin - For illustrations and specifications that relate to this valve type, refer to Fisher Specification Bulletin 51.1:A.

Construction Features - The double-ported, post guided valve was one of the first valves that was applied in oil and gas production. The double-ported valve design includes two ports and a stem with two plugs. Body geometry forces the fluid to split into two streams. Half of the fluid flows up and half flows down before the two streams combine at the valve outlet. Both plugs are machined as one component, and they are post-guided. Because the guide bushings are located out of the flow stream, the valve is compatible with erosive and dirty fluids.

Options - The options include various body and trim materials and a choice of flow characteristics. Flow characteristics are determined by the shape of the plugs.

Features - The double-ported valve is virtually the only post-guided valve that provides the advantages of a balanced design. The absence of small clearance flows within the valve and the protected guide bushings make this valve suitable for use with a variety of dirty fluids, including coking applications.

Limitations - Because there are two seats and two leakpaths, shutoff is limited to ANSI Class II. This valve type also demonstrates a unique form of plug instability and vibration at high pressure drops; therefore, the published pressure drop limits must be strictly followed.

Typical Applications - While this valve style has fundamentally been replaced by modern, single-seated valve designs, the double-ported valve design is still preferred for a few refinery applications that require a high capacity, ANSI Class 600 valve that is compatible with coking fluids.

Cage-Guided, Unbalanced Design (Fisher ES)

Specification Bulletin - For illustrations and specifications that relate to this valve type, refer to Fisher Specification Bulletin 51.1:ES.

Construction Features - This design is the most basic of a large family of cage guided valves. In the basic unbalanced design, standard metal seats provide ANSI Class IV shutoff over a wide range of temperatures and pressure drops. The valve is available through ANSI Class 600 and in sizes through 8-inch.

Options - Options include metal-to PTFE seats for ANSI Class VI shutoff, angle bodies with liners for mildly erosive and flashing applications, choice of flow characteristic, and a wide range of materials including NACE approved constructions.

Features - The primary features of this valve are simplicity, versatility, and good shutoff in high temperature applications. Pressure drop ratings to the full ANSI Class inlet pressure are common.

Limitations - The chief drawback of this valve is the unbalanced design, which may require the use of large actuators in high pressure drop applications.

Typical Applications - These valves are commonly applied in many general and moderately severe applications with gas, steam, and liquids. Angle-body-with-liner constructions enhance performance in flashing and erosion control. As with most cage-guided valves, erosive services are limited to non-coking applications.

Cage-Guided, Balanced Design (Fisher ED)

Specification Bulletin - For illustrations and specifications that relate to this valve type, refer to Fisher Specification Bulletin 51.1:ED.

Construction Features - This valve design includes a balanced plug, but otherwise, the design is similar to the Fisher ES. To seal the leak path between the plug and cage, one of several different types of piston ring seals is specified. These valves are available through ANSI Class 600 and in sizes through 8-inch.

Options - The options include all those associated with cage-guided valves.

Features - The primary feature of this valve type is the balanced design, which generally allows the use of smaller actuators in large pressure drop applications. Pressure drop ratings to the full ANSI Class inlet pressure are common.

Limitations - Because it is a balanced plug design, this valve type has a limited shutoff capability compared to balanced valves. Also, the massive guiding is not well suited for extremely dirty fluids.

Typical Applications - Applications include a variety of moderately severe services where the features of a balanced valve plug are desirable.

Cage-Guided, Balanced Tight Shutoff Design (Fisher ET)

Specification Bulletin - For illustrations and specifications that relate to this valve type, refer to Fisher Specification Bulletin 51.1:ET.

Construction Features - This design improves the shutoff of the standard balanced valve plug design by incorporating a more effective piston ring seal. Metal or soft seats are available and combine with the various piston-ring seals to provide either ANSI Class IV or V shutoff.

Options - Options include various types of piston ring seals for different service conditions, and all other options that are associated with the basic cage-guided valve design.

Features - The primary feature is reasonably tight shutoff in a balanced design along with ÆP ratings to the full ANSI Class inlet pressure.

Limitations - The primary limitation is the maximum temperature rating of the elastomers that are used, typically 400 degrees F. Also, like all cage-guided valves, this design is not well suited for extremely dirty fluids.

Typical Applications - This valve is commonly specified for applications that include a requirement for tight shutoff and a balanced valve construction. Examples include vent to flare and backpressure control.

Cage-Guided, High Pressure Design (Fisher HP)

Specification Bulletin - For illustrations and specifications that relate to this valve type, refer to Fisher Specification Bulletin 51.2:HP.

Construction Features - This high pressure design is characterized by its heavy pattern. Bodies are available with ratings through ANSI Class 1500 and in sizes through 6-inches. Extra body thickness for strength and corrosion and erosion protection, and hardened trim are standard. The result is a severe service valve type.

Options - Options include angle bodies, unbalanced plug designs (HPS), balanced plug designs (HPD and HPT), and most of the options that are associated with cage-guided valves.

Features - The primary feature is high pressure ratings and the possibility for pressure drop ratings to the full ANSI Class inlet pressure.

Limitations - The unbalanced design may require very large actuators.

Typical Applications - These valves are commonly specified for high pressure, high pressure drop applications such as flow control, bypass, and recirculation control in water flood and gas injection systems.

Cage-Guided, High Capacity Design (Fisher EU/EW)

Specification Bulletin - For illustrations and specifications that relate to this valve type, refer to Fisher Specification Bulletin 51.1:EU.

Construction Features - This valve design is fundamentally an extension of the cage-guided valves that are commonly available in smaller sizes. The large cast body is used to provide high-capacity in 12 through 30 inch sizes. The larger valve sizes include smaller-than-line-size ports. This approach allows economy of material and weight while retaining good throttling control. Bodies are available through ANSI Class 600. Because of the potential for very large unbalance forces, large valves always include balanced plugs.

Options - Options include the choice of a seat ring that is threaded into the cage or a bolted-in seat ring. The threaded-in seat ring provides a 'quick-change' feature but is not well suited to high temperature applications. The bolted seat ring is used whenever temperature gradients could cause gasket and cage failure because of thermal expansion and contraction.

Both metal and soft seats are available.

Features - The primary advantage of this valve design is large capacity in a cage-guided, ANSI Class 600 valve body.

Limitations - These include size and weight; for example, a typical 20x16 valve body without actuator or accessories weighs approximately 8200 pounds.

Typical Applications - The screwed-in seat ring construction was developed specifically for oil and gas production where large capacity and easy field maintenance are attractive features. Applications include liquid level control in separator systems, backpressure control in metering runs, and general pipeline service.

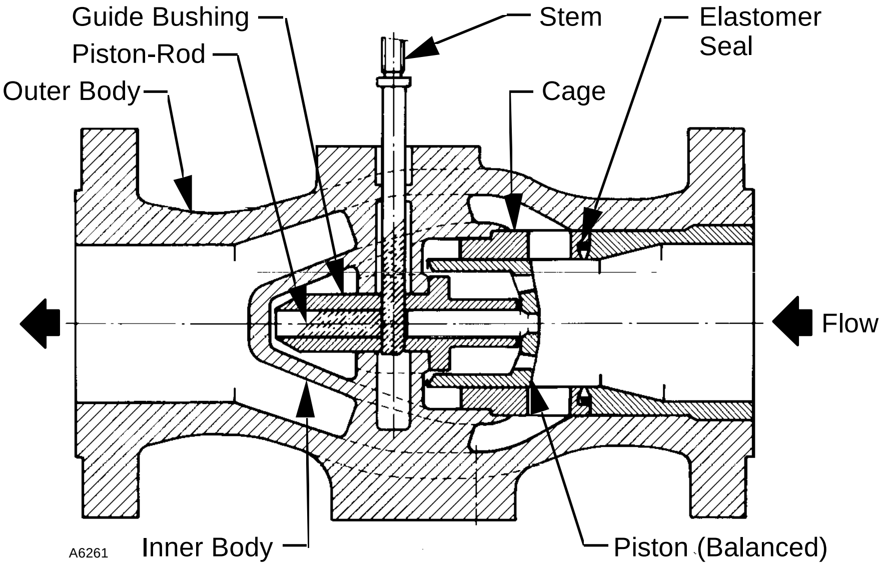
The bolted-in seat ring version is useful in power generation, steam, and other high-temperature applications.

Axial Flow Valve (Mokveld)

Axial Flow Defined - Axial flow valves are those in which the flow stream is fundamentally parallel to the pipeline.

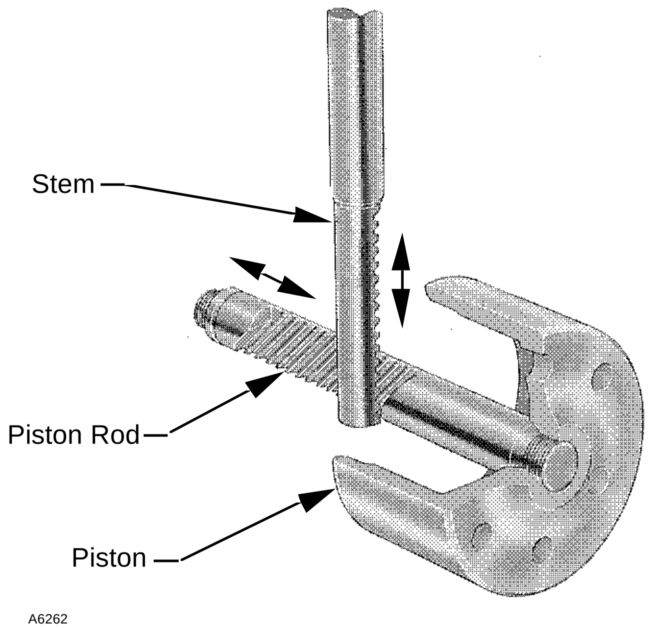
Nomenclature - A popular axial flow control valve is shown in Figure 76. The outer body of the valve includes the end connections and the packing bore, and it supports all internal components. The inner body supports and encloses the actuating components and it supports the cage. The inner body and outer body are a single-piece casting. Fluid flows axially through the annular area between the inner body and the inner wall of the outer body.

A pressure-balanced, cage-guided piston serves as the closure member. As with other sliding-stem valve types, cage options are available to provide various flow characteristics.



Axial Flow Valve Construction
Figure 76

Actuation System - The piston is positioned by a 90 degree transmission system that consists of a pair of sliding toothracks. One toothrack is on the piston rod and the other is on piston stem as shown in Figure 77. The actuation system can be packed with grease to reduce the service interval, and seals (not shown) on the stem and piston rod prevent the process fluid from entering the actuation system.



Actuation Of Axial Valve Piston
Figure 77

Operation - Because the valve is actuated by a sliding-stem action, the valve can be used with pneumatic, hydraulic, electric, or electro-hydraulic actuators. Figure 77 shows a push-down-to-close configuration.

Shutoff - To provide bi-directional, bubble-tight shutoff, the piston seals against an elastomer seal ring . Elastomer seals have the usual upper temperature limit of approximately 400 degrees F.

SAES-J-700 - Section 4.7 of SAES-J-700 specifies that all axial valves shall have a minimum body rating of ANSI Class 300 for sizes through 16-inch; however, it allows ANSI Class 150 bodies in larger sizes, provided that the piping specifications allow these ratings.

Features - Because of their straight-through flow geometry, axial valves can provide very high capacity. They are available with characterized cages to suit a variety of application requirements, and they are available in large sizes - typically through 48-inches or larger. Pressure balanced pistons help minimize the required actuation force.

Limitations - Limitations of axial valves include limited flowing and shutoff pressure drop ratings. Designs that include elastomer seals have limited temperature ratings. A significant design limitation is that the right-angle tooth beds present an opportunity for friction, wear, lost motion, and valve sticking.

Applications - Axial valves are often specified for high capacity applications such as gas and oil pipelines, pump and compressor bypass systems, and gas and water injection systems.

Rotary-Shaft Valve Construction Options

In the rotary-shaft valve category, many different valve styles of butterfly, ball, and ball segment valves are available. The various types of rotary-shaft valves are distinguished by the shape and closure action of the closure member (disk, ball, or ball segment). Rotary-shaft valves can be further characterized according to specific design features, including:

- Seal technology (heavy or thin, metal or soft)
- Closure member rotation
- Shafting
- Bearing types

Rotary Valve Seals

Rotary valve seal selection depends on the shutoff requirement, temperature, pressure drop, flow direction, and whether or not the fluid is erosive. Available seals can be seen as falling into one of the following four categories:

- Soft (composition or elastomer), heavy seals
- Soft, thin seals
- Metal, heavy seals
- Metal, thin seals

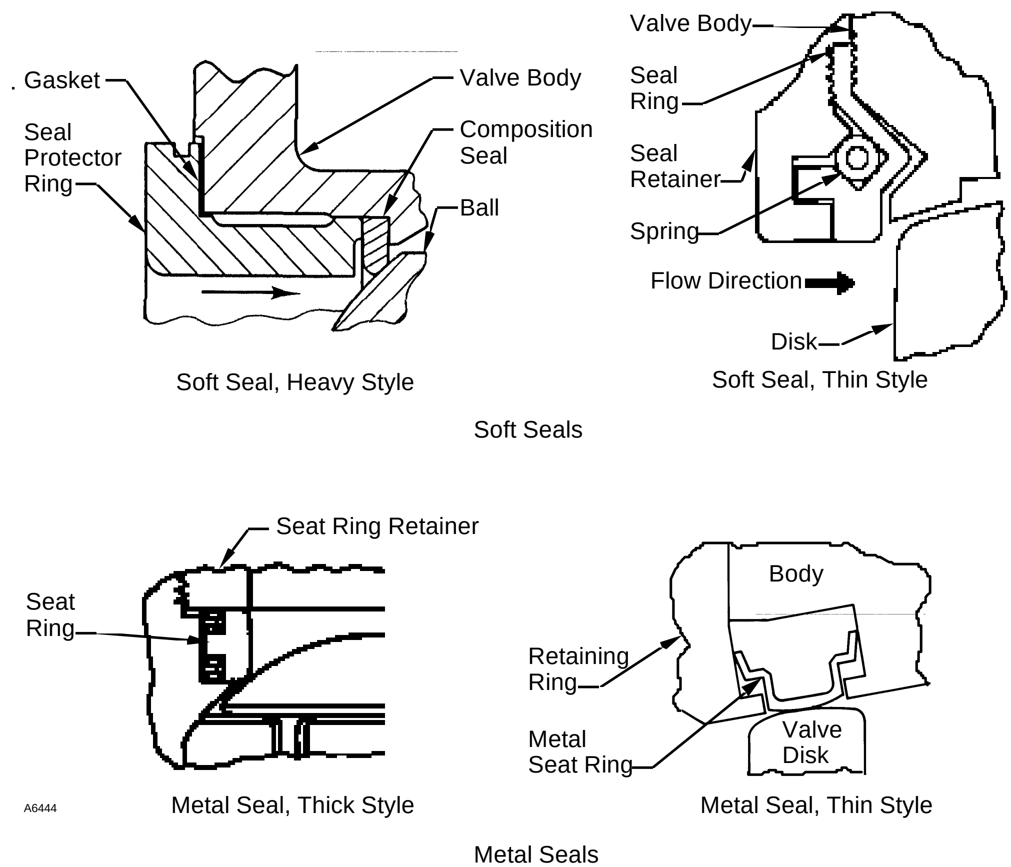
For the discussion that follows, refer to Figure 78.

Soft Seal, Heavy Style - Heavy soft seals are generally selected for tight shutoff. The soft seal will achieve ANSI Class VI shutoff, but is generally limited to 450 degrees F or less. Heavy, soft seals that are in contact with the surface of a ball or ball segment can result in significant friction.

Soft Seal, Thin Style - Soft, thin seals can also achieve ANSI Class VI shutoff, and they have the standard temperature limit of 450 degrees F. Thin seals are not generally suitable for erosive or dirty applications, and they may have lower pressure drop ratings than heavy soft seals.

Metal Seal, Heavy Style - Heavy metal seals are typically selected for higher temperatures or for erosive applications. Shutoff to ANSI Class V is common. When heavy metal seals are specified, the normal flow direction is often reverse flow, which directs erosive flow away from critical surfaces and toward hard components such as seals and seat rings that can be renewed or replaced.

