

ENGINEERING AND MATERIAL STANDARD
FOR
CONTROL VALVES

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1. SCOPE

This engineering and material standards covers the minimum requirements for control valve bodies, actuators and accessories, designed, constructed and materially tested in accordance with the References outlined herein. This practice is intended to be used in the petroleum industries of Iran.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor/Consultant.

ISA (INSTRUMENT SOCIETY OF AMERICA)

- S75.01 ANSI / ISA "Flow Equations for Sizing Control Valves" 1986
- S70.02 ANSI / ISA "Control Valve Capacity Test Procedure" 1988
- S75.03 ANSI / ISA "Face-to-Face Dimensions for Flanged Globe Style Control Valve Bodies (ANSI Class 125, 150, 300, 600)" 1985
- S75.04 ANSI / ISA "Face-to-Face Dimensions for Flangeless and Control Valve Bodies (ANSI Class 150, 300 and 600)" 1985
- S75.05 ANSI / ISA "Control Valves Terminology" 1986
- S75.06 ANSI / ISA "Control Valve Manifold Designs" 1981
- RP-39.6 ISA "Valve Leakage Rates"

API (AMERICAN PETROLEUM INSTITUTE)

- RP-550 "Process Instrumentation and Control Section 6-Control Valve and Accessories" 1985
- STD-598 "Valve Inspection and Tests" 1987
- STD-609 "Butterfly Valves Lug Type and Wafer Type" 1983

ANSI (AMERICAN NATIONAL STANDARDS INSTITUTE)

- B-2.1 "Pipe Threads" 1968
- B-16.5 "Pipe Flanges and Flanged Rating for Class 150, 300, 400, 600, 900, 1500 and 2500" 1988
- B-16.10 "Face-to-Face Dimensions" 1980
- B-16.34 "Steel Valve Flanged Butt welding End" 1981
- B-16.37 "Hydrostatic Testing of Control Valves" 1980
- ANSI / FCI-70.2 (1976) (R 1982) Formerly ANSI B16.104 (1982) "Valve Leakage Classifications"

BSI (BRITISH STANDARDS INSTITUTION)

- BS-5155 "Butterfly Valves" 1988
- BS-1560: Part 2 "Flange Dimensions for Butterfly Valves" Class 150 and Class 300

IEC (INTERNATIONAL ELECTROTECHNICAL COMMISSION)

- IEC-34.5 "Classification of Degree of Protection Provided by Enclosure for Rotating Machines" 1981
- IEC-144 "Degree of Protection of Enclosures" 1963
- IEC-534.1 "Control Valve Terminology" 1984

NACE (NATIONAL ASSOCIATION FOR CORROSION ENGINEERS)

- MR-01-75 "Material Recommendation in Corrosive Atmosphere" 1975

NFPA (NATIONAL FIRE PROTECTION ASSOCIATIONS)

- 70 "Practical Safeguarding of Persons and Property from Hazards Arising from the Use of Electricity" 1989

UL (UNDERWRITERS LABORATORIES)

- 1002 "Electrically Operated Valves for Use in Hazardous Locations" 1983

BASEFA (BRITISH APPROVALS SERVICE FOR ELECTRICAL EQUIPMENT IN FLAMMABLE ATMOSPHERES)

IPS (IRANIAN PETROLEUM STANDARDS)

- E-SF-900 "Noise and Vibration Control System"
- E-EL-110 "Electrical Area Classifications"
- E-IN-100/1 "Hazardous Area Classifications"
- M-PI-110/2 "Pressure-Temperature Rating of Globe Control Valves"
- M-PI-110/5 "Pressure-Temperature Rating of Butterfly Valves"

3. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

4. CONTROL VALVE BODY DESIGN REQUIREMENTS

The following description is primarily intended to indicate the general and minimum requirement of the control valves body design criteria, to be used in Iranian Petroleum Industries. The supplier's design calculations, drawings, and material selection shall be approved by the purchaser before order placement.

4.1 Control valves have inherent operation characteristics that hinder precise positioning under varying operating conditions. Factors such as pressure differential across the valve seat, overtightening of packing, and viscous or fouling service can create additional forces preventing the valve from assuming the position called for by the controller.

4.2 Valve types shall be selected by taking into account such factors as operating and design conditions, fluids being handled, rangeability required, cost, allowable leakage, noise and other special requirements.

- 4.3** Pneumatic control valves in electronic control loops shall be equipped with a 24 V. d.c. device (converter or transducer) to convert 4-20 mA, d.c. electronic instrument signal to a 0.2-1 barg pneumatic signal.
- 4.4** Control valves shall be furnished with pneumatic type (or d.c. electric-pneumatic) positioners in the following applications:
- a)** Temperature control valve other than minor applications.
 - b)** Valves 4 inches body size and over.
 - c)** More than one valve on a single controller.
 - d)** Critical pressure drop service for valve trim 1 inch and larger.
 - e)** Line pressure exceeding 20 bar.
 - f)** Extension bonnets (includes radiation fins and belows seals).
 - g)** Butterfly valves (rotary action).
 - h)** Sounders patent bodies.
 - i)** Three-way valves.
 - j)** Slow system, such as mixing, thermal, or level process.
 - k)** For fast systems, detailed stability analysis should be presented and if required boosters will be used instead.
 - l)** On duties where the controlled liquid will vaporize across the ports.
- 4.5** Filter Regulators and Positioners or Boosters shall be factory mounted and tubbed. All connecting tubing in instrument air service shall be plastic coated copper with brass compression type fittings, unless otherwise specified.
- 4.6** Single seated bodied valves shall be top guided, Double seated bodied valves shall be top and bottom guided construction. Unless otherwise as specified in data sheet.
- 4.7** Control valves shall have removable trims and sufficient clearance shall be allowed for access and removal.
- 4.8** Buttwelding valves should not be used, however, if line specification calls for buttwelding, consideration shall be given to the welding of control valves.
- 4.9** For flashing conditions, the type and size and additionally the flashing condition of the control valve shall be specified in data sheet and/or agreed with the user.
- 4.10** For control valves intended for operating high temperature, particular attention shall be paid to the clearance between plug and guide bushing to avoid valve sticking when the valve is hot.
- 4.11** In gas pressure let down stations when high differential pressure is present across the valve, special low noise valve shall be used. In this case the noise level should not exceed certain limits as specified in IPS-E-SF-900 (Noise and vibration control standard) or through the requirement of data sheets.
- 4.12** The action of valves on failure of the operating medium shall be determined by process requirements with regard to safe operation and emergency shut-down requirements.
- 4.13** Where cage guided control valves are specified, balanced trim should be considered for large sized valves.
- 4.14** For control valves on vacuum services, special provisions should be considered for prevention and detection of leakage.
- 4.15** Where temperature of control fluid is below zero degree celsius a bonnet extension shall be used.
- 4.16** Extension bonnet or finned also shall be provided on services above 200 degree celsius, in order to maintain the temperature of stuffing box within the limits specified in accordance with the manufacturer's recommendations.
- 4.17** Air operated diaphragms and springs shall be selected to optimize a bench setting range of 0.2-1 barg for the specified maximum upstream pressure with the downstream pressure of zero bar. The "Bench Setting Range" and the "In Service Stroking Range" shall be specified on the control valve data plates. Air operated control valves with an in-service stroking range other than 0.2-1 barg may be used if so dictated by availability of standard operators, and user's approval.

4.18 Manual Loading Type Hand Operators shall be considered in lieu of a side mounted handwheel in relatively low pressure/pressure drop applications where block and bypass valves are not provided and a handwheel may cause a hazardous condition for automatic start-up or shutdown of the related equipment. These hand operators shall consist of a three-way air switch and a handwheel operated air regulator. The handle and ports shall be clearly marked as, MAN-AUTO. The regulators may be common to other components.

4.19 For globe body control valves, the trim construction shall be either single-seated with heavy duty top guiding for the plug, Double-seated with top and bottom guiding for the plug, or cage type. For liquid services with a high pressure drop i.e., (boiler feed water), and gas service (pressure let down), cage trims shall be specified to have the plug supported at the critical area.

Balance type control valve in place of single seat valve in high pressure service shall be considered.

4.20 Control valves for steam heated reboilers shall be located in the steam lines and not in the condensate lines, unless otherwise agreed by the user.

4.21 Where control valves are liable to freezing due to operating or ambient conditions, they shall be insulated or heat-traced.

5. CONTROL VALVE MATERIALS SELECTION

5.1 Since majority of control valve applications are relatively non-corrosive at reasonable pressure and temperature, cast iron and carbon steel bodies are the most common valve body materials used in the oil industries.

5.2 Most control valve materials can be placed in two categories:

5.2.1 The pressure containment materials for valve body, bonnet, bottom flange and bolting.

5.2.2 The valve trim materials for valve plug, seat ring, cage, valve stem, guide bushing and packing box parts.

5.3 For oxygen services, body and trim materials shall be AISI-316 stainless steel. Body casting shall internally be completely machined to a smooth surface to remove any casting imperfections.

5.4 For material selection of body, bolts, nuts etc., the relevant piping class or any other information for the particular application shall be adhered to.

5.5 Control valve material shall be as specified in data sheets or shall be selected from ANSI-B16.5 specifications and applicable sections of the codes and standards.

5.6 Supplier shall comply with the pressure and temperature ratings of more common materials established by the ANSI-B16.5.

5.7 In case, corrosive condition would require very exotic materials, consideration may be given to a composite construction, such as internal metallic lining of the body.

5.8 For very severe erosive services the small fluid impact area inside the valve body shall be covered with a hard facing.

5.9 The minimum requirement for the body material is that the valve shall have a cast steel body, and the trim, consist of plug, seat ring and stem, shall have stainless steel 316, unless otherwise specified by the nature of process fluid being handled and/or requested through relevant data sheet.

5.10 When valves are used for chlorine service or other fluids which become corrosive when in contact with a moist atmosphere, suitable valve stem material must be chosen or other precautions taken.

For chlorine services neoprene diaphragm valves is recommended.

5.11 For extremely erosive-and-corrosive services the hard facing material made of two disks of tungsten carbide material in angle pattern body can be used. This material is specially useful in oil production where severe sand erosion exists.

5.12 Hardened plug and seat rings shall be Selected for the following applications:

- 1) Erosive service.
- 2) Wet gas or wet steam service with a pressure drop above 5 bars, other services when the pressure drop is above 10 bar, at design condition.

5.13 Small-sized valves for erosive services shall have their plug and seat rings made for solid satellite No. 6. For economical reasons hardened stainless steel 440°C may be used as trim material if this is suitable for the particular process conditions.

5.14 When tight shut off is required, a ball or plug valve, a single seated globe body valve shall be selected. The seats shall be of soft material, such as glass fiber filled PTFE, the selection shall be based on suitability for the specified process conditions. The selected material shall be suitable for temperature at least 50°C above the maximum process design conditions. The soft seat ring shall be properly clamped between metal parts.

5.15 When valves are used for sour gas services the trim and bolting material construction shall comply with the recommendation of National Association of Corrosion Engineers (NACE) MR-01-75 latest revision.

5.16 Packing glands shall be equipped with flange style gland followers with bolted constructions. A lubricator with steel isolating valve shall be provided where packing lubrication is required.

5.17 Guide bushing shall be a corrosion resistant material. It is preferred that the guide bushing material be a minimum of 125 brinnel harder than the trim, i.e., 17-4 PH (Precipitation Hardened) stainless steels or better.

5.18 Stainless steel bellows seals may be considered for services with dangerous and or poisoning fluids such as TEL or TML (Tetra Ethyl Lead, Tetra Methyl Lead) but should be avoided wherever possible. A purge with suitable pressure shall be used (monitored for purge) as an alternative method of sealing.

5.19 Butterfly valves material shall be as specified in data sheet for the related service conditions or shall be at manufacturer's option and in accordance with the applicable standard such as BS-5155.

5.20 Butterfly valves body material shall be selected from those listed in Table 1, if not specified in data sheets.

5.21 Butterfly valves trim material shall be suitable for specified service conditions and compatible with the piping material.

5.22 Butterfly valves trim material including disks, shafts, bushings, body and/or disk seating surfaces, internal keys and pins and screws when in contact with the contained fluid shall be selected from Table 1, if not specified in data sheet.

5.23 Seats in the body and on the disk may be separate or integral. Seat facings may be applied to valve bodies and/or disks as deposited metal, integral metal, mechanically retained metal, or resilient materials.