Metal Seal, Thin Style - Thin metal seals are generally pressure assisted. They can achieve ANSI Class V shutoff, and they may be rated to 1 000 degrees F. Thin seals are typically not recommended for erosive or dirty fluids, and they may have reduced pressure drop ratings.



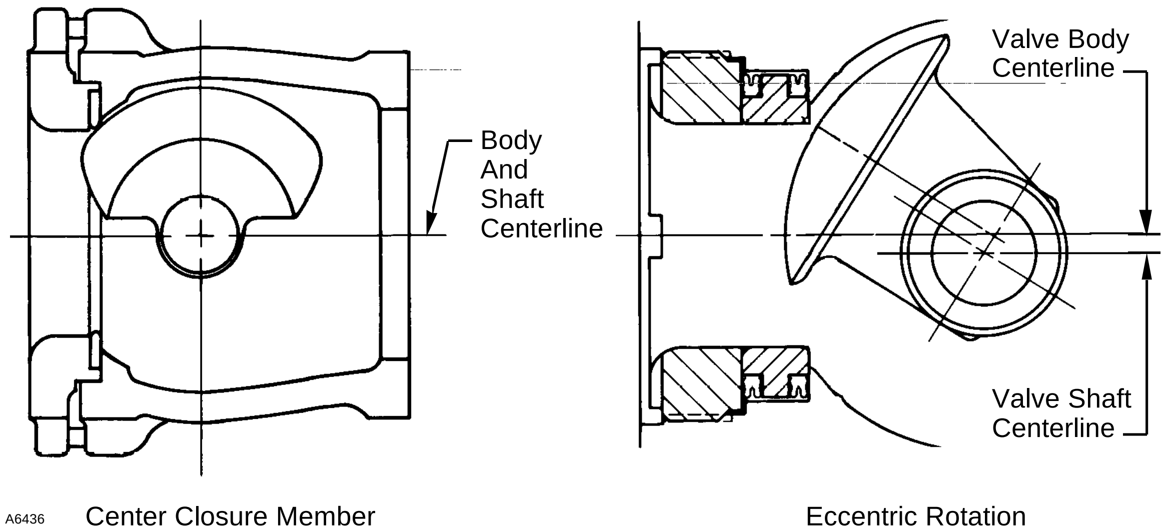
Rotary Valve Seal Types
Figure 78

Closure Member Rotation

For the discussion that follows, refer to Figure 79.

Centered Closure Members - In some valve styles, the centerline of the valve shaft aligns with the body centerline. When the axis of closure member rotation is centered on the body centerline, the spherical surface of the closure member is always in contact with the seal; therefore, some seal friction exists at all angles of rotation, and increased seal wear may result.

Eccentric Rotation - In some designs, the valve shaft is offset from the centerline of the valve body. The result is that the spherical surface of the closure member contacts the seal only when the closure member approaches the closed position. After the closure member is rotated out of its seat, there is no contact between the closure member and the seal. This design reduces seal friction and seal wear.



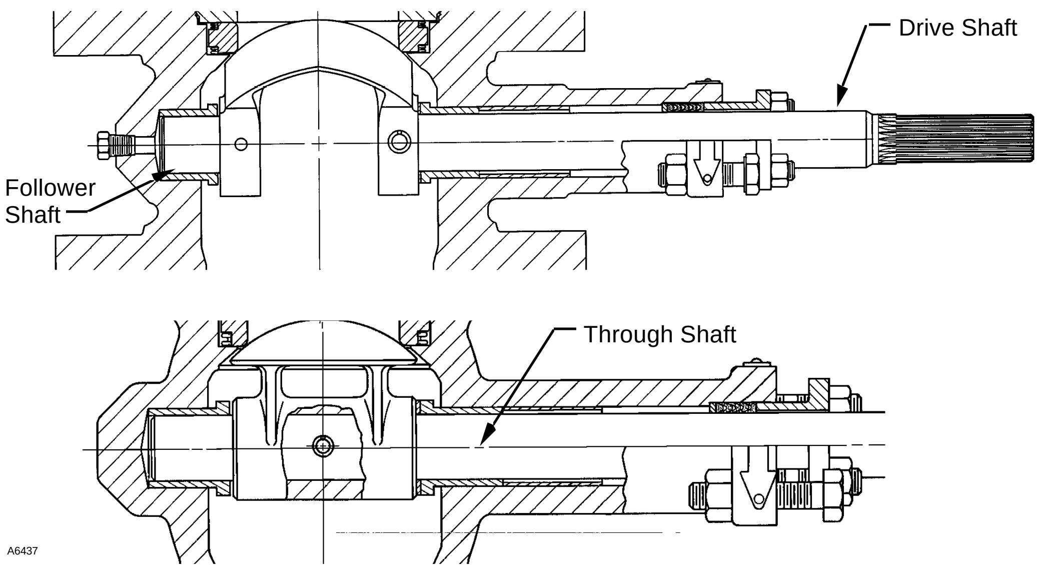
Closure Member Rotation
Figure 79

Shafting

Some rotary-shaft valves include a two-piece drive shaft that consists of a drive shaft and a follower shaft (or stub shaft). In other valve styles, the drive shaft is a single through shaft. Refer to Figure 80.

Two-Piece Shaft Designs - In a two-piece shaft design, the shaft does not reduce the flow capacity of the valve. The result is high capacity and compatibility with fluids that include entrained solids; however, because the two-piece design does not provide as much strength as a through shaft, the pressure drop limits may be reduced.

Through Shafts - A through shaft provides increased support for the closure member. As a result, the pressure drop limits for valves with through shafts are generally greater than the pressure drop limits for valves with two-piece shafts. A through shaft does impose a restriction to flow which can limit valve capacity. The capacity-reducing effect is most significant in small valves where the shaft occupies a large percentage of the bore.



Shaft Designs
Figure 80

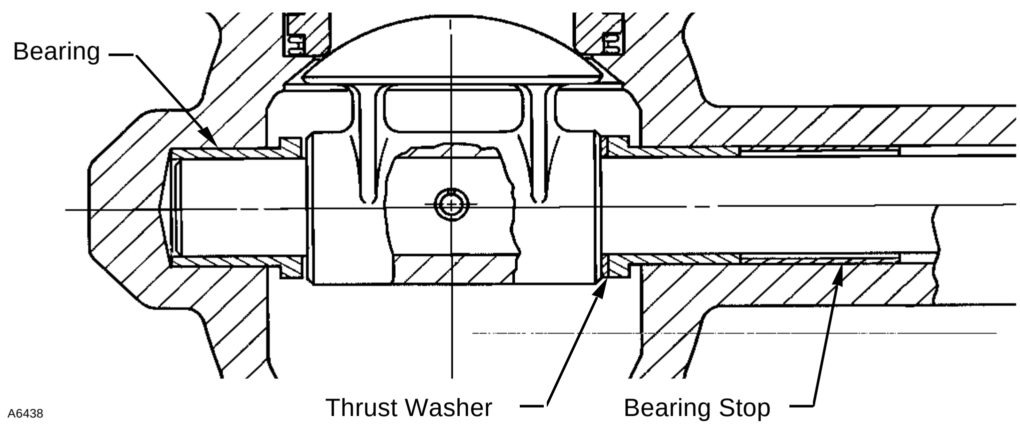
Bearing Types

Bearings (refer to Figure 81) serve two major roles in a rotary-shaft control valve. They:

- Support the drive shaft
- Center the closure member in the body

Bearing Materials - Bearings materials are typically either a composition (soft) material, or they made of a metal alloy.

- Composition bearings may be in the form of a lined metal, or they may be made completely of a composition material. Composition bearings produce very low friction. As a result, they can carry large loads and typically have relatively high pressure drop ratings. The maximum temperature rating for composition bearings is generally in the neighborhood of 450 degrees F.
- Metal bearings have higher temperature limits than composition bearings; however, they produce more friction. Increased friction results in reduced pressure drop ratings and the need for larger actuators.

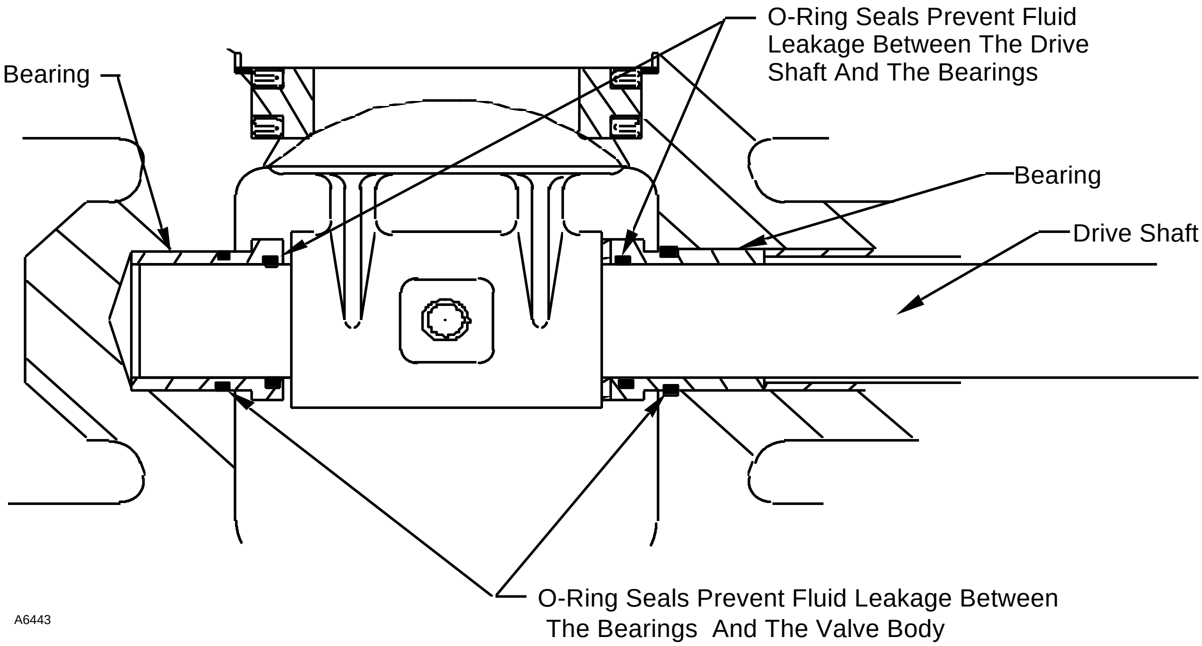


Bearings And Related Components
Figure 81

Bearing Position - Bearings and thrust washers center the closure member in the body to ensure that the closure member makes the proper contact with the seal. Refer to Figure 81. To properly locate the bearing, a bearing stop may be pressed into the bearing bore, or a stop may be cast into the valve body.

Thrust Washer - If process pressure is allowed to register on one end of the valve shaft only (which is the case for many valve types), pressure will tend to force the drive shaft toward the actuator side of the valve. In high pressure applications, the lateral force of the valve shaft can be quite large. The force can cause excessive wear of the closure member and bearing mating surfaces. To reduce wear, a thrust washer may be installed between the closure member and the bearing.

Sealed Bearings - To prevent the process fluid from entering the bearing area, O-rings may be included in the bearing design as shown in Figure 82. The result is a sealed bearing. Sealed bearings are a desirable feature for erosive applications where particulate could enter the bearing area and damage bearing surfaces.

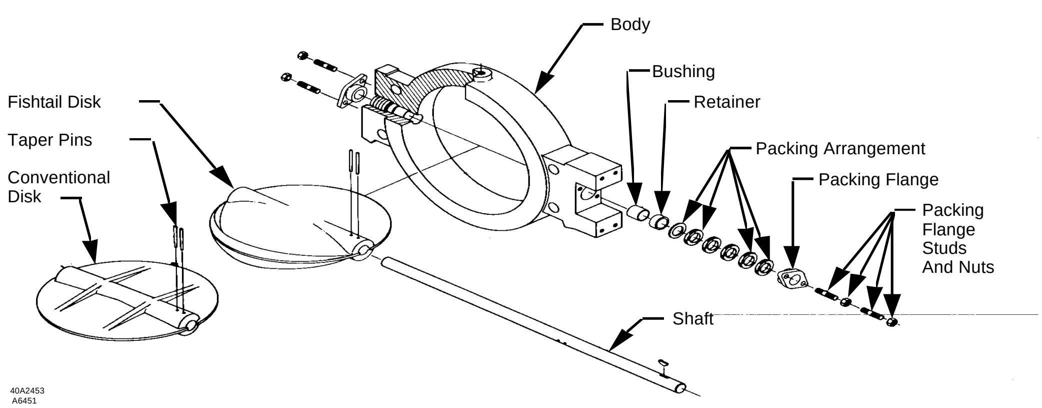


Sealed Bearing Detail
Figure 82

Butterfly Valves

Standard Design

Swing-Through Design - The basic butterfly valve (see Figure 83) is typically a "swing-through" design, meaning that the disk can rotate a full 360 degrees. **Nomenclature -** The closure member of a butterfly valve is referred to as a disk. The disk may be a conventional disk, or it may be a special design such as a Fishtail disk. (The Fishtail disk will be discussed later in this section). The disk is commonly attached to the shaft with taper pins. Bushings (or bearings) may be positioned by a retainer or by a bearing stop that is cast into the valve body or pressed into the valve body. The packing serves the same function as it does in sliding-stem valves. Jam style packing is compressed by the packing flange as the packing flange nuts are tightened.



Butterfly Valve Nomenclature
Figure 83

Shutoff - In a swing-through design, the considerable clearance flow between the disk and the valve body when the valve is in the closed position results in a shutoff ability that is less than ANSI Class II.

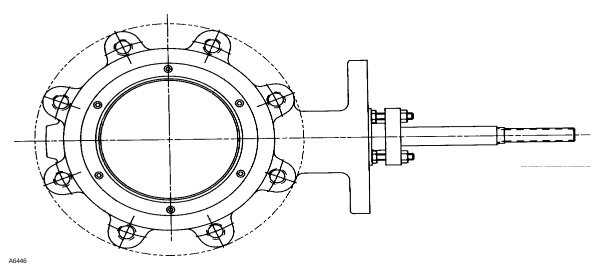
Pressure Ratings - Butterfly valves are commonly available with pressure-temperature ratings through ANSI Class 2500. However, the pressure drop rating for a specific construction depends on the materials of construction, the valve size, and the strength of the shaft and disk. Compared with other valve types, butterfly valves often have relatively low pressure drop ratings, especially in larger valve sizes.

Flow Characteristic - The flow characteristic of most butterfly valves is approximately equal percentage.

Torque Characteristics - With a conventional disk design, fluid forces produce significant torque on the drive shaft as the disk is rotated between 60 and 90 degrees. Therefore, the rotation of a standard disk is generally limited to 60 or 70 degrees for throttling applications.

Available Sizes - Butterfly valves are available in sizes to 72-inches or larger. However, process pressure can produce exceptionally large forces on the disk and correspondingly high torque on the valve shaft. As a result, large butterfly valves are generally suitable for relatively low pressure drop applications only.

Body Styles - Wafer style bodies are popular because they are easily installed by clamping the body between two pipeline flanges. Lugged bodies (refer to Figure 84) include a bolt pattern that mates with standard ANSI Class flanges. The elimination of long bolting reduces the risk of leakage during a fire.