TABLE 1 - BASIC MATERIALS FOR BUTTERFLY VALVES

1	2	3
COMPONENT	MATERIAL	BS REFERENCE
Body Body with integral seat Disk Handwheel Disk with integral seat Rings fitted to body or disk for sealing, seating, or retaining purposes	Cast iron	1452
	Austenitic cast iron	3468
	Spheroidal graphite iron	2789
	Carbon steel	1501.151
		1503.221
		1504.161
	Stainless steel	1501: Part 3
		1503 1504, 3100 1504
Gunmetal	1400	
Aluminum bronze	1400	
Rings of deposited metal or resilient + material		
Shaft	Carbon steel	970: Part 1
	Stainless steel	970: Part 4
	Aluminum bronze	2672 or 2874
	Nickel copper alloy	3076
Shaft bearings seals (when fitted)	No requirement in this Standard	
Internal fastenings	Carbon steel	
	Stainless steel	
	Phosphor bronze	2870, 2873
	Aluminum bronze	2872, 2874, 2875
	Nickel copper alloy	3076

+ When the resilient seal forms part of:

- a) The body and the disk is of grey cast iron, spheroidal graphite iron or carbon steel, it is recommended that the disk should be provided with a disk facing ring deposit, on the edge, or coated all over.
- b) The disk and the body is grey cast iron, spheroidal iron or carbon steel, it is recommended that the body should be provided with a facing ring, deposit on diameter in contact with the resilient seal, or coated all over.

6. CONTROL VALVE BODIES

6.1 General

6.1.1 A control valve consist of two major sub-assemblies, a valve body sub-assembly and an actuator. The valve body sub-assembly is the portion that actually controls the passing fluid. It consist of a housing, internal trim, bonnet and sometimes a bottom flange (Fig. 1).

6.1.2 Body sub-assemblies occur in many shapes and working arrangements depending upon the individual service conditions and piping requirements. Each type has certain advantages and disadvantages for given service requirements and should, therefore, be selected with care.

6.1.3 Control valves operate by one of two primary motions: Reciprocating (sliding stem) motion or rotary motion. The selection of a valve for a particular application is primarily a function of the process requirements. Some of the more common types of control valve bodies are discussed in the following sections.

6.2 Globe Body Control Valves

The most common control valve body style is in the form of a globe; (Fig. 1), such a control valve body can be either single or double-seated:

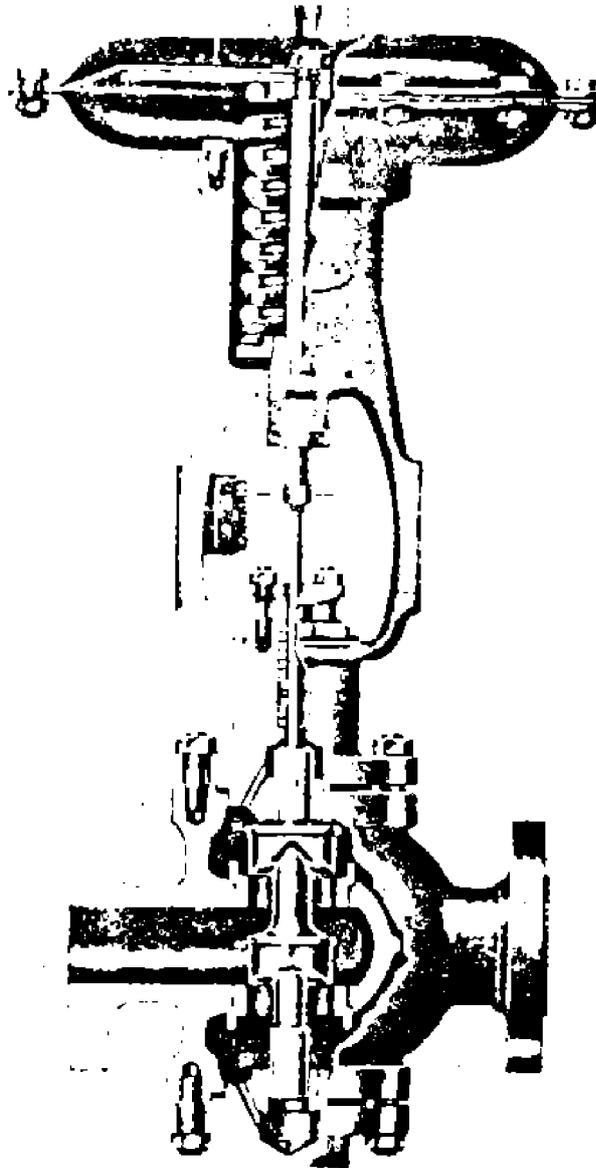
6.2.1 A single-seat construction, for minimum leakage in the close position shall be employed.

6.2.2 A double-seat or balance construction when requiring less actuator force, but allowing some leakage in the close position, shall be used.

6.2.3 Single-seated valves shall have a top guided construction. The valve plug is guided within the lower portion of the valve bonnet (Fig. 2).

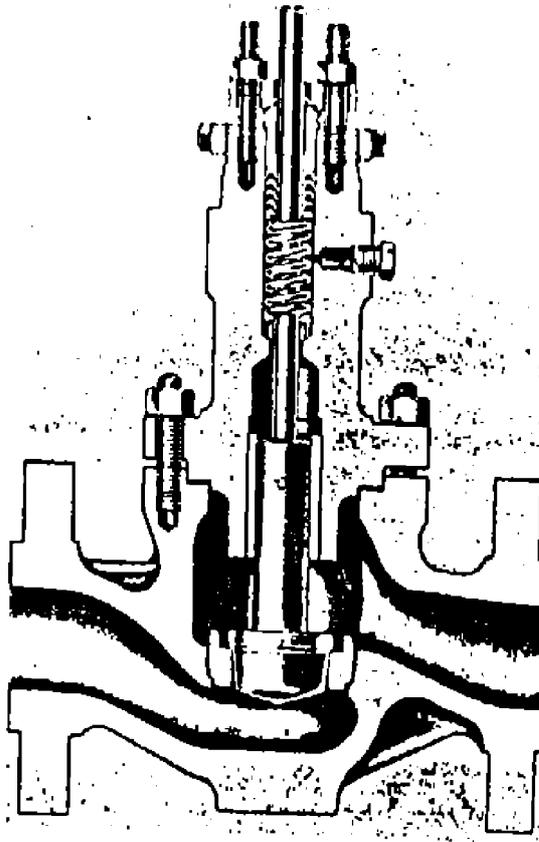
6.2.4 Double-seated valves shall be top and bottom guided construction (Fig. 3).

6.2.5 Threeway valves are a design extension of a typical double-ported globe valve. They are used for diverting services and mixing or combining services (Fig. 4).

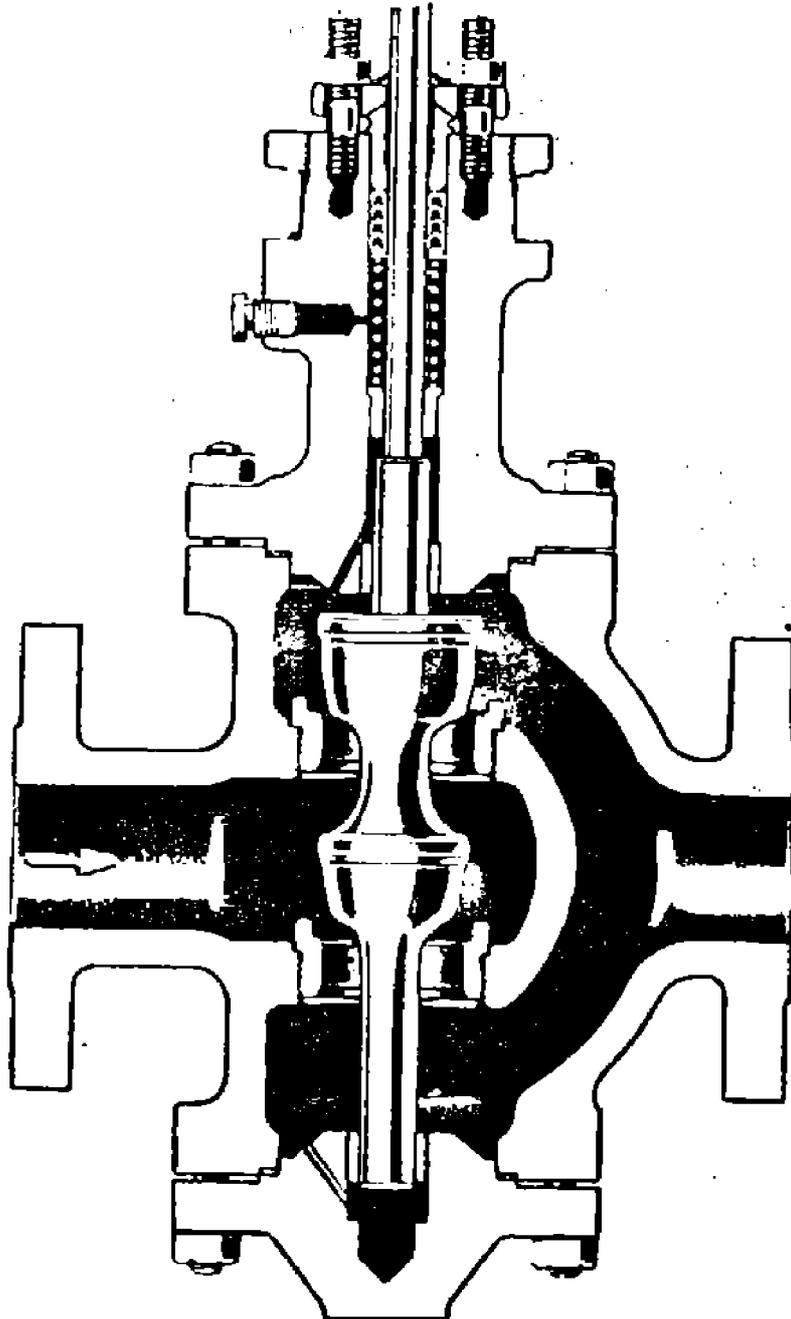


TYPICAL CONTROL VALVE ASSEMBLY

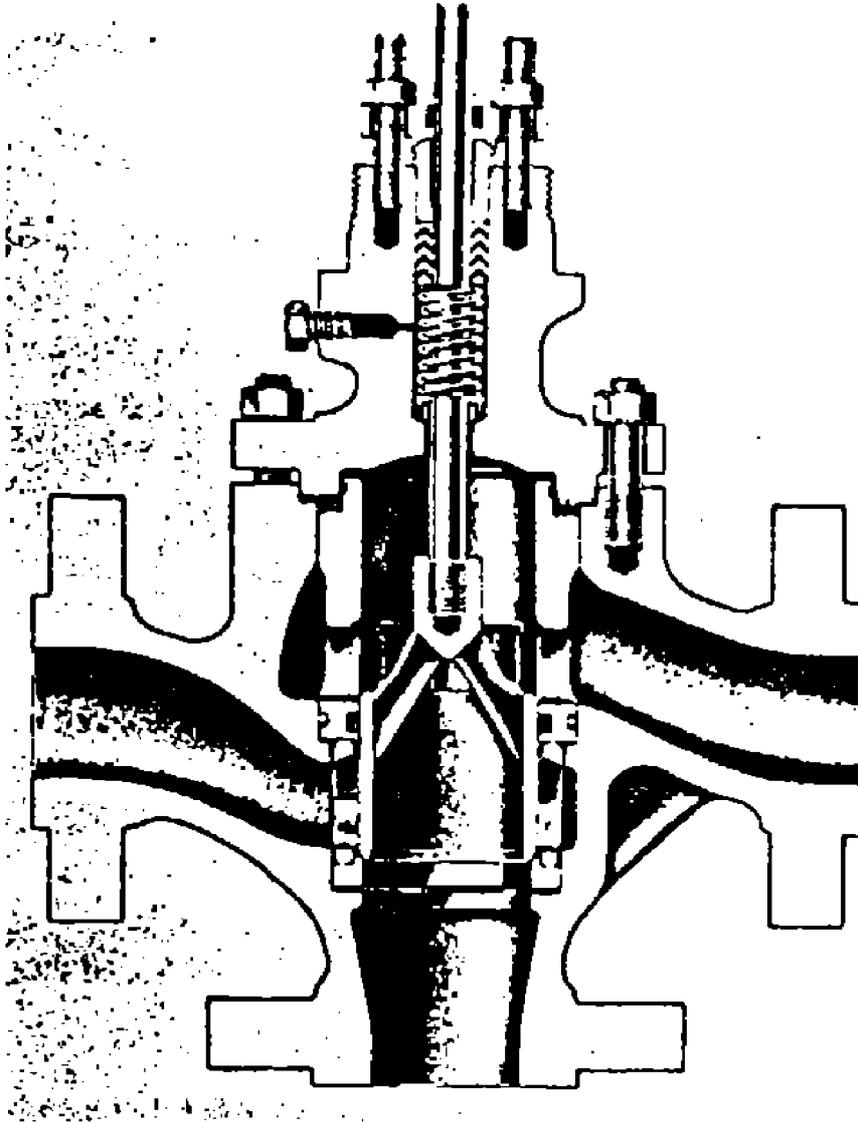
Fig. 1



GLOBE BODY VALVE, TOP GUIDED
Fig. 2



GLOBE BODY VALVE, TOP AND BOTTOM GUIDED
Fig. 3



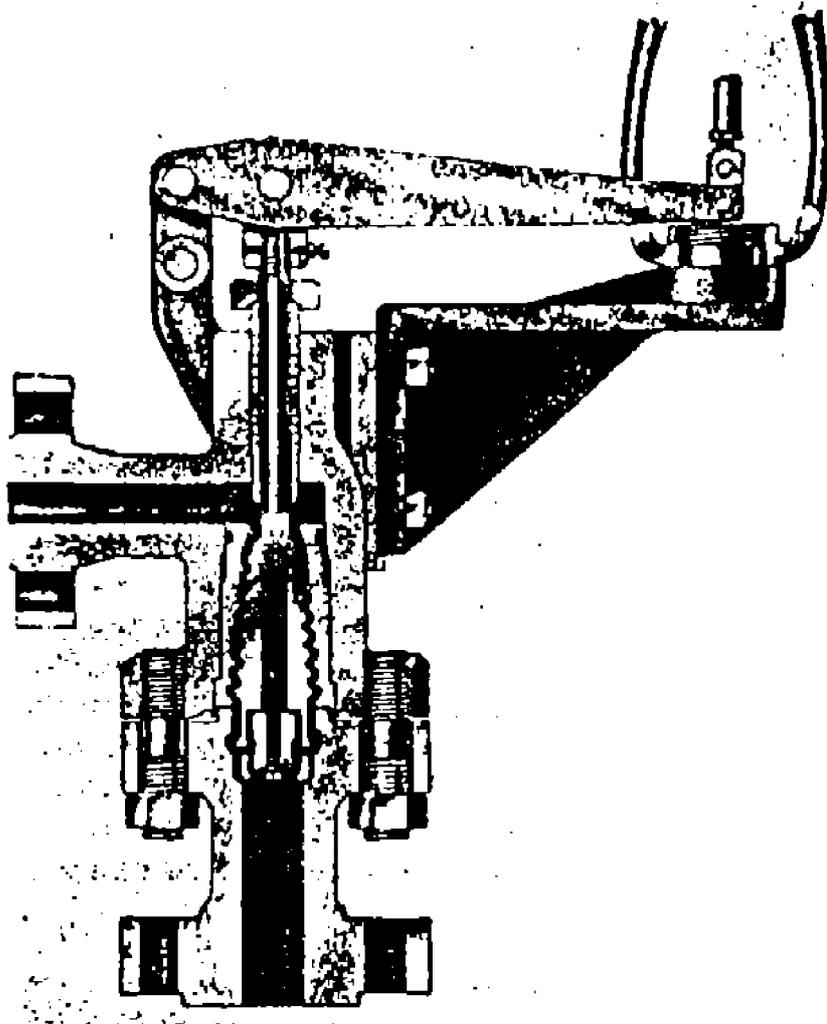
THREE-WAY VALVE

Fig. 4