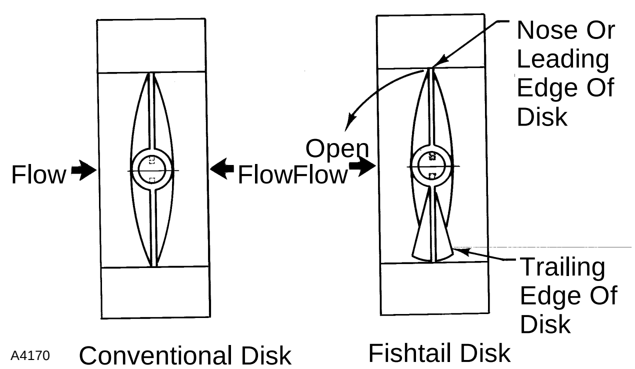


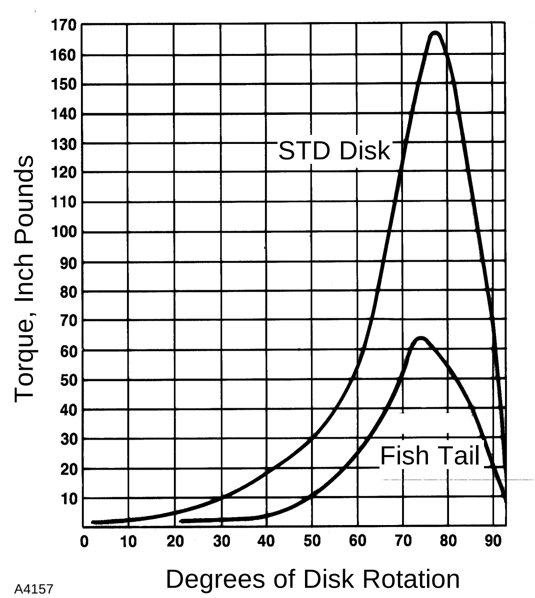
Lugged Body Construction
Figure 84

Saudi Aramco Engineering Standards - Section 4.5 of SAES-J-700 allows wafer style bodies in non-hydrocarbon applications only. Lugged bodies are required for hydrocarbon services.

Fishtail› Design (Fisher 7600)

The dynamic torque peaks of a conventional disk can be reduced by using a dynamically balanced disk that is commonly referred to as a Fishtail disk. The "fishtail" shape on the downstream edge of the disk helps to balance fluid forces and reduce the torque on the valve shaft. Figure 85 compares the geometry and torque of a Fishtail disk with the geometry and torque of a conventional disk. When Fishtail disks are specified for throttling applications, disk rotation may be extended beyond the normal 60-70 degree limit, and smaller actuators may be selected.





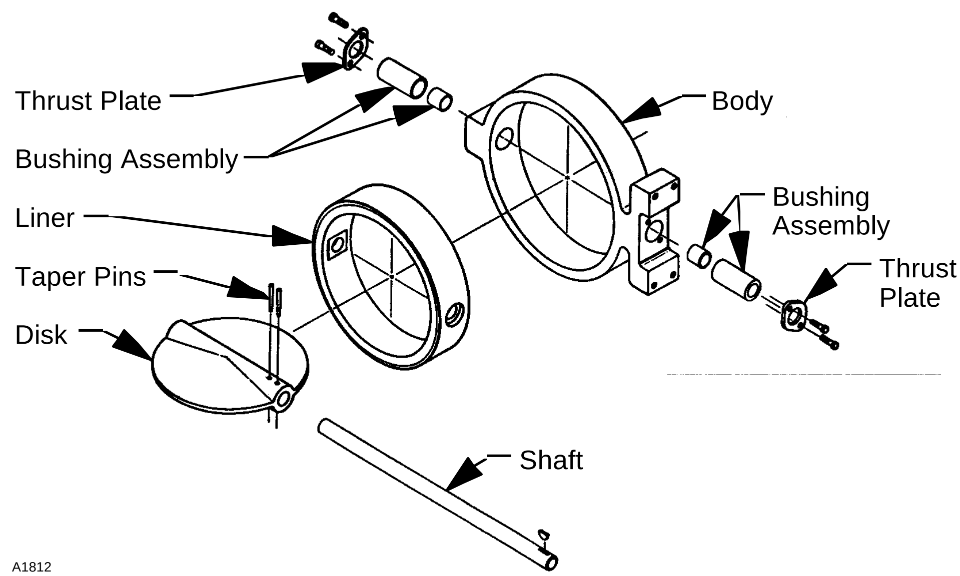
Geometry And Torque Characteristics Of Standard And Fishtail Disks
Figure 85

Lined Butterfly Valves (Fisher 9500)

Butterfly valve components that are made of common and inexpensive metals can be isolated from damaging process fluids by lining the bore of the valve body and/or coating the disk with suitable elastomers. Lined butterfly valves (refer to Figure 86) are popular for some corrosive applications.

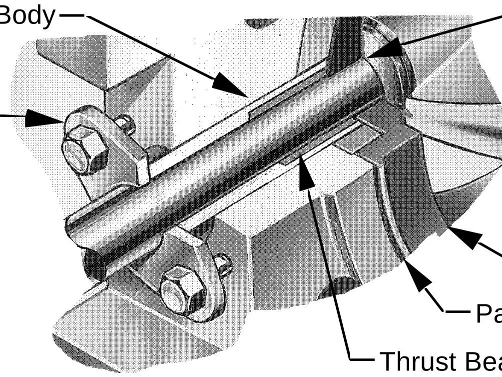
Liners And Disks - Body liners are typically either a PTFE or a nitrile material. Refer to Figure 87 and note the partial O-ring that is molded into the liner. The partial O-ring serves as a flange gasket; therefore, standard flange gaskets are not required.

In some designs, an alloy disk provides the required corrosion protection. In other designs, the disk may be coated with a compatible elastomer.



Lined Butterfly Valve Construction Details
Figure 86

Shaft Seals - Several different designs have been employed to prevent leakage along the shaft. Some constructions include conventional packing arrangements. Other designs include adjustable flanges, or thrust plates as shown in Figure 86 and in Figure 87. When the thrust plate is tightened, the compressive load is transmitted through a thrust bearing to the liner, and the liner is compressed against the hub of the disk. The interference seal between the liner and the flat hub of the disk prevents fluid leakage along the valve shaft.



Adjustable Shaft Seals
Figure 87

Shutoff - Shutoff to ANSI Class VI is common; however, if the liner is gouged or abraded by pipeline debris, or if it is damaged through high heat or high pressure drops, the valve will not shut off tightly.

Because of friction that results from the interference fit of the disk and the liner, relatively large actuators may be required to rotate the disk into the fully seated position. To reduce the required actuator force, the actuator travel stops may be adjusted to prevent the disk from reaching the zero degree position. In some applications, limiting the rotation of the disk can reduce the actuator force that is required to operate the valve with no loss of shutoff capability. To maintain tight shutoff, the liner must be in perfect condition.

Pressure Drop - Because high pressure drops would tend to pull the liner out of the valve body, the pressure drop ratings for lined butterfly valves are typically lower than for other types of butterfly valves. The maximum pressure drop for many lined valves is in the neighborhood of 200 psid.

Maximum Temperature Ratings - The temperature limits of the materials that are used for body liners and disk coatings result in temperature limits in the neighborhood of 200 to 250 degrees F.

Applications - Lined butterfly valves are typically applied only in low pressure, low temperature applications where corrosion resistance and/or tight shutoff are required. Because of the close fit of the disk and liner, lined butterfly valves are not suitable for erosive applications, slurries, or fluids with entrained solids.

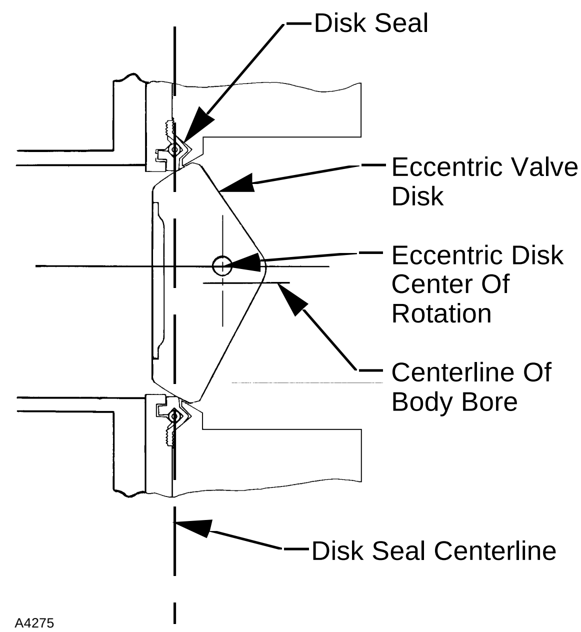
High Performance Butterfly Valves (Fisher 8560)

Another type of butterfly valve is the high-performance type, or HPBV. These valves are so-named because they include disk seals to provide better shutoff than conventional butterfly valves.

Offsets In Shafting - All HPBV valves use either a single or double offset disk (see Figure 88). In a single offset design, the shaft is offset from the disk seal centerline. In a double offset design, the center of disk rotation is also moved away from the centerline of the body bore. These offsets enhance sealing by allowing the disk to contact the seal only as the disk nears the closed position. Separation of the disk from the seal during throttling helps to minimize seal friction and seal wear.

Note that sealing is established by forcing the edge of the disk against seal, rather than by sliding the disk edge across the seal. Tighter shutoff can be achieved by forcing the disk against the seal (instead of allowing the disk to slide alongside the seal).

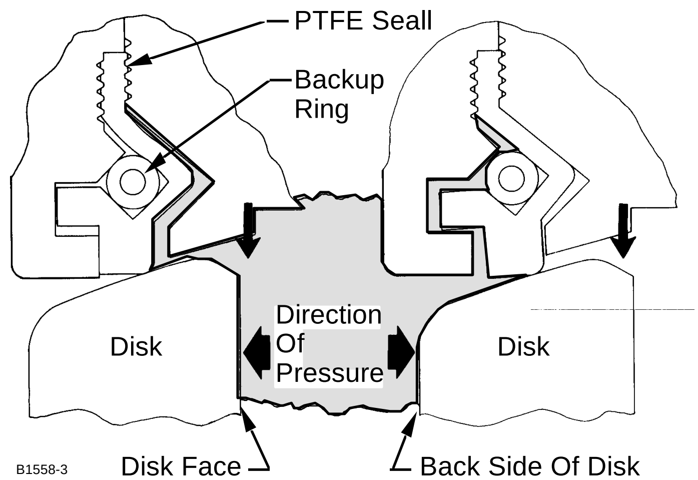
Proper adjustment of actuator travel stops is very important to the successful operation of all HPBV's. If the disk is rotated too far, the seal, the seal retainer, the valve disk, or even the valve body can be permanently damaged



Offset Shafts And Seating Action
Figure 88

Seal Types - While different suppliers offer slightly differing sealing technologies, specifiers can generally select among various elastomer and metal seal options. The choice of a particular seal type is directed by the degree of shutoff that is required and the temperature limits of the seal material. The following basic seal types are commonly available.

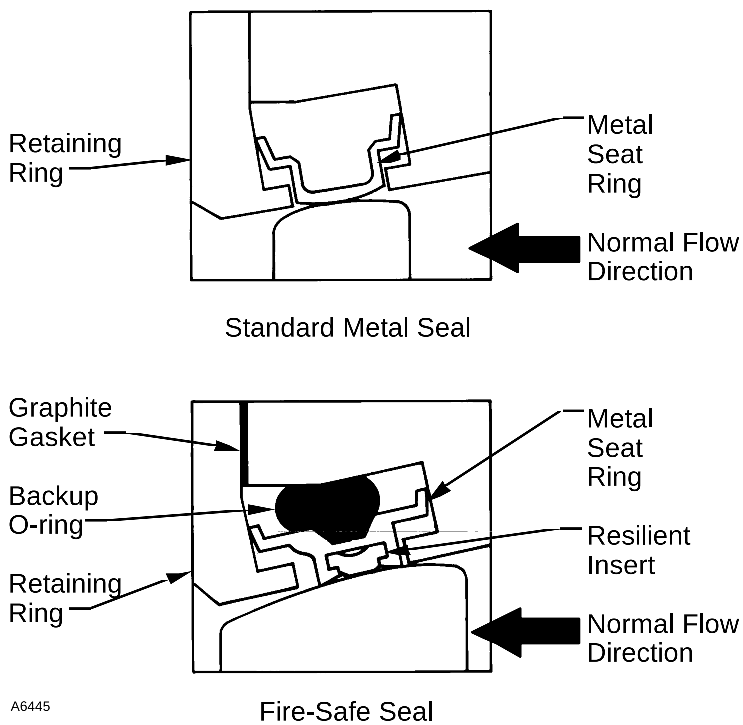
- PTFE seals are capable of achieving up to ANSI Class VI shutoff. Figure 89 shows the operation of a pressure-assisted, bi-directional seal design. Note that the design includes a backup ring that helps to preserve the shape of the PTFE seal. With fluid flow toward the disk face, process pressure forces the disk into the seal. With flow toward the backside of the disk, process pressure enters the volume behind the seal and forces the seal against the disk edge.



Typical PTFE Seal Detail
Figure 89

- Metal seals are required for temperatures that are above the limits of soft seals. The standard metal seal that is shown in Figure 90 is a pressure-assisted seal that is designed to provide ANSI Class V shutoff in the normal flow direction only. The metal seal ring is secured between the valve body and a retaining ring. When the disk is in the closed position, process pressure fills the volume behind the seal ring and forces the metal seal ring against the valve disk. Depending on the seal material and the pressure drop, temperature limits in the range of 700 degrees F are possible.

- Fire-safe seals are often used in hydrocarbon processing applications. In the fire-safe seal design that is shown in Figure 90, the metal seal ring holds a resilient insert that makes a bubble-tight seal with the valve disk during normal shutoff conditions. The metal seal ring is loaded onto the disk edge with a backup O-ring. If the valve assembly is exposed to fire or high heat, the elastomer components may disintegrate, but the metal seal will maintain tight shutoff. A graphite gasket that is located between the retaining ring and the body also helps preserve leak-free operation during and after a fire.



Typical Metal Seals
Figure 90

ÆP Limits - Many HPBV constructions have pressure drop ratings to the full ANSI Class inlet pressure. However, the ÆP limit of each specific construction depends on the following:

- Seal material
- Bearing material
- Valve size
- Temperature
- Flow direction

Features - The advantages of HPBV valves include:

- The ability to achieve Class VI shutoff
- Overall economy compared to sliding-stem valves, especially in larger sizes

Limitations - The limitations of HPBV's include:

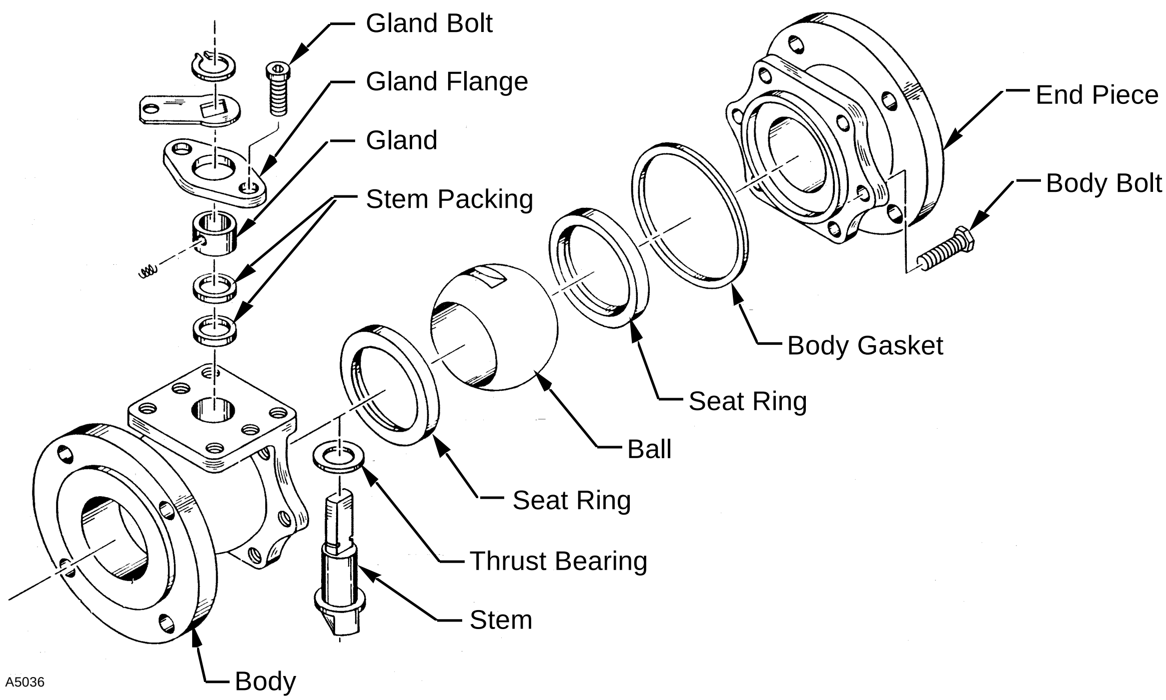
- Limited pressure, temperature, and pressure drop ratings compared to sliding-stem valves.
- Fewer trim options for severe and special service applications.