6.2.6 Control valve with a globe body shall be considered for all applications, (throttling or on-off control) except where adverse operating conditions such as high pressure drops or high capacities make other types more suitable.

6.3 Angle Body Valves

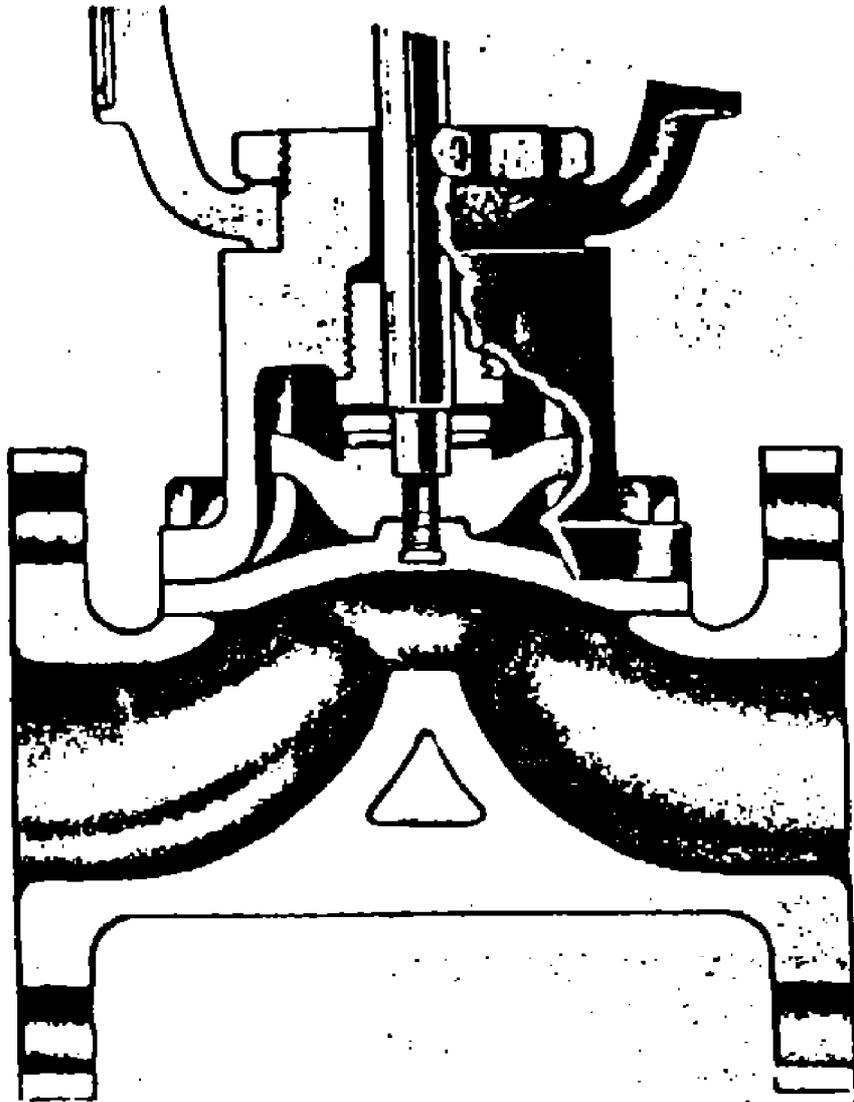
Angle body valves should be considered for hydrocarbon services with a tendency for high pressure drop or coking and erosive services such as slurries and applications where solid contaminants might settle in the valve body (Fig. 5).



ANGLE BODY VALVE, LOW NOISE TRIM
Fig. 5

6.4 Diaphragm Valves

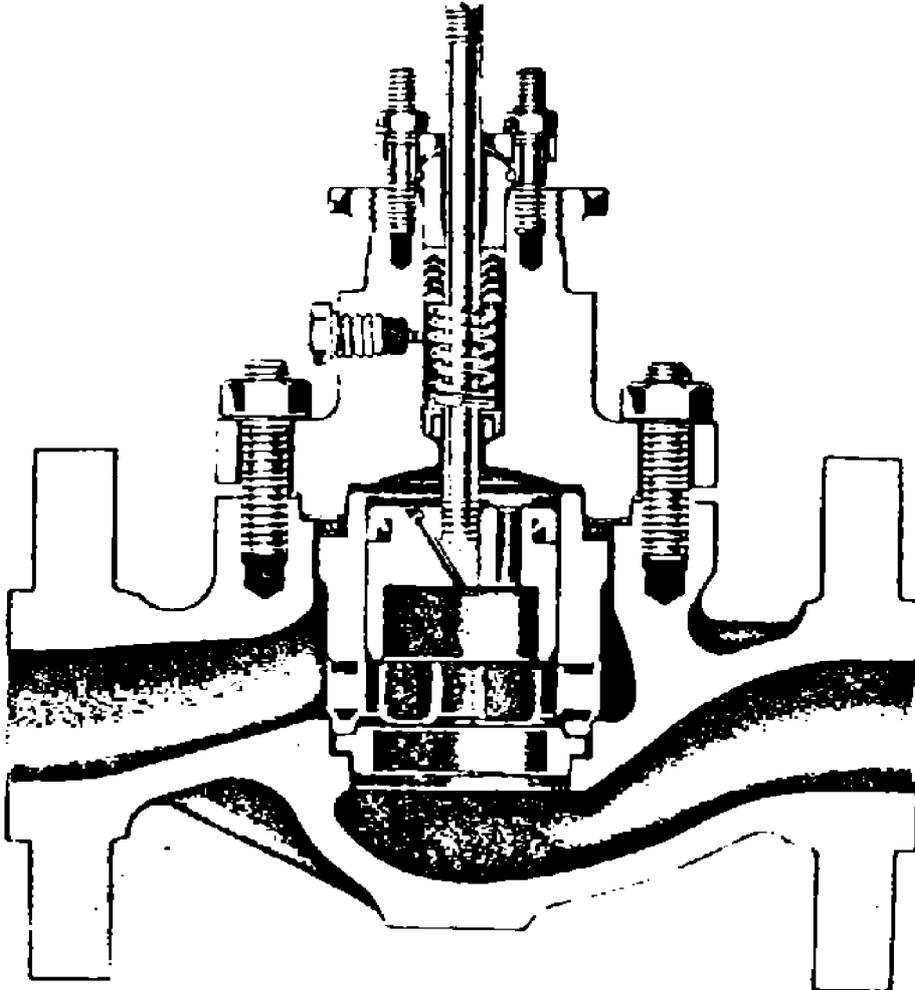
Diaphragm valve may be considered for simple services and applications where the body lining in a standard valve becomes economically unattractive. When used for throttling service a characterized positioner may be required for obtaining the required valve-characteristic (Fig. 6).



DIAPHRAGM VALVE
Fig. 6

6.5 Cage Guided Valves

Top entry or cage guided valves have the advantages of easy trim removal. Valves of this type usually have stream lined body passages to permit increased flow capacity (Fig. 7).



GLOBE BODY VALVE, CAGE GUIDED

Fig. 7

6.6 Rotary Type Control Valves

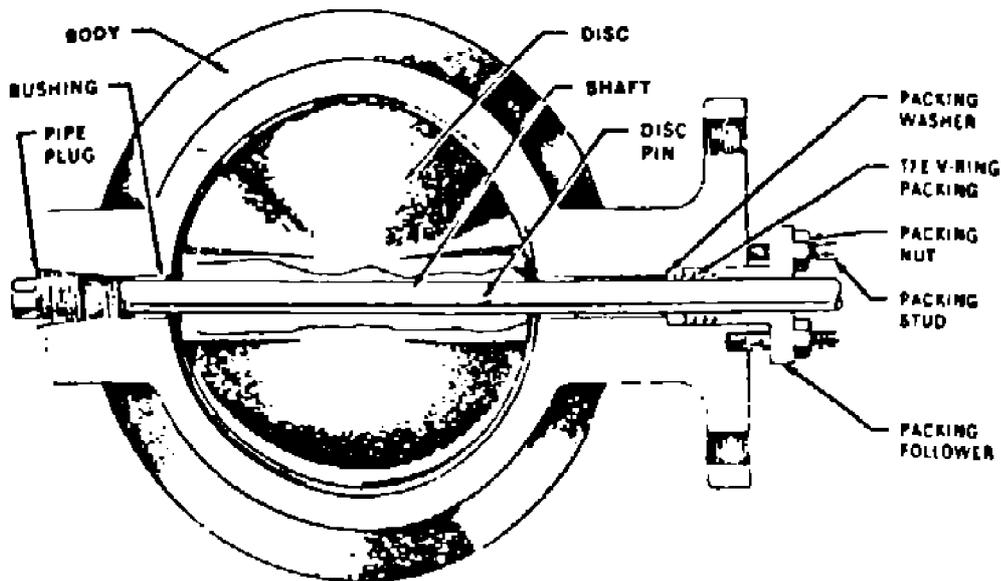
All types of rotary valves share certain basic advantages and disadvantages among the advantages are low weight, simplicity of design, high relative C_V , more reliable, and friction-free packing, and generally low initial cost. They are generally not suitable in size, below 2 inches and pressure-drop ratings are limited.