Full Ball Valve Designs

Compared to other valve types with the same port size, ball valves have very high flow coefficients. High capacity results from the unobstructed flow path when the ball is in the fully open position. Ball valves may be differentiated according to whether they are full-bore designs or reduced-bore designs.

Full Bore Ball Valves

Basic Construction - The construction of full-bore ball valves differs somewhat from manufacturer to manufacturer. Bodies may be a split-body construction or a top-entry style that includes a bonnet. A split-body construction is shown in Figure 91. Note that the end piece is bolted to the body, and the joint is sealed with a body gasket. The stem transmits torque to the ball. Stem packing prevents leakage of the process fluid to the atmosphere. The packing is adjusted by tightening the gland bolts. As the gland bolts are tightened, a loading force is transmitted to the stem packing through the gland flange.



Split-Body, Ball Valve Construction
Figure 91

Floating-Ball Seal Design - Figure 91 illustrates a floating ball design. In a floating ball design, the ball floats between two seat rings (or ball seals). The floating ball design results in a pressure assisted seal because process pressure forces the ball against the seal on the low pressure side of the valve. To allow the ball to float while maintaining a reasonably positive stem-to-ball connection, a tang (or flat) on the stem (or drive shaft) fits into a slot in the ball. When the ball is in the closed position, the slot is parallel with the piping and the ball is free to move toward the seal on the low pressure side of the valve. When the ball is in any open position, the tang and slot rub together, which results in friction and wear. In addition, there is always some degree of lost motion in the linkage. Lost motion can result in imprecise throttling control.

Limitations Of Full Bore Valves - Full-bore ball valves provide maximum flow capacity; however, their flow characteristic is not desirable for throttling control.

Throttling Vs. Block Valve Designs - Full bore, floating ball valves are useful for shutoff applications; however, they are not well suited for throttling applications because of the following:

- High friction - High friction is inherent in floating ball designs because line pressure tends to drive the ball into the seal.
- Lost motion - The loose fit of the drive tang and the ball slot results in lost motion and poor control.
- Poor flow characteristic - Flow control is imprecise in the first increments of valve opening or valve closing.
- Seal blowout - Floating ball designs have had chronic problems with line pressure forcing the seals out of the valve body.

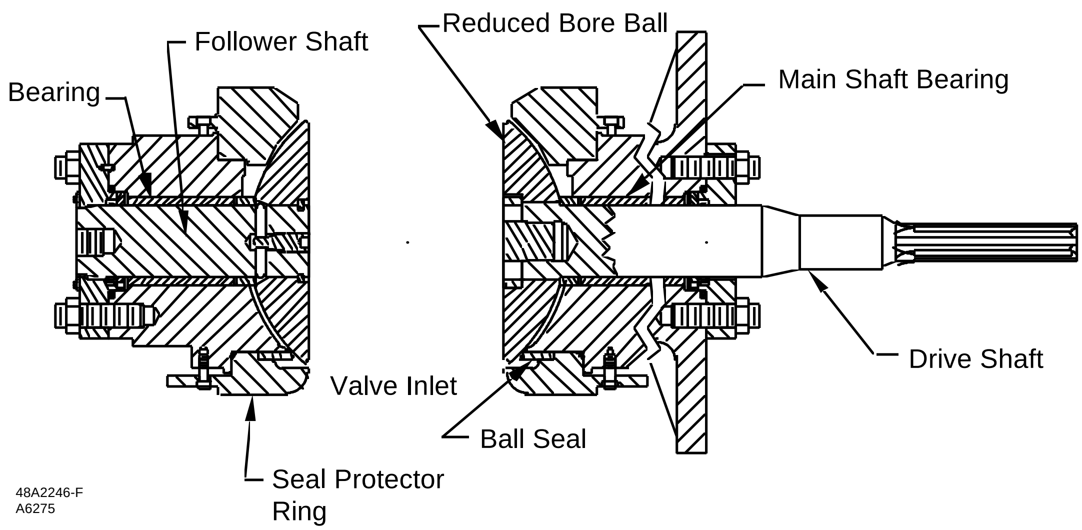
Reduced Bore Ball Valves (Fisher V250)

To take advantage of the high capacity that is inherent in ball valves while avoiding the limitations of the full bore, floating ball design, valves that have been specifically designed for throttling applications are available. A heavy-duty ball valve that is designed for throttling applications is shown in Figure 92. Features that make this valve type useful for throttling control valve include the following:

Trunnion Mounted Ball - In a trunnion mounted ball valve, the drive shaft and follower shaft are rigidly secured to the ball, and the shafts are supported by massive bearings. One benefit of trunnion mounting is reduced operating friction. Trunnion mounting also helps to eliminate the lost motion that is common to floating ball designs. The splined drive shaft also helps minimize lost motion.

Reduced Bore Design - A reduced ball bore results in a flow characteristic that is useful in throttling applications. Specifically, the valve controls flow in the first increments of valve opening and valve closing.

Protected Seals - Heavy ball seals are protected and secured by a massive seal protector ring. The seal protector ring prevents pipeline debris from impinging on the seal, and it minimizes potential for seal blowout.



Reduced Bore Ball Valve For Throttling Applications
Figure 92

Seal Options - Seal options include single pressure-assisted seals for unidirectional shutoff and twin seals for bi-directional shutoff. Seat leakage is 0.0001% of the maximum valve capacity (1% of ANSI Class IV). Flow ring constructions are available for use with dirty or mildly erosive fluids. These seal-less constructions allow seat leakage to 1% of the rated capacity of the valve, but they allow the passage of grit and particulate that would quickly damage a regular seal.

ÆP Limits - The pressure drop rating for this valve style can be the same as the full ANSI Class inlet pressure; however, the pressure drop rating for each specific construction depends on the valve size, seal type, and other construction options.

Features - Features of reduced-bore ball valves include the following:

- High capacity compared to other valve types
- Excellent flow characteristic for throttling applications
- Heavy-duty construction that is well suited to the rigors of throttling applications
- Range of ball seal options

Limitations - Limitations of reduced-bore ball valves include the following:

- High cost, especially in larger sizes
- May require considerable actuator force for operation

Typical Applications - Because of their good throttling control and high capacity, reduced-port ball valves are commonly specified for gas and oil pipeline applications.

Section 4.4 Of SAES-J-700 4.4 addresses several application issues that relate to the selection of ball valves. This standard requires:

- ANSI Class 300 bodies (minimum) for sizes to 16 inch.
- Characterized ports, positioners, or both, when ball valves are specified for throttling applications.
- Designs that prevent seal blow-out during throttling.

This standard reinforces the fact that there are fundamental differences in the requirements for valves that are used in throttling applications and in on-off applications.

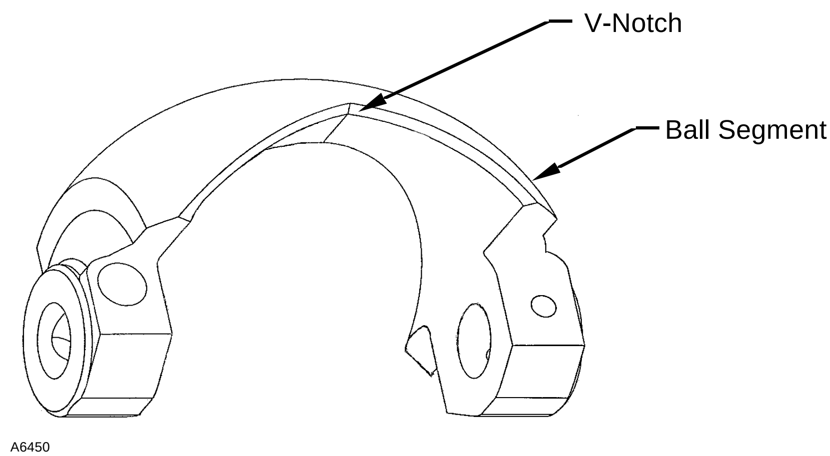
Ball Segment Valve Designs

V-Ball Valve (Fisher V150, V200, V300)

In a V-ball (or V-notch) control valve, the closure member is a partial ball segment. A V-notch ball segment is illustrated in Figure 93.

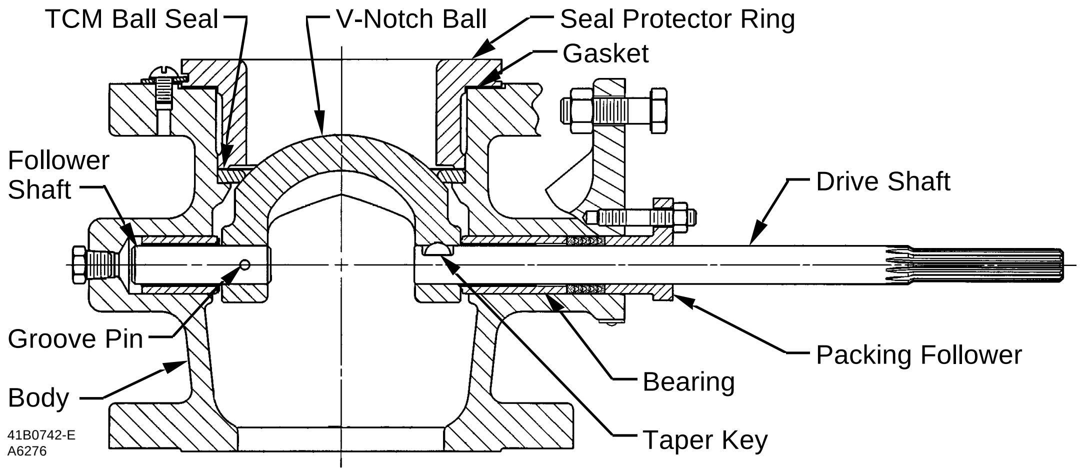
V-Notch Ball Segment - The ball segment includes a notch that is designed to provide wide rangeability, and to provide a shear-on-closing action. The shear-on-closing action is desirable when fluids include solids or when fluids include fibrous material.

Flow Characteristic - As a result of the shape of the V-notch, this valve type provides an approximate equal percentage flow characteristic that is well suited to many control applications.



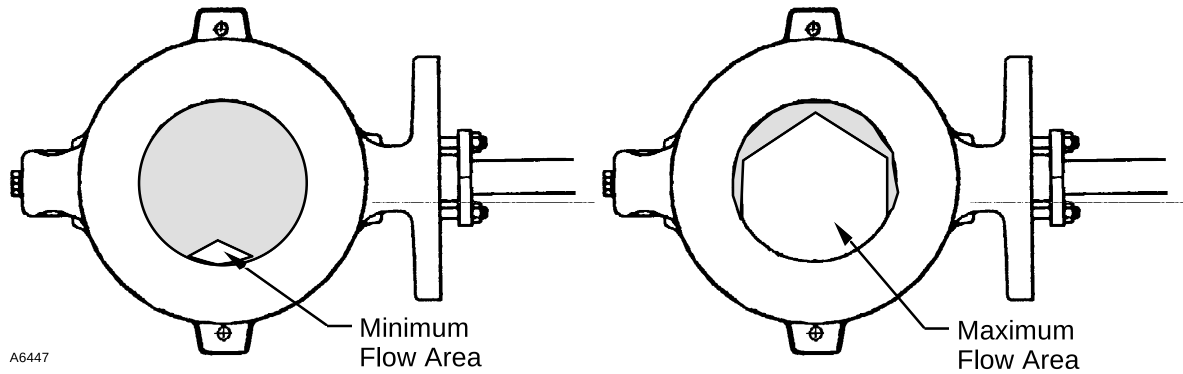
V-Notch Ball Segment
Figure 93

Construction - In a typical construction (refer to Figure 94), the V-notch ball (ball segment) is supported by a two-piece shaft arrangement. Both shafts are supported by bearings. The ball segment is attached to the drive shaft with a taper key and to the follower shaft with a groove pin. Several seal options are available. The TCM seal that is shown in Figure 94 is a soft elastomer seal. The seal is secured between the seal protector ring and the body.



V-Notch Ball Segment Valve Construction
Figure 94

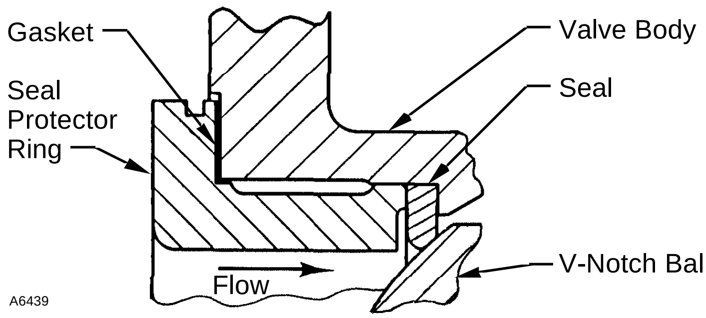
Rangeability - As the ball segment is rotated out of the closed position, a very small portion of the V-notch is exposed. Refer to Figure 95. This small flow area results in a very low minimum flow coefficient. In the fully open position, the segment is positioned in the top of the body cavity and out of the flow stream. Because the segment is located out of the flow stream, and because there is no through shaft to obstruct flow, this valve design also provides high capacity compared to other control valve types. The combination of low minimum flow and high maximum capacity results in wide rangeability.



V-Notch Ball Segment Minimum And Maximum Flow Areas
Figure 95

Seal Options - Elastomer seals provide for tight shutoff at low temperatures, and metal seals are typically specified for high temperature applications.

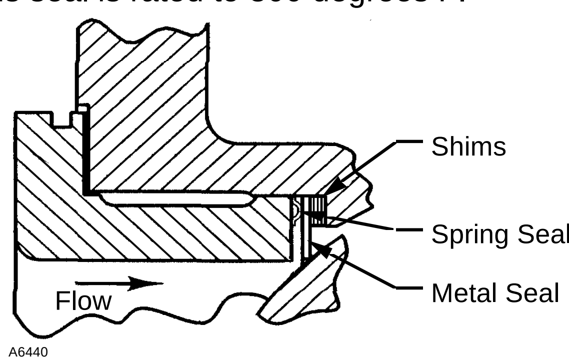
- The soft seal that is shown in Figure 96 provides ANSI Class VI shutoff. The seal is in constant contact with the ball and therefore produces some friction. The seal is pressure assisted, and it produces the rated shutoff in the forward flow direction only. Forward flow is with flow toward the face (convex side) of the ball.



Cutting Action - Good
Shutoff, Class VI
Max Temp, 450°F
Friction Low

Soft (Composition) Seal
Figure 96

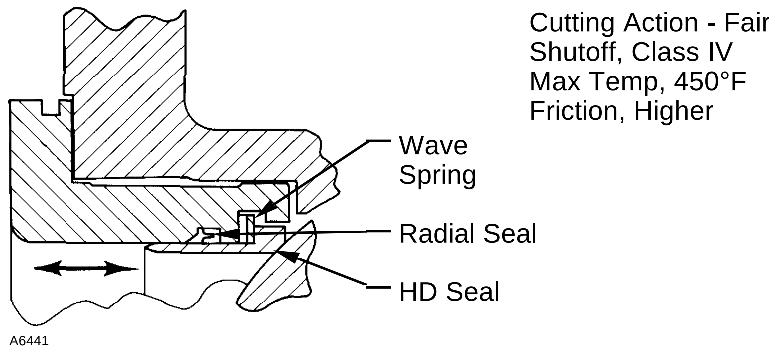
- The flat metal seal (refer to Figure 97) is a thin metal ring that constantly wipes the ball surface. The seal is retained between a spring seal and a stack of shims. The role of the shims is to adjust the loading of the seal against the ball surface. This pressure-assisted seal provides ANSI Class IV shutoff with flow in the forward direction. The flat metal seal produces the most effective cutting action of all the seal options, but it also produces the highest friction. Because there are no elastomer parts, this seal is rated to 800 degrees F.



Cutting Action - Excellent
Shutoff, Class IV
Max Temp, 800°F
Friction, Highest

Flat Metal Seal
Figure 97

- The heavy duty metal seal (refer to Figure 98) includes a heavy duty metal seal ring (HD seal) that is constantly loaded against the ball by a wave spring. A radial seal prevents fluid from leaking between the seal and the seal retainer. The design is pressure balanced and achieves bi-directional shutoff to ANSI Class IV. The heavy duty seal provides a fair cutting action and generates a moderate amount of friction. Because the radial seal is an elastomer, the seal is rated for temperatures up to 450 degrees F.



Heavy Duty Seal
Figure 98

Flow Characteristics - V-notch ball valves have an approximately equal percentage flow characteristic that is appropriate for many applications.

Rangeability - The rangeability of V-notch ball valves is unequaled by any other valve type.

ÆP Ratings - V-notch ball valves may have pressure drop ratings to the full ANSI Class inlet pressure; however, the rating for a specific construction depends on the seal material, the bearing material, the valve size, and the operating temperature.

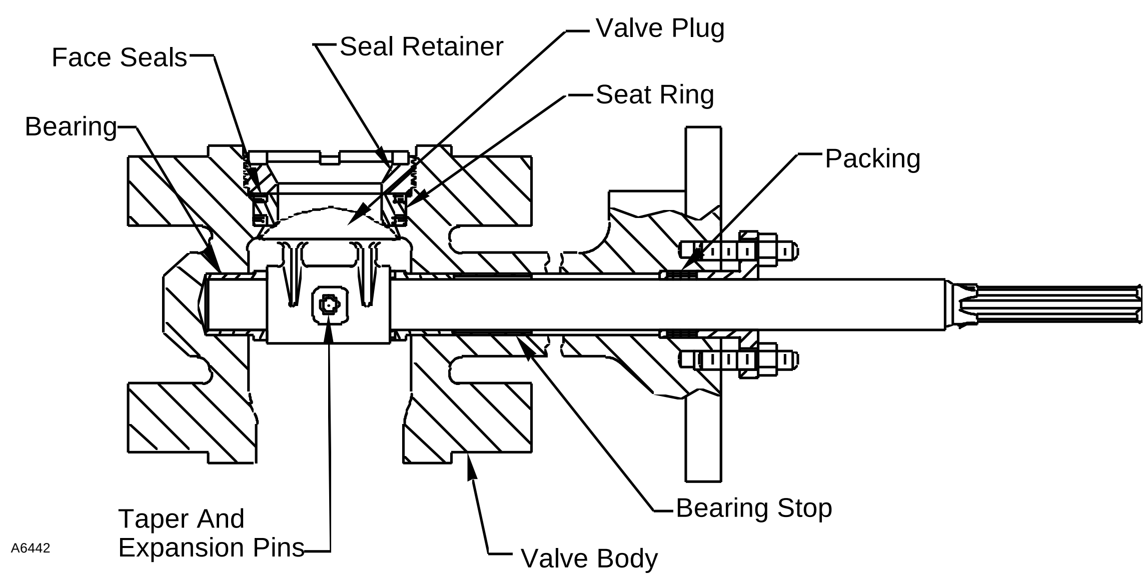
Features - The key features of V-notch ball valves include wide rangeability, the shear-on-closing action, and excellent flow characteristic.

Limitations - The key limitations of V-notch ball valves include reduced pressure drop ratings compared to sliding-stem valves.

Applications - V-notch ball valves are typically specified for applications that require wide rangeability, large flow rates, or a shear on closing feature. They are popular with fibrous slurries and with viscous fluids.

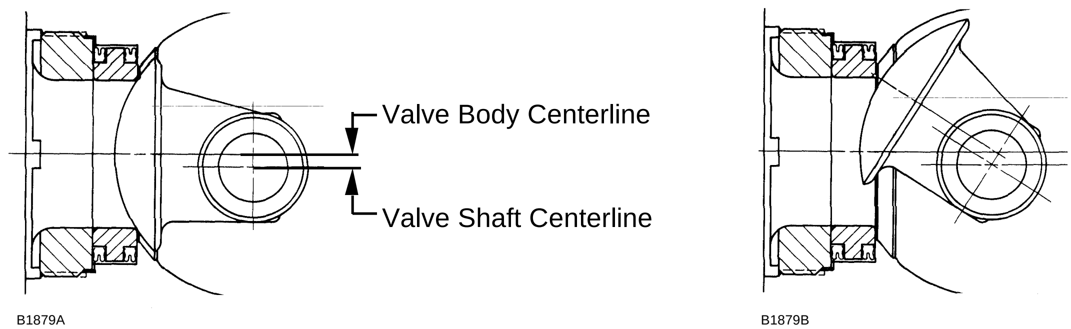
Eccentric Rotary Plug Valve (Fisher V500)

Construction - The eccentric rotary plug valve (refer to Figure 99) is designed specifically for erosive, dirty, or coking applications. The closure member is a massive, partial ball segment that is referred to as a valve plug. The plug seats against a heavy metal seat ring. The seat ring is held in position with a retainer that threads into the body. The plug is attached to a one-piece valve shaft (a through shaft) with a taper pin and an expansion pin. The shaft is supported by heavy bearings. To center the plug, the bearings are positioned by a bearing stop. A thrust washer minimizes wear of the bearing and plug mating surfaces. Packing prevents leakage of the process fluid along the valve shaft.



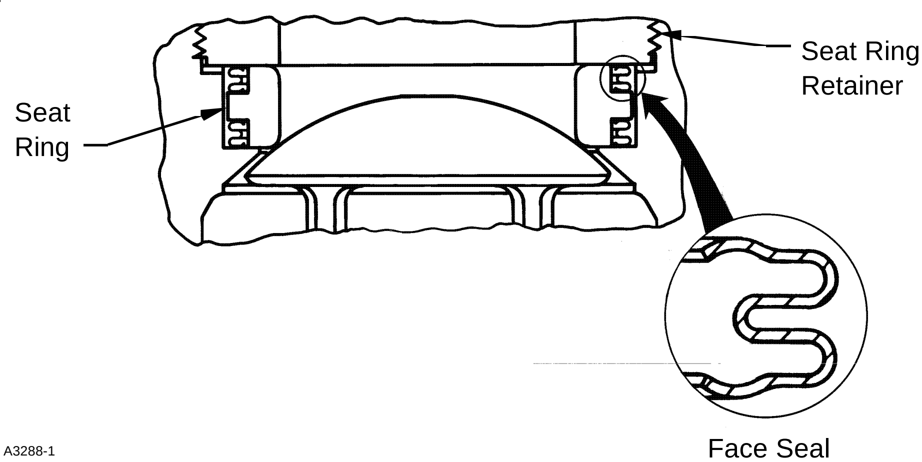
Eccentric Rotary Plug Valve Construction
Figure 99

Double Offset Design - The shaft centerline is offset from the centerline of the seal, and it is offset from the centerline of the valve body as shown in Figure 100. Because of the eccentric path, the plug moves away from the seat immediately after the valve is opened. The advantage is less seal friction and less seal wear during throttling. As the valve is closed, the cam action of eccentric rotation forces the plug into the valve seat to ensure tight shutoff.



Eccentric Valve Plug Rotation
Figure 100

Floating Seat - A small clearance between the seal and retainer allows the plug to seat firmly against the seat ring without placing undue stresses on the valve plug or other components. In addition, the seal is allowed to float from side to side. The result is a self-centering feature that ensures the optimum seat ring location for tight shutoff. Because the seat ring is allowed to float, pressure assisted face seals (refer to Figure 101) are included in the design to prevent leakage around the seat ring. The massive seat ring has a seating surface on both sides; therefore, it can be reversed in the field to provide a new seating surface.



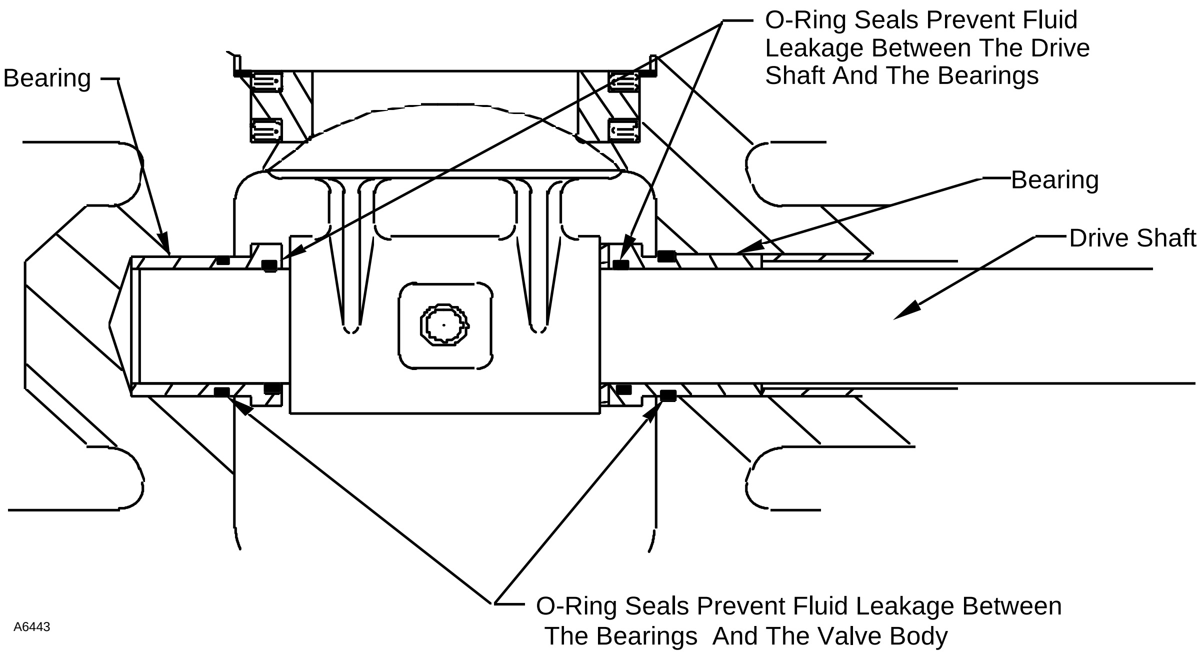
Face Seals
Figure 101

Trim Options - Because the eccentric rotary plug valve is designed for use in erosive applications, it is typically available with several different 'levels' of trim. The various trim levels are defined in Figure 102. Higher levels indicate increasing erosion resistance. Level 1 trim may specified for mildly erosive fluids. Level 2 and level 3 trim are commonly specified for moderately erosive fluids. Level 4 (ceramic) trim is specified for extremely erosive applications for which no other solution has proven satisfactory.

Trim	Plug	Seat Ring	Retainer
1	Chrome Plated 316 Stainless Steel	316 Stainless Steel	17-4 Stainless Steel
2	Alloy 6	Alloy 6	17-4 Stainless Steel
3	Alloy 6	Alloy 6	Alloy 6
4	Ceramic	Ceramic	Ceramic Bore

Trim Levels And Materials
Figure 102

Bearings - The selection criteria for bearing material are related to temperature compatibility. At low temperatures, PTFE lined materials are popular because of their low friction. Alloy bearings provide high temperature compatibility but they also introduce additional friction. The sealed bearing option that is shown in Figure 103 may be specified whenever the fluid is dirty or erosive.



Sealed-Bearing Detail
Figure 103

Flow Direction - The eccentric plug valve is normally installed so that fluid flow is directed toward the back side of the plug. Although this flow direction is referred to as reverse flow, it is the preferred flow direction for this valve style. Reverse flow protects the sealing surface of the plug. Reverse flow also results in a flow geometry that minimizes the impingement of erosive particles on the seat ring.

Flow Characteristic - The flow characteristic of an eccentric plug valve is approximately linear over a large range of travel.

Rangeability - The rangeability of an eccentric plug valve is higher than many globe valves, but it is less than that of V-notch valve designs.

ÆP Limits - Because of its heavy construction, the pressure drop limits of eccentric rotary plug valves are higher than many other rotary-shaft control valves. In smaller valve sizes, the pressure drop ratings can be equal to the full ANSI Class inlet pressure rating.

Shutoff - ANSI Class IV shutoff is standard for this valve style.

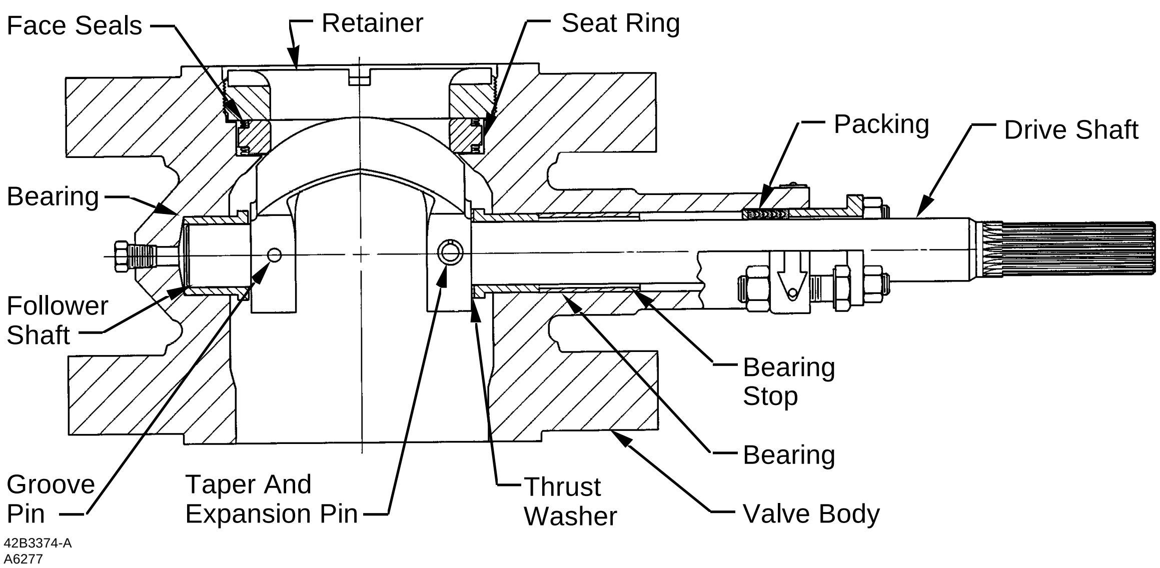
Features - The primary feature of the eccentric rotary plug valve is its superior erosion resistance. High temperature capability and high pressure drop ratings are also beneficial in many applications.

Limitations - Eccentric rotary plug valves are available only in a limited range of sizes. In addition, pressure drop ratings decrease rapidly as valves sizes increase.

Typical Applications - Eccentric rotary plug valves are commonly specified for flashing applications, coking applications, and for erosive services such as scrubbers and dump valves.

Eccentric V-Notch Valve (Fisher CV 500)

Construction - The eccentric V-notch valve (see Figure 104) is a hybrid design that combines selected features of the V-notch ball segment valve design and selected features of the eccentric rotary plug valve. The closure member is a V-notch ball segment that provides good throttling control and wide rangeability. The split-shaft arrangement provides high capacity when the valve is fully open. The massive seat ring (from the eccentric rotary plug design) is compatible with dirty and erosive fluids, and it allows higher pressure drop ratings than are possible with any of the standard V-notch ball seal options. The eccentric rotation of the ball segment improves shutoff.



Eccentric V-Notch Valve Design
Figure 104

ÆP Ratings - Pressure drop ratings to 600 psid are common in smaller valve sizes. Factors that can lead to reduced ÆP ratings include increased valve size, the selection of metal bearings, and elevated temperatures.

Features - Features include an equal-percentage flow characteristic, a shear-on-closing action, relative high capacity, good erosion resistance, and bi-directional shutoff to ANSI Class IV

Applications - This valve style is commonly specified for erosive fluids, viscous fluids, slurries, and coking applications.

Rotary-Shaft Valve Selection Criteria

There are many different basic styles of rotary-shaft valves, and there are many options for each style. To simplify the selection process, specifiers can apply a process of elimination that is based on the properties of the process fluid.