6.6.1 Butterfly valves

The most common type of rotary valve, is the butterfly valve. Butterfly valves shall be considered for high capacity low pressure drops and where no tight shut-off is required (Fig. 8). Although not normally used in minimum leakage applications, it is available with piston ring, pressurized seat or various types of elastomer seating surfaces if minimum leakage is required.

Heavy pattern butterfly valves shall be used where they are practical and economical.

They shall normally be furnished with diaphragm or piston actuators with positioners. Where handwheel is required, the shaft mounted declutchable type is preferred. Long stroke position actuators shall be used where practical.



**TYPICAL CONSTRUCTION DETAILS OF 2 THROUGH 12 - INCH
BODY SIZES FOR BUTTERFLY VALVES**

Fig. 8

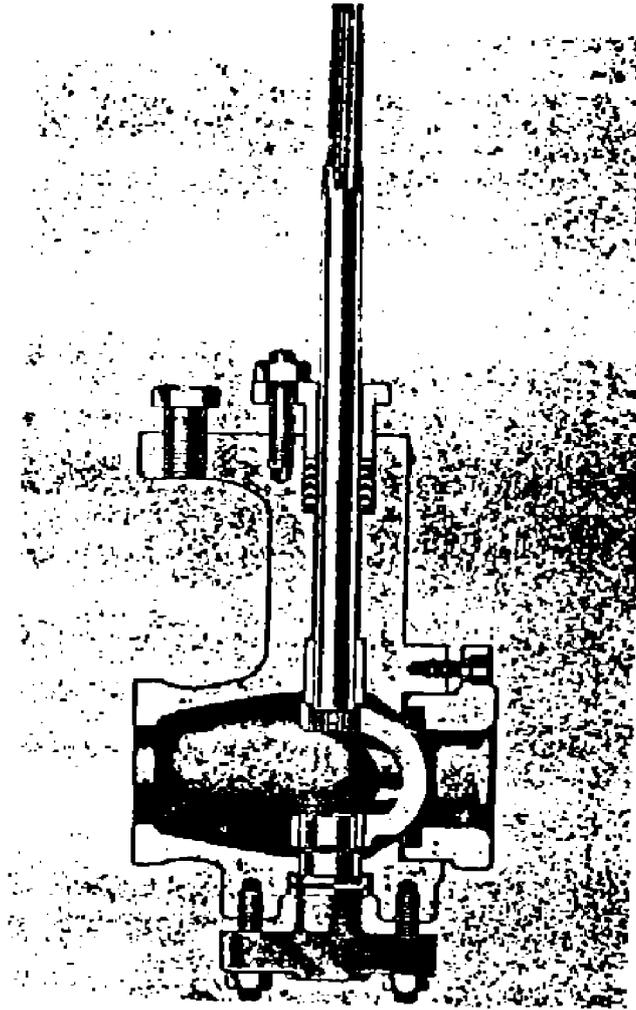
6.6.2 Ball valves

Ball valves may be considered for on-off and throttling services under moderate operating conditions.

Characterized ball valves may be used for fluids containing suspended solids or fluids likely to polymerize or crystallize (Fig. 9).

6.6.3 Emergency shut-off valves

For emergency shut-off valves on fuel service Ball Valve shall be used for temperature up to 150°C. Above this temperature single seated tight shut-off globe valves shall be used.



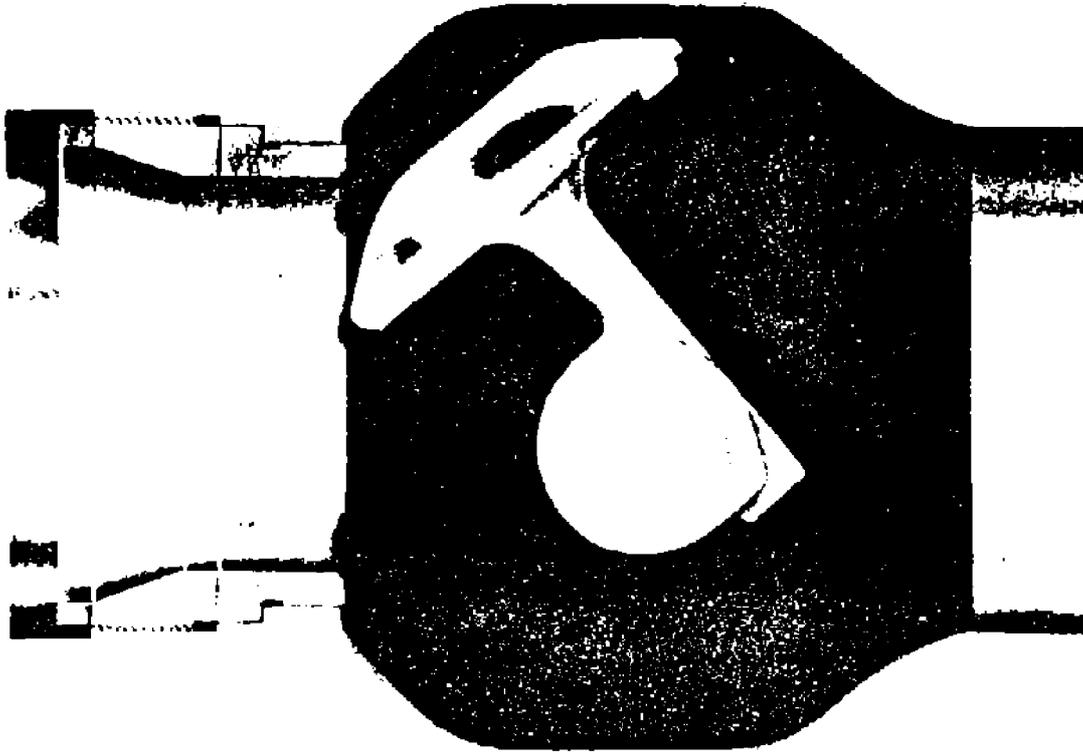
CHARACTERIZED BALL VALVE
Fig. 9

6.6.4 Plug valves

Plug valves may be considered for special applications such as throttling control on slurry services in chemical plants (Fig. 10).