Control Valve Selection Based on Properties of Process Fluid

The table that is included in Figure 105 provides general guidance for rotary-shaft valve selection. For each of several valve types, the table indicates:

- Fluid compatibility
- Rangeability
- Flow Characteristics

Fluid Properties	**Reduced Bore Ball**	**V-Notch Ball Segment**	**Eccentric Plug**	**Eccentric V-Notch Ball Segment**	**Lined Butterfly**	**HPBV**
Clean	A	A	A	A	A	A
Dirty/Erosive	B	B	A	B	C	C
Viscous	A	A	C	A	C	B
Fibrous Slurry	C	A	C	B	C	C
Coking	C	B	A	A	C	C
Wide Rangeability	A	A	B	B	B	B
Flow Characteristic	Equal Percentage	Equal Percentage	Linear	Equal Percentage	Equal Percentage	Equal Percentage

A = Well suited

B = Possible with appropriate options or special design

C = Not recommended

Fluid Compatibility And Major Features Of Rotary-Shaft Control Valves
Figure 105

Clean Fluids - Not surprisingly, nearly all valve types are compatible with clean fluids.

Erosive Fluids - Erosive fluids generally disqualify valves with soft seals or thin seals. Lined butterfly valves are not recommended for erosive applications because erosive particles may interfere with the tight disk-to-liner seal. For erosive applications, the rotary-shaft valve of choice is the eccentric plug valve because of its heavy seal. The selection of hard and tough materials such as Stellite and ceramics further increases erosion resistance.

Viscous Fluids - Viscous fluids often disqualify valves with thin seals. The preferred designs are typically ball valves and ball segment valves with a heavy seal option.

Fibrous Slurries - Fibrous slurries present a problem for any valve that does not provide a shear-on-closing action. V-notch ball valves are specifically designed to provide the required shearing action.

Coking - Coking refers to the build-up of sooty, carbon-based materials on critical valve surfaces. Coking applications require erosion resistance, a self cleaning action, and an overall heavy-duty construction. Within the rotary-shaft valve family, the heavy-duty V-notch valve and the eccentric rotary plug valve are appropriate selections.

Control Valve Selection Based on Rangeability

In some applications, wide rangeability is a prime consideration. For example, if one valve can provide a range of flow rates that would normally require two valves of a different type, the wide rangeability of V-notch ball segment valves is particularly attractive.

Control Valve Selection Based on Flow Characteristic

The flow characteristic of a rotary-shaft control valve can influence the selection process; however, because most rotary-shaft valves provide an equal percentage characteristic (and because the equal percentage characteristic is appropriate for many applications), the availability of a particular characteristic rarely influences selection.

Other Selection Criteria

In addition to the criteria that are listed in the table, specifiers must consider the same factors as they would for a sliding-stem valve type. These factors include:

- ANSI Class pressure temperature ratings
- Pressure drop ratings
- Corrosion resistance
- Erosion resistance
- End connections
- Temperature ratings of all components including gaskets, packing, and seals

Control Valve Selection Concepts

This Module has discussed sliding-stem valves and rotary-shaft valves as two different subjects. However, as one begins the selection process, one must consider the entire range of available valve types. Because so many valve types are available, and because each application is unique, it is easy to see that control valve selection is a both a science and an art. Selection criteria include not only the technical specifications of a broad range of available valve types and options, but also company standards, maintainability, cost, and a historical perspective of what valve types have performed well in specific applications.

Control Valve Selection Basics

Over time, all specifiers develop their own system of logic for valve selection. While every specifiers personal system may be unique, the specifier must perform the following:

- Select a valve style that is suitable for the characteristics of the process fluid (clean, viscous, erosive, corrosive, etc.).
- Select a valve construction that is adequately rated to provide the required pressure, pressure drop, temperature, and shutoff capabilities, as well as meet certain other requirements such as end connection style, rangeability, applicable standards, etc.

Control Valve Selection Tables And Associated Logic

To help summarize the information that has been presented in this Module, and to help build a sense of intuition for valve selection, three selection guides are included in Figures 106 through 108. For the discussion that follows, refer to Figure 107.

Organization Of The Selection Guides- The following summarizes the organization of the guides, which are in table form:

- There is a separate table for each ANSI Class pressure-temperature rating (ANSI Class 150, ANSI Class 300, and ANSI Class 600).
- The relative maximum pressure drop is listed on the left hand side of the table.
- The ANSI shutoff class is listed along the bottom side of the table.

In the general area of the table where the shutoff pressure drop and the ANSI Class shutoff rating intersect, the specifier selects a suitable valve type from one or more possible choices. For sliding-stem valves, choices are further differentiated according to whether the process fluid is clean or dirty (erosive).

285 psid							
		Balanced	**Unbalanced**	**Balanced**	**Unbalanced**	Balanced	Unbalanced
Maximum Shutoff ÆP	**Clean Fluid**	Full Guide Metal Seat	---	Full Guide Metal Seat	Full Guide Metal Seat	---	Full Guide Soft Seat
	Dirty Fluid	---	---		Post Guide Metal Seat	---	Post Guide Soft Seat
				Segmented Ball Heavy Metal Seal		Segmented Ball Composition Seal	
220 psid				High Performance Butterfly Metal Seal		High Performance Butterfly Soft Seal	
						Lined Butterfly	
	Shutoff Class	**II**		**IV**		**VI**	

Selection Guidelines For ANSI Class 150 Control Valves
Figure 106

		Balanced	Unbalanced	Balanced	Unbalanced	Balanced	**Unbalanced**
740 psid							
Maximum Shutoff ÆP	**Clean Fluid**	Full Guide Metal Seat	---	Full Guide Metal Seat	Full Guide Metal Seat	---	Full Guide Soft Seat
	Dirty Fluid	---	---		Post Guide Metal Seat	---	Post Guide Soft Seat
				Segmented Ball Heavy Metal Seal		Segmented Ball Composition Seal	
300 psid				High Performance Butterfly Metal Seal		High Performance Butterfly Soft Seal	
	Shutoff Class	**II**		**IV**		**VI**	

Selection Guidelines For ANSI Class 300 Control Valves

Figure 107

1480 psid							
		Balanced	**Unbalanced**	**Balanced**	**Unbalanced**	**Balanced**	**Unbalanced**
Maximum Shutoff ÆP	**Clean Fluid**	Full Guide Metal Seat	---	Full Guide Metal Seat	Full Guide Metal Seat	---	Full Guide Soft Seat
	Dirty Fluid	---	---		Post Guide Metal Seat	---	Post Guide Soft Seat
740 psid				Eccentric Plug Metal Seal			
600 psid				Segmented Ball Heavy Metal Seal		Segmented Ball Composition Seal	
				Eccentric Segmented Ball Metal Seal			
	Shutoff Class	**II**		**IV**		**VI**	

Selection Guidelines For ANSI Class 600 Control Valves
Figure 108

Selection Logic In The Tables - The basic logic of these tables is as follows:

- With notable exceptions, valves in the rotary-shaft family are often best suited for special applications; e.g., erosive applications (eccentric rotary plug valves), fibrous slurries (V-notch ball segment valves), requirements for wide rangeability (most ball and butterfly valve types), requirements for low cost corrosion resistance (lined butterfly valves), etc.

- Increasing pressure drop requirements generally lead to sliding-stem valve types.

- Increasing shutoff requirements lead to the selection of unbalanced plugs, soft seals, or both.

- Dirty fluids generally indicate a requirement for post guiding in sliding-stem valves or, in the rotary-valve family, valves with heavy seals.

Example Problem - Assume an application with the following conditions and requirements:

- ANSI Class 300 body

- Shutoff pressure drop of 500 psid

- Class IV shutoff

- Dirty fluid

Referring to the selection guide for ANSI Class 300 valves (see Figure 107), the intersection of the pressure drop requirement and the shutoff requirement falls in the upper portion of the middle column. From the table, the choices are a segmented ball valve with a heavy seal (a Fisher V300 or a Fisher CV 500), or a post-guided, metal-seated, sliding-stem valve (a Fisher EZ).

entering control valve selection data on the iss

Overview

Saudi Aramco personnel specify control valves on a Saudi Aramco Instrument Specification Sheet (ISS). A different ISS form is used for each different style of control valve. Three popular forms are:

- Form 8020-711 for globe and angle (sliding-stem) valves
- Form 8020-712 for ball valves
- Form 8020-713 for butterfly and rotary plug control valves

Major Sections of the ISS

A sample of a completed ISS is shown in Figure 109. Although only the form for globe and angle sliding-stem valves is shown, the forms for ball and butterfly valves are similar. Refer to Figure 109 and note that an ISS is organized into five major sections.

General - This section lists the application, the required flow characteristic, the valve manufacturer and the valve type, and other basic information.

Process Data - This section lists detailed information about the properties of the fluid and the service conditions; i.e., the inlet pressure, the outlet pressure, the shutoff pressure drop, and the operating temperature.

Actuator - This section is where the actuator and actuator accessories are specified.

Valve Body - This section is where the specifier enters information to describe the selected valve.

Accessories - This section is where many valve accessories are specified.

Saudi Aramco Instrument Specification Sheet
Figure 109

Valve Body Information

Entering Valve Body Information

This Module has presented sufficient information to complete the **Valve Body** section of the ISS only. Refer to Figure 109. The lines that relate specifically to the specification of a particular valve type (the subject of this Module) are listed below, along with a brief instruction on how to enter the appropriate information.

Line 5 Manufacturer - Enter the name of the manufacturer; e.g., Fisher, Valtek, etc.

Line 6 Model/Type Number - Enter the valve type number; e.g., ED, Camflex, etc. If appropriate, also enter other descriptive information such as the trim option number, special options, etc.

Line 9 Overall Valve/Actuator Characteristic - Enter the flow characteristic; e.g., equal percentage, linear, etc.

Line 50 Inlet Flange Size Rating/Style - The flange size can only be determined after sizing, which is the subject of another Module in this Course. The rating refers to the ANSI Class; e.g., ANSI Class 300, ANSI Class 600, etc. The style refers to the end connection style; e.g., RF for raised-face flanges, RTJ for ring type joint, etc.

Line 51 Outlet flange size Rating/style - The same type of information that was listed on Line 50 is entered here for the outlet flange.

Line 52 Body And Bonnet Material - Enter the materials of construction for the body and the bonnet; e.g., WCC (carbon steel), WC9 (chrome moly steel), etc.

Line 53 Bonnet Standard/Extended Or Column - Circle whether a standard or extended bonnet is appropriate. (A column refers to a custom, fabricated bonnet extension that is beyond the scope of this Module.)

Line 54 Gland Packing Material - Enter whether the basic packing material is PTFE, graphite, or another material. If a special packing arrangement is required, this line should be starred and a note should be entered in any available space; e.g., "* low-leakage packing required".

Line 55 Lubricator Or Isolating Valve - Enter whether or not a lubricator and/or isolating valve is required. Generally speaking, enter "none" on this line.

Line 56 Stem Material - Enter the stem material; e.g., 316 SST (stainless steel).
Line 57 Type Of Plug Guiding - Enter whether the valve plug is cage guided or post guided.
Line 58 Plug And Cage Material - Enter the construction materials for the plug and for the cage, and separate the two materials with a backslash; e.g., 416 Hardened/17-4PH Hardened.
Line 59 Leakage Class - Enter the ANSI Shutoff Class for the selected valve; e.g., ANSI Class II, ANSI Class V, etc.
Line 60 Seat Type/Material - Enter whether the seat is metal or soft, and the material type; e.g., Metal/416 hardened, and Soft/TFE.
Line 61 Valve Plug Action - Circle whether fluid flow will tend to open or close the valve. Note that this action has also been discussed as pressure-tends-to-open (PTTO) and pressure-tends-to-close (PTTC).
Line 72 Face-To-Face Dimension - Enter the face-to-face dimension (for flanged end connections) or the end-to-end dimension (for welded and threaded ends).
Line 73 Wetted Parts Per NACE STD MR-01-75 - Circle 'Yes' if wetted parts are exposed to a sour fluid (one that includes H_2S). Circle 'No' if the construction materials do not need to comply with NACE guidelines.

Work aid 1: standards, control valve specification bulletins, and selection guidelines that are used to specify required control valve performance attributes

Work Aid 1A: ANSI Class Pressure-Temperature Tables That Are Used To Specify Appropriate ANSI Class Ratings

The ANSI Class pressure and temperature limits of various materials are published in table form. Portions of the ANSI Class ratings are located in Fisher Bulletin 59.1:021 (Fisher Catalog 71).

To complete Exercise 1A, refer to Bulletin 59.1:021 and locate the lowest possible ANSI Class rating for each material, temperature, and pressure that is given in the Exercise. Ensure that you select a Standard ANSI Class rating (rather than a Special ANSI Class rating).

Work Aid 1B: Specifications And Procedures That Are Used To Specify Body-To-Bonnet Bolting Material

Bolting pressure and temperature limits are sometimes different from the body and bonnet pressure and temperature limits. The information that is required to determine the pressure and temperature limits of various bolting materials for the valve that is described in the Exercise are listed in Tables 8 and 9 of Fisher P.S. Sheet 59.1:031(A), "Bolting Material Pressure/Temperature Derating And Nameplate Marking".

Work Aid 1C: Specifications And Procedures That Are Used To Specify Control Valve Trim For Pressure Drop And Temperature Capability

The pressure and temperature ratings of various trim options may be published in chart form, or the information may be listed in tables. For Exercise 1C, the required information is presented in a chart. For each application that is described in Exercise 1C, perform the following:

1. Locate Fisher Bulletin 51.1:ED.
2. Refer to the charts that are included in Figure 7. Locate the chart that describes the trim options that are available for the body material that is specified in the Exercise.
3. Mark the point on the chart where the pressure drop and the temperature intersect.
4. Select the lowest numbered trim option that is capable of meeting the pressure drop and temperature requirements.
5. Refer to Table 2 to identify the materials that are included in the selected trim option. Enter the data that is requested in the Exercise.

Work Aid 1D: Standards, Procedures, And Material Cross-Reference That Are Used To Specify Control Valve Body And Trim Materials For Corrosion Resistance

Saudi Aramco Engineering Standards

To help identify appropriate materials, a material compatibility chart, or selection guide, is included in Table I of Saudi Aramco Engineering Standard SAES-L-008.

Material Cross-Reference Table

In some instances, the material designations that are included in SAES-L-008 are different than the material designations that are used by valve manufacturers. To cross-reference Saudi Aramco designations to other common material designations, refer to the table that is included on the following page.

Material Selection Procedures

For each application that is described in Exercise 1D, perform the following:

1. Refer to Table 1 of SAES-L-008 and locate the fluid that is described in the Exercise. Identify the recommended body and trim materials

2. Locate Valve Specification Bulletin 51.1:ED. Refer to the information that is listed under the heading **Construction Materials** (see page 2). Select a body and bonnet material that is consistent with the guidelines that are included in SAES-L-008.

3. Record the selected body and bonnet material.

4. To select a trim material, refer to the charts that are included in Figure 7 of Bulletin 51.1:ED. Ensure that you refer to the trim chart that is appropriate for the body material that you have selected. Identify a trim option that meets pressure drop and temperature requirements, and that is consistent with the guidelines that are listed in Table I of SAES-L-008. Refer to Table 2 in the specification bulletin to identify the materials of construction that are included in the various trim options.

5. Record the trim option number and the trim materials.

Notes:

- Recall that 410 stainless steel and 416 stainless steel are equivalent materials (for most applications); in addition, Table II of SAES-L-008 lists 17-4 stainless steel as an equivalent to 410 stainless steel.

- Steam is generally considered an erosive application, and often requires alloy steel (chrome-moly) valve bodies and hardened trim.

Material Cross-Reference

Some of the material designations that are included in SAES-L-008 do not conform to either the ACI, UNS, or ASTM specifications. To aid in material identification, the table below cross-references Saudi Aramco material designations to the corresponding ACI, UNS, and ASTM designations.

Saudi Aramco Material Designation	Common Name	Cast Form (ACI or ASTM)	Wrought Form (UNS)	Primary Characteristics And Remarks
B-2	Hastelloy B-2	CN7M	N10665	Corrosion resistance; hydrochloric acid
CrMo5	Alloy steel	C5	J42045	Higher temperatures, better erosion resistance than carbon steel; WC9 an emerging standard
CrMo11	Alloy steel	WC6	J12072	
CrMo22	Alloy steel	WC9	J21890	
CS	Carbon Steel	WCC, WCB, etc	N.A.	Economical, good strength
C-276	Hastelloy 276	CW2M	N10276	Corrosion resistance; acids, chlorides, oxidizers
LTS	Low temperature carbon steel	LC3		To -150 degrees F with impact testing
M400	Monel 400	M35-1	N04400	Corrosion resistance; chlorine, hydrogen chloride, brine, seawater
N50	Nitronic 50	CG6MMN	S20910	High strength; stems and shafts
SSS	Special Stainless Steel			Special stainless steels such as duplexes (Ferralium, etc.)
ST6	Stellite 6, Alloy 6, CoCr-A(1)	R30006	Alloy 6B	Very tough; erosion resistant
17-4	17-4PH (precipitation hardened)	CB7Cu-1	S17400	Hard, strong
304	304 stainless steel	CF8	S30400	Compatible with nitric acid
304L	304 stainless steel, low carbon	CF3	S30403	Standard for nitric acid; low carbon version of 304 that can be welded
316	316 stainless steel	CF8M	S31600	Low and high temperature; corrosion resistance superior to 304
316L	316 stainless steel, low carbon	CF3M	S31603	Low carbon version of 316 that can be welded
410	410 stainless steel	CA15, or CA6NM (modified version)	S41000	Hard, poor corrosion resistance; S41600 is free-machining equivalent
1. CoCr-A is the appropriate designation for this material when it is applied as a hardfacing				

Work Aid 1E: Standards, Specification Bulletins, And Procedures That Are Used To Specify Control Valve Body And Trim Materials For Sour Hydrocarbon Applications

Saudi Aramco Engineering Standards

To help identify appropriate materials, refer to Table I of Saudi Aramco Engineering Standard SAES-L-008. Locate 'Crude Oil' in the column labeled 'Environment'. Observe that Footnote 15 requires the selection of materials that comply with NACE MR0175.

Specification Bulletins

Locate Specification Bulletin 51.1:ED.

Procedures

For each application that is described in Exercise 1E, perform the following:

1. Refer to the trim charts that are included in Figure 10 of Specification Bulletin 51.1:ED.

2. Identify a NACE approved trim option that is compatible with the service conditions that are described in the Exercise.

3. Refer to Table 8 of Specification Bulletin 51.1:ED and identify the construction materials that are included in the selected trim option.

Work Aid 1F: Specification Bulletins And Procedures That Are Used To Specify Control Valve Body And Trim Materials For Erosive Applications

Specification Bulletins

Locate Fisher Specification Bulletin 51.1:ED

Procedures

For the application that is described in Exercise 1F, perform the following:

1. Select a body material. An alloy steel such as C5 or WC9 is recommended for erosive applications. WC9 offers improved weldability.

1. Refer to the charts that are included in Figure 7 of the bulletin that is described above. Locate a trim option that is compatible with the application pressure drop and temperature.

2. Refer to Table 2 and identify the trim materials that are included in the selected trim option. To achieve additional erosion resistance, select a trim option that includes alloy 6 (CoCr-A) hardfacing on both the seating surface and the guiding surface of the plug. Also ensure that the cage and the seat ring are made of solid alloy 6 (R30006).

3. Refer back to Figure 7 and verify that the selected trim is compatible with the pressure drop and temperature conditions.

Work Aid 1G: Selection Guidelines That Are Used To Specify Appropriate Control Valve Flow Characteristics

Flow characteristics are sometimes selected only after an in-depth dynamic analysis of the control system has been completed. More often, specifiers refer to guidelines to select the appropriate flow characteristic. One set of selection guidelines is shown below. Refer to these guidelines to complete Exercise 1G.

Flow Characteristic Selection Guidelines

Process	Application	Best Inherent Flow Characteristic
Pressure	Liquid Process	Equal Percentage
	Gas Process, Small Volume	Equal Percentage
	Gas Process, Large Volume Maximum ÆP < 5X Minimum ÆP	Linear
	Gas Process, Large Volume Maximum ÆP > 5X Minimum ÆP	Equal Percentage
Temperature	Most Applications	Equal Percentage
Flow	Small Range Of Flow, Large ÆP Change	Equal Percentage
	Liquid, Wide Range Of Setpoint	Linear
Liquid Level	Maximum ÆP > 5X Minimum ÆP	Equal Percentage
	Maximum ÆP < 5X Minimum ÆP	Linear

Work Aid 1H: Equations, Standards, and Procedures That Are Used To Calculate Seat Leakage

Equations

Basic Equation - To calculate seat leakage, the following equation is solved:

$$Q_{seat\ leakage} = C_{v\,shutoff}\sqrt{\frac{\Delta P}{G}}$$

where:

$Q_{seat\ leakage}$ = Seat leakage in GPM

$C_{v\ shutoff}$ = Shutoff C_v = maximum leakage per ANSI Standard B16.104 (in percent) x maximum rated C_v of the valve x 0.01. The required information from the ANSI Standard is located on the following page. The maximum rated C_v of the control valve is listed in the Exercise.

ÆP = Pressure drop (see below)

G = Specific gravity of the fluid (SG=1.0 for water at standard conditions)

ÆP: Test Seat Leakage Calculation - To calculate the maximum leakage that is allowed under test conditions, the ÆP is the pressure drop that is listed in ANSI Standard B16.104.

ÆP: Installed Seat Leakage - To calculate the installed seat leakage, the ÆP is the shutoff ÆP that is listed in the Exercise.

ANSI Standard B16.104

Seat Leakage Per ANSI Standard B16.104

<table>
<tr><th>ANSI Class</th><th colspan="4">Maximum Leakage</th><th>Medium</th><th>Pressure And Temperature</th></tr>
<tr><td>Class II</td><td colspan="4">0.5% valve capacity at full travel</td><td>Air</td><td>Lower of service ÆP or 50 psid at 50 to 125 degrees F</td></tr>
<tr><td>Class III</td><td colspan="4">0.1% valve capacity at full travel</td><td>Air</td><td>Lower of service ÆP or 50 psid at 50 to 125 degrees F</td></tr>
<tr><td>Class IV</td><td colspan="4">0.01% valve capacity at full travel</td><td>Air</td><td>Lower of service ÆP or 50 psid at 50 to 125 degrees F</td></tr>
<tr><td>Class V</td><td colspan="4">$5x10^{-4}$ mL/minute/psid/inch port diameter
($5x10^{-12}$ m^3/second/bar differential/mm port diameter)</td><td>Water</td><td>Service ÆP at 50 to 125 degrees F</td></tr>
<tr><td rowspan="10">Class VI</td><td colspan="2">Port Diameter</td><td rowspan="2">Bubbles per minute</td><td rowspan="2">mL per minute</td><td rowspan="10">Air</td><td rowspan="10">Lower of service ÆP or 50 psid at 50-125 degrees F</td></tr>
<tr><td>In</td><td>mm</td></tr>
<tr><td>1</td><td>25</td><td>1</td><td>0.15</td></tr>
<tr><td>1 1/2</td><td>38</td><td>2</td><td>0.30</td></tr>
<tr><td>2</td><td>51</td><td>3</td><td>0.45</td></tr>
<tr><td>2 1/2</td><td>64</td><td>4</td><td>0.60</td></tr>
<tr><td>3</td><td>76</td><td>6</td><td>0.90</td></tr>
<tr><td>4</td><td>102</td><td>11</td><td>1.70</td></tr>
<tr><td>6</td><td>152</td><td>27</td><td>4.00</td></tr>
<tr><td>8</td><td>203</td><td>45</td><td>6.75</td></tr>
<tr><td colspan="7">Extracted from American National Standard for Control Valve Seat Leakage, ANSI B16.104-1985 with the permission of the publisher, Fluid Controls Institute, Inc.</td></tr>
</table>

Procedures That Are Used To Calculate Seat Leakage

Calculate $C_{V\ shutoff}$ - Because six equations will be solved to complete this Exercise, the first step is to calculate and record the $C_{V\ shutoff}$ for ANSI Class II, III, and IV shutoff ratings. Calculate the C_V shutoff for each ANSI Class as follows:

1. Refer to ANSI Standard B16.104 and locate the maximum leakage in percent.

2. Calculate the $C_{V\ shutoff}$ according to the following:

   $C_{V\ shutoff}$ = maximum leakage per ANSI B16.104 (in percent) x maximum rated C_V of the valve (listed in the Exercise) x 0.01. (Multiplying times 0.01 converts the percentage to a decimal value.)

   Example for ANSI Class II Shutoff:

   $C_{V\ shutoff} = 0.5\% \times 300 \times 0.01$

   $C_{V\ shutoff} = 0.15$

3. Enter the $C_{V\ shutoff}$ for each ANSI Class on the Exercise Sheet.

Calculate The Maximum Test Seat Leakage - To calculate the maximum test seat leakage for each ANSI Class rating, the following equation is solved:

$$Q_{seat\ leakage} = C_{V\,shutoff}\sqrt{\frac{\Delta P}{G}}$$

To solve the equation for each ANSI Class, perform the following

1. Set the $C_{V\ shutoff}$ to the value that was calculated above.

2. Set the ÆP to the test ÆP that is listed in the ANSI Standard B16.104.

3. For this application, assume that G=1.0.

4. Solve the equation and enter the seat leakage on the Exercise Sheet.

5. Repeat steps 1 through 5 for ANSI Class III and IV shutoff.

Calculate The Installed Seat Leakage - To calculate the installed seat leakage for each ANSI Class rating, set the ÆP to the shutoff ÆP and solve the equation. Enter the installed seat leakage on the Exercise Sheet.

work aid 2: control valve Specification bulletins, selection aids, and saudi aramco engineering standards that ARE USED TO select control valve types for specific service conditions

Work Aid 2A: Selection Guidelines, Valve Specification Bulletins, And Procedures That Are Used To Select Sliding-Stem Control Valves Types

For each of the three applications that are described in Exercise 2A, select the appropriate options, valve types, and material options according to the following procedures:

1. Refer to table below for guidance in selecting a guiding method (post or cage guiding). Whenever possible, select cage-guiding.

Fluid Properties	Cage Guided	Post Guided
Clean Fluid	A	A
Erosive/Dirty Fluid	B	A
Viscous Fluid	B	A
Fibrous Slurry	C	C
Wide Rangeability	C	C
Flow Characteristics	All	All

A = Best choice. Highly suited to this type of service.

B = Good Choice. May Require the use of options for enhanced performance.

C = Not typically recommended.

2. Refer to the table below for guidance in selecting the appropriate seat (soft or metal), plug style (balanced or unbalanced), and plug seal material (if applicable). When possible, select a balanced valve plug to help minimize the required actuator force.

ANSI Class Shutoff Rating	Unbalanced Plug	Balanced Plug	
		Below 450 Degrees F	Above 450 Degrees F
II		Metal Seat, PTFE Plug Seal (Split)	Metal Seat, Graphite Plug Seal
III			3" & Larger Metal Seat, Graphite Plug Seal
IV	Metal Seat	Metal Seat, PTFE Plug Seal (2 Piece)	4 inch And Larger - Metal Seat, And Multiple Graphite Plug Seals
V	Metal Seat, Larger Actuator, Custom Lapping	PTFE Seat, PTFE Plug Seal (2 Piece)	
VI	PTFE Seat		

3. Select the flow direction that will result in a pressure-tends-to-open (PTTO) condition. Recall that:

   - For balanced valves, the PTTO condition is achieved with a flow down flow direction.
   - For unbalanced valves, the PTTO condition is achieved with a flow up flow direction.

4. Select a packing material that is compatible with the service temperature. Recall that PTFE packing has an upper temperature limit of 400 degrees F per Section 4.1.5 of SAES-J-700.

5. Select a bonnet type according to the guidance that is included in Section 4.1.5 of SAES-J-700, as follows:

   - Select a standard bonnet for temperatures that are below 450 degrees F.
   - Select an extended bonnet or special packing (graphite) for temperatures that are above 450 degrees F.

6. Refer to specification bulletins in Fisher Catalog 71 to identify a valve type that includes the valve design options that were selected above. The appropriate valve style will be one of the following:

   - Fisher ES (Bulletin 51.1:ES)
   - Fisher ED (Bulletin 51.1:ED)
   - Fisher ET (Bulletin 51.1:ET)
   - Fisher EZ (Bulletin 51.1:EZ)

7. Refer to the specifications table for the selected valve (the specifications table begins on page 2 in every specification bulletin), and select a body and bonnet material according to the following general guidelines:

   - Select carbon steel (WCC or WCB) for general service applications as long as the ANSI Class pressure temperature limits are adequate for the application.
   - Select alloy steel (WC9 or equivalent) for erosive applications or when higher pressure or temperature ratings are required.
   - Select stainless steel for very high temperature applications, or when additional corrosion resistance is required.

8. Refer to the appropriate charts that show the pressure drop and temperature limits of the various trim options. Select a trim option that is compatible with the application pressure drop and temperature. Also consider any requirement for corrosion resistance or for erosion resistance.

9. After selecting a trim option, locate the table that identifies the materials that are included in the selected trim option.

10. Locate the table that is titled "Materials and Temperature Limits For All Other Parts." If there are options for the valve stem material, select an appropriate material.

11. Referring to the table that is titled "Materials and Temperature Limits For All Other Parts," select appropriate materials for the seat ring and bonnet gaskets, and for the spiral wound gasket.

Work Aid 2B: Valve Specification Bulletins And Procedures That Are Used To Select Butterfly Control Valves

To complete Exercise 2B, perform the following:

1. Locate the following specification bulletins:

   - Type 7600 Bulletin 51.4 7600
   - Type 9500 Bulletin 51.4 9500
   - Type 8560 Bulletin 51.6 8560

2. Refer to the specifications table that begins on page 2 of each bulletin, and to the various tables and charts that list the pressure, temperature, and pressure drop limits for each valve type. Select a valve type that is appropriate for the fluid, conditions, and valve requirements that are listed in the Exercise.

3. For the selected valve type, evaluate all available options for materials of construction. Select the most appropriate materials and circle the options that are best suited to the application.

Work Aid 2C: Valve Specification Bulletins And Procedures That Are Used To Select Ball-Segment Control Valves

To select an appropriate valve for each of the applications that are described in Exercise 2C, perform the following:

1. Locate the following specification bulletins:

   - Type V150 Bulletin 51.3 V150
   - Type V300 Bulletin 51.3 V300
   - Type V500 Bulletin 51.3 V500

2. Refer to the specifications table that begins on page 2 of each bulletin, and to the various tables and charts that list the pressure, temperature, and pressure drop limits for each valve type. Select a valve type that is appropriate for the fluid, conditions, and valve requirements that are listed in the Exercise.

3. For the selected valve type, evaluate all available options for materials of construction. Select the most appropriate materials and circle the options that are best suited to the application.

Clues: Application 1

To select a particular valve type for Application 1, evaluate the specifications for each valve type in the following order:

- ANSI Class pressure-temperature ratings
- End connections (availability of raised face flange designs)

Clues: Application 2

To select a particular valve type for Application 2, evaluate the specifications for each valve type in the following order:

- ANSI Class pressure-temperature ratings
- Availability of highly erosion resistant trim options

Work Aid 3: Procedures that are used to Enter Control Valve Selection Data On The Saudi Aramco ISS

Complete Exercise 3 according to the following procedures:

Line 5: Manufacturer - Enter "Fisher"

Line 6: Model/Type Number - Enter "ED, Trim 1"

Line 9: Overall Valve/Actuator Characteristic - Enter "Equal Percentage"

Line 50: Inlet Flange Size Rating/Style - Following the instructions that were given in the Exercise, assume that the valve size is the same as the pipeline size. Enter "4-inch" for the flange size. Refer to Fisher Bulletin 59.1:021 and determine the appropriate ANSI class rating for a carbon steel body (refer to the body and bonnet material specification that is discussed in the instructions for line 52). Enter the ANSI Class rating. Assume that raised-face flanges are acceptable and enter "RF" for the flange style.

Line 51: Outlet Flange Size Rating/Style - Enter the same information that was entered for Line 50.

Line 52: Body And Bonnet Material - Because the fluid is clean (non-erosive), assume that carbon steel is a satisfactory body and bonnet material. Refer to the ED specification bulletin, select an appropriate and available grade of carbon steel, and enter your selection on the ISS.