6.6.5 Eccentric rotating plug valves

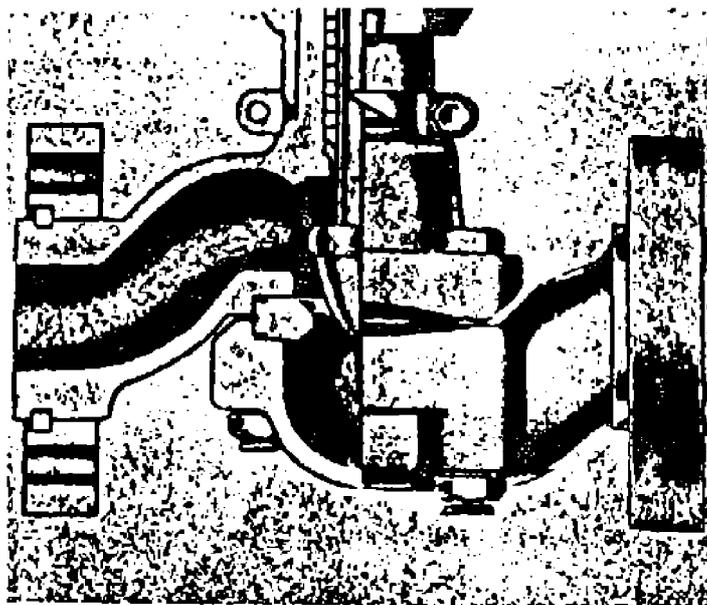
Eccentric rotating-plug valves are general substitute for globe body control valves provided that the application allows the use of long bolting (Fig. 10).



ECCENTRIC PLUG VALVE
Fig. 10

6.7 Special Type Control Valves

Special body types, such as angle, split body (Fig. 11), low noise (Fig. 12) low flow valves shall be considered where the process fluid may be erosive, viscous or carrying suspended solids and or high differential pressure is required. Flushing connection shall be provided on slurry services.

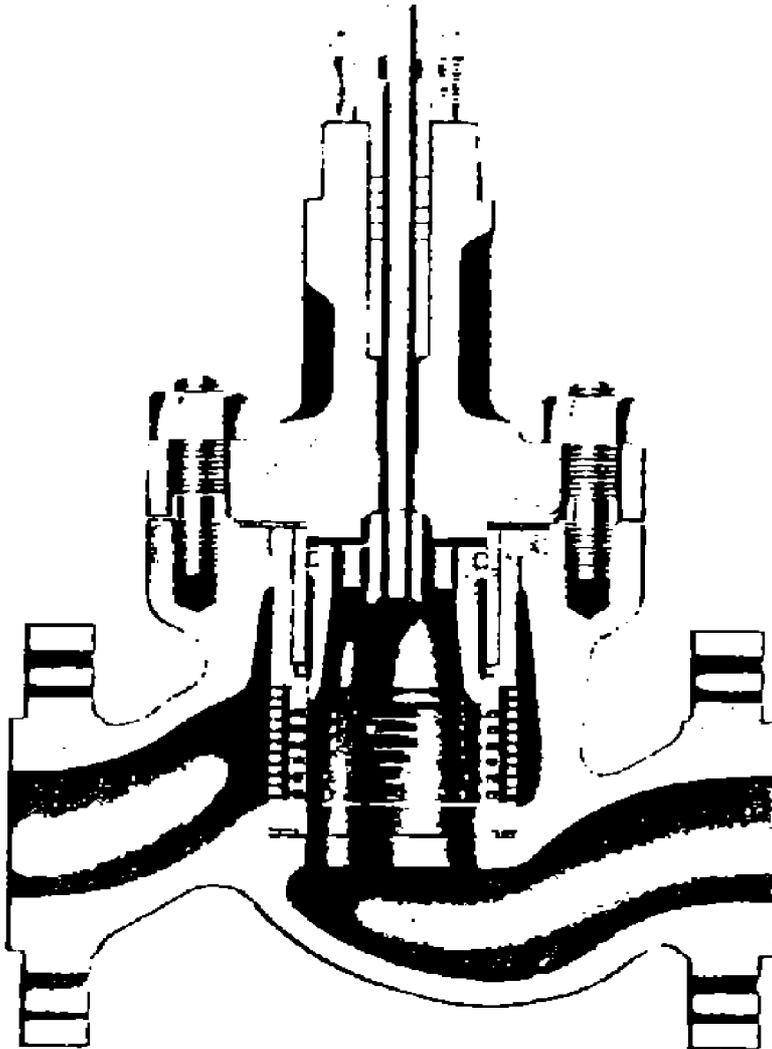


SPLIT BODY VALVE, STEM GUIDED
Fig. 11

6.7.1 Low noise valves

For services at high pressure drops, the application of a conventional valve trim often results in very high fluid velocities and unacceptable high noise levels.

Where this would be the case, the fluid velocity must be controlled by using a valve trim having specially designed multiple orifices in series and/or in parallel, or having a tortuous path forcing the fluid to change the direction continuously, causing high turbulence friction (Fig. 12).



GLOBE BODY VALVE, LOW NOISE TRIM
Fig. 12

6.7.2 Low flow or miniature valves

Where control valves with a very low capacity factor (C_v) are required, these may be of the miniature valve type with flanged or threaded connections and a needle trim.

7. CONTROL VALVE BODY SIZE AND FLANGE RATING

7.1 Globe Body Valves

7.1.1 Body sizes

Nominal body sizes for the globe body, shall be selected from the following series;

(Inches)	1	1½	2	3	4	6	8	10	12	etc.
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The use of odd sizes such as 1¼", 2½", 5", 7", 9" etc., shall be avoided. 1½ "and 3" valves are less common in petroleum industries.

7.1.2 The minimum globe control valve body size to be used shall be 1 inch screwed, unless flange type is specified, and the internal trim size shall be in accordance to the requirements as specified in data sheet.

7.1.3 Body sizes smaller than 1 inch may be used for special applications, and pressure regulation services. For valve sizes smaller than 1 inch, reduced trim in 1 inch size bodies normally will be preferable.

7.1.4 Flange rating-Globe control valves shall normally have flanged ends, but flangeless bodies may be considered for special applications.

7.1.5 The flange rating shall generally be in accordance with the piping class, but for carbon steel bodies