Line 53: Bonnet Standard/Extended - Although the fluid temperature is greater than 450 degrees F, graphite packing will be selected; therefore, a standard bonnet is acceptable. Circle "Std" on the ISS.

Line 54: Gland Packing Material - Because the process temperature is greater than 400 degrees F, enter "graphite".

Line 55: Lubricator And Isolating Valve - A lubricator and isolating valve is not required; therefore, enter "None".

Line 56: Stem Material - Refer to Table 4 in the ED specification bulletin, select the standard stem material, and enter the material designation.

Line 57: Type Of Plug Guiding - The ED is a cage-guided valve; therefore, enter "Cage" or "Cage-Guided".

Line 58: Plug/Cage Material - Refer to Table 2 in the ED specification bulletin and identify the materials for trim option number 1. Enter the material designations for the plug and the cage. Separate each designation with a backslash.

Line 59: Leakage Class - Enter the ANSI Shutoff class that was listed in the Exercise.

Line 60: Seat Type/Material - Enter "Metal" for a metal-seated valve, or "Soft" for a soft-seated valve. Enter a backslash and then enter the seat material; e.g., PTFE, 316, etc. The seat materials for trim option 1 are listed in Table 2 of the ED specification bulletin.

Line 61: Valve Plug Action - Recall that for the proper operation of general service control valves, fluid flow (pressure) should *generally* tend to open the valve. Circle "Open".

Line 72: Face-To-Face Dimension - Refer to Figure 11 in the ED specification bulletin. Locate the face-to-face dimension (Dimension A) of a 4-inch, ANSI Class 600 valve with raised-face flanges. Enter the dimension on the ISS. Circle the appropriate units of measure (inches or mm)

Line 73: Wetted Parts Per NACE STD MR-01-75 - The description of the process fluid did not indicate that the flowing gas is sour; therefore, assume that compliance with NACE MR0175 is not required. Circle "NO" on the ISS.

GLOSSARY

Note: The definitions for the terms that are marked with an asterisk (*) are taken from ISA Standard S75.05-1983, Control Valve Terminology.

actuator*	An actuator is a fluid powered or electrically powered device which supplies force and motion to a valve closure member.
ANSI	American National Standards Institute.
ASME	American Society of Mechanical Engineers.
balanced trim*	An arrangement of ports and plug or combination of plug, cage, seals and ports that tends to equalize the pressure above and below the valve plug to minimize the net static and dynamic fluid flow forces acting along the axis of the valve stem.
balanced valve	A valve that includes balanced trim.
ball valve*	A valve which modifies flow rates with rotary motion of the closure member, which is either a sphere with an internal passage or a segment of a spherical surface.
ball*	A spherically shaped part which uses a portion of a spherical surface or an internal path to modify flow rate with rotary motion.
ball, full port	The closure member of a ball valve in which the port diameter is equal to the diameter of the adjacent piping.
ball, reduced port	The closure member of a ball valve in which the port diameter is smaller that the diameter of the adjacent piping.
V-notch ball	The flow-controlling member for a popular style of throttling ball valve. The V-notch ball includes a polished or plated partial-sphere surface that rotates against the seal ring throughout the travel range. The V-shaped notch in the ball permits wide rangeability and produces an equal percentage flow characteristic.
block valve	An isolating valve, often a butterfly, gate, or ball valve, that is used to stop flow.
body cavity*	The internal chamber of the valve body including the bonnet zone and excluding the body ends.
body*	The part of the valve which is the main pressure boundary. The body also provides the pipe connecting ends, the fluid flow passageway, and may support the seating surfaces and the valve closure member.
bonnet bolting*	A means of fastening the bonnet to the body. It may consist of studs with nuts for a flanged bonnet joint, studs threaded into the bonnet neck of the body, or bolts through the bonnet flange.

bonnet gasket*	A deformable sealing element between the mating surfaces of the body and bonnet. It may be deformed by compressive stress or energized by fluid pressure within the valve body.
bonnet types*	Typical bonnets are bolted, threaded, or welded to or integral with the body. Other types sometimes used are defined below.
bonnet*	That portion of the valve pressure retaining boundary which may guide the stem and contains the packing box and stem seal. It may also provide the principal opening to the body cavity for assembly of internal parts or be an integral part of the valve body. It may also provide for the attachment of the actuator to the valve body.
bubble tight*	A nonstandard term. Refer to ANSI B16.104 for specification of leakage classifications.
butterfly valve*	A valve with a circular body and a rotary motion disk closure member, pivotally supported by its stem.
cage guide*	A valve plug fitted to the inside diameter of the cage to align the plug with the seat.
cage*	A part in a globe valve surrounding the closure member to provide alignment and facilitate assembly of other parts of the valve trim. The cage may also provide flow characterization and/or a seating surface for globe valves and flow characterization for some plug valves.
capacity*	The rate of flow through a valve under stated test conditions.
closure member*	A movable part of the valve which is positioned in the flow path to modify the rate of flow through the valve.
C_V	see *flow coefficient*
differential pressure	The difference between two measured pressures, expressed in psid.
disc, eccentric	The closure member for a high-performance butterfly valve. Eccentric rotation results by offsetting the axis of rotation from the seal centerline, the body centerline, or both.
disk*	An essentially flat, circular shaped part which modifies the flow rate with either linear or rotary motion.
disk, balanced	A butterfly valve disk that is contoured to balance fluid forces that act on either side of the disk; e.g., the Fishtail disk.
downstream	Any point located away from a reference point in the direction of fluid flow.

dynamic unbalance*	The net force produced on the valve stem in any given open position by the fluid pressure acting on the closure member and stem within the pressure retaining boundary, with the closure member at a stated opening and with stated flowing conditions.
end connection*	The configuration provided to make a pressure tight joint to the pipe carrying the fluid to be controlled.
equal percentage characteristic*	The inherent flow characteristic which, for equal increments of rated travel, will ideally give equal percentage changes of the existing flow coefficient (Cv).
erosion	The damage that results from the impingement of particles or vapor droplets on critical valve surfaces. Erosion may be forestalled with hardened materials or with valve designs that separate the flow stream from critical valve components.
erosion resistant trim*	Valve trim which has been faced with very hard material or manufactured from very hard material to resist the erosive effects of the controlled fluid flow.
extension bonnet*	A bonnet with a packing box that is extended above the bonnet joint of the valve body so as to maintain the temperature of the packing above or below the temperature of the process fluid. The length of the extension bonnet is dependent upon the difference between the fluid temperature and the packing design temperature limit as well as upon the valve body design.
face to face dimension*	The dimension from the face of the inlet opening to the face of the outlet opening of a valve or fitting.
flanged body*	Valve body with full flanged end connections.
flanged ends*	Valve end connections incorporating flanges which allow pressure seals by mating with corresponding flanges on the piping.
flangeless control valve*	A valve without integral line flanges, which is installed by bolting between companion flanges, with a set of bolts, or studs, generally extending through the companion flanges.
floating ball*	A full ball positioned within the valve that contacts either of two seat rings and is free to move toward the seat ring opposite the pressure source when in the closed position to effect tight shutoff.
flow characteristic*	Indefinite term, see *inherent flow characteristic* and *installed flow characteristic*

flow coefficient*	A constant (C_V), related to the geometry of a valve, for a given valve opening, that can be used to predict flow rate. See ANSI/ISA S75.01 "Control Valve Sizing Equations" and ANSI/ISA S75.02 "Control Valve Capacity Test Procedure". (The number of U.S. gallons of water at 60 degree F that will flow through a valve with a one pound per square inch pressure drop in one minute.)
flow rate	The amount (mass or volume) of fluid that flows past a point over a specified period of time.
fluid	Substance in a liquid, gas, or vapor state.
full ball*	A closure member that is a complete spherical surface with a flow passage through it. The flow passage may be round, contoured or otherwise modified to yield a desired flow characteristic.
globe valve plug guides*	The means by which the plug is aligned with the seat and held stable throughout its travel. The guide is held rigidly in the body or bonnet.
globe valve trim*	The internal parts of a valve which are in flowing contact with the controlled fluid. Examples are the plug, seat ring, cage, stem and the parts used to attach the stem to the plug. The body, bonnet, bottom flange, guide means and gaskets are not considered as part of the trim.
globe valve*	A valve with a linear motion closure member, one or more ports and a body distinguished by a globular shaped cavity around the port region.
guide bushing	A bushing in a bonnet, bottom flange, or body that guides the movement of a valve plug.
hardfacing	The process of applying a harder material to the surface of a softer material. This technique is used to resist fluid erosion and/or to reduce the chance of galling between moving parts, particularly at high temperature.
hardness	Metallic material hardness is commonly expressed by either a Brinell number or a Rockwell number. (In either case, the higher the number, the harder the material; for example, a material with a Rockwell “C” hardness of 60 is as hard as a metal file, while a hardness of 20 is fairly soft.)
inherent flow characteristic*	The relationship between the flow rate through a valve and the travel of the closure member as the closure member is moved from the closed position to rated travel with constant pressure drop across the valve.
inlet	The body opening through which fluid enters the valve.

installed flow characteristic*	The relationship between the flow rate through a valve and the travel of the closure member as the closure member is moved from the closed position to rated travel when the pressure drop across the valve varies as influenced by the system in which the valve is installed.
ISA	Instrument Society of America.
lantern ring*	A rigid spacer assembled in the packing box with packing normally above and below it and designed to allow lubrication of the packing or access to a leak-off connection.
lapped-in*	Mating contact surfaces that have been refined by grinding and/or polishing together or separately in appropriate fixtures.
leak-off gland*	A packing box with packing above and below the lantern ring so as to provide a sealed low pressure leak collection point for fluid leaking past the primary seal (lower packing).
leakage*	The quantity of fluid passing through a valve when the valve is in the fully closed position under stated closure forces, with the pressure differential and temperature as specified. Leakage is usually expressed as a percentage of the valve capacity at full rated travel. Refer to ANSI B16.104 for specification of leakage quantity.
linear flow characteristic*	An inherent flow characteristic which can be represented by a straight line on a rectangular plot of flow coefficient (C_V) versus per cent rated travel. Therefore, equal increments of travel provide equal increments of flow coefficient (C_V) at constant pressure drop.
lined body* (butterfly valve)	A body having a lining which makes an interference fit with the disk in the closed position thus establishing a seal.
lubricator isolating valve*	In a control valve, an isolating valve is a small hand operated valve located between the packing lubricator assembly and the packing box assembly. It shuts off the fluid pressure from the lubricator assembly.
metal-to-metal seal	A seal generated between two smooth surfaces on mating metal parts.
modulating*	The actions to keep a quantity or quality in proper measure or proportion. Also see *throttling*.
outlet	The body opening through which fluid exits the valve.
packing*	A sealing system consisting of deformable material of one or more mating and deformable elements contained in a packing box which may have an adjustable compression means to obtain or maintain an effective pressure seal.
packing	A soft or deformable material that is used to seal valve shafts and stems.

packing box*	The chamber, in the bonnet, surrounding the stem and containing packing and other stem sealing parts.
packing flange	A component that compresses packing directly or by means of a packing follower.
packing follower*	A part which transfers mechanical load to the packing from the packing flange or nut.
packing lubricator	A device, either manual or automatic, that is used to inject packing into the packing bore.
PDTC (push-down-to-close)	Referring to the motion that is required to seat the closure member of a control valve.
PDTO (push-down-to-open)	Referring to the motion that is required to open the closure member of a control valve.
plug*	A cylindrical part which moves in the flow stream with linear motion to modify the flow rate and which may or may not have a contoured portion to provide flow characterization. It may also be a cylindrical or conically tapered part, which may have an internal flow path, that modifies the flow rate with rotary motion.
plug, eccentric	The flow controlling member of the eccentric rotary plug valve. Because of its eccentric action, it clears its seat soon after opening.
port guide*	A valve plug with wings or a skirt fitted to the seat ring bore.
post guide*	Guide bushing or bushings fitted to posts or extensions larger than the valve stem and aligned with the seat.
pressure unbalance	Condition where the pressure acting on one side of a component is greater than the pressure acting on the opposite side.
purged packing box*	A packing arrangement consisting of a lantern ring inside the packing rings to permit introduction of a purge fluid to continually flush the space between the stem and body. It is usually used to purge, admit cooling fluid or detect stem seal leakage.
quick opening flow characteristic*	An inherent flow characteristic in which there is a maximum flow with minimum travel.
rangeability, inherent*	The ratio of the largest flow coefficient (C_V) to the smallest flow coefficient (C_V) within which the deviation from the specified inherent flow characteristic does not exceed the stated limits.
rated flow coefficient*	The flow coefficient (C_V) of the valve at rated travel.
rated travel*	The amount of movement of the valve closure member from the closed position to the rated full open position.
restricted trim*	Control valve trim which has a flow are less than the full flow area for that valve.

reversible seat*	Refers to a seat ring with seating surfaces on both sides such that when one surface has worn, the ring may be reversed to present a new surface to contact the closure member.
rotary shaft control valve	A control valve in which the closure member is positioned by rotary motion (torque) to modulate flow.
seat leakage	Quantity of fluid passing through an assembled valve when the valve is in the fully closed position under stated closure forces, with pressure differential and pressure as specified.
seat ring*	A part that is assembled in the valve body and may provide part of the flow control orifice. The seat ring may have special material properties and may provide the contact surface for the closure member.
segmented ball*	A closure member that is a segment of a spherical surface which may have one edge contoured to yield a desired flow characteristic.
single flange (lugged)*	A thin annular section body whose end surfaces mount between the pipeline flanges, or may be attached to the end of a pipeline without any additional flange or retaining parts, using either through bolting and/or tapped holes.
sliding-stem valve	A control valve construction in which the closure member moves in a linear path.
soft seated trim*	Globe valve trim with an elastomeric, plastic or other readily deformable material used either in the valve plug or seat ring to provide tight shutoff with minimal actuator forces. See ANSI B16.104 for leakage classifications.
split body*	A body divided in half by a plane containing the longitudinal flow path axis.
static unbalance*	The net force produced on the valve stem by the fluid pressure acting on the closure member and stem within the pressure retaining boundary with the fluid at rest and with stated pressure conditions.
stem guide*	A guide busing closely fitted to the valve stem and aligned with the seat.
stem seals*	The part or parts needed to effect a pressure-tight seal around the stem while allowing movement of the stem.
stem*	The rod, shaft or spindle which connects the valve actuator with the closure member.
threaded ends*	Valve end connections incorporating threads, either male or female.
throttling*	The actions to regulate fluid flow though a valve by restricting its orifice opening. Also see "Modulating".

travel indicator*	A means of externally showing position of the closure member; typically in terms of percent of or degrees of opening. Can be a visual indicator at or on the valve or a remote indicating device by means of transmitter or appropriate linkage.
travel*	The amount of movement of the closure member from the closed position to an intermediate or the rated full open position.
trim*	The internal parts of a valve which are in flowing contact with the controlled fluid.
trim, reduced capacity	A valve trim package that provides a smaller than standard port diameter to reduce the capacity of the valve. Often used in startup situations when it is known that capacity requirements will increase.
trim, soft-seated	Trim with an elastomer, or other deformable material that is used as an insert, either in the valve plug or seat ring, to provide tight shutoff with minimal actuator force.
trunnion*	Extensions of the ball used to locate, support and turn the ball within the valve body. May be integral or attached to the ball.
turndown*	An obsolete term - See "Rangeability, Inherent".
unbalanced valve	A (sliding stem) valve design in which the pressure unbalance across the valve plug is equal to the shutoff pressure drop. These valves often produce large stem forces and may require the use of large actuators.
valve plug*	An obsolete term, see "Closure Member".
valve*	A valve is a device used for the control of fluid flow. It consists of a fluid retaining assembly, one or more ports between end openings and a movable closure member which opens, restricts or closes the port(s).
wafer body*	A body whose end surfaces mate with the pipeline flanges. It is located and clamped between the piping flanges by long bolts extending from flange to flange. A wafer body is also called a flangeless body.
weld ends*	Valve end connections which have been prepared for welding to the line pipe or other fittings. May be butt weld (BWE) or socket weld (SWE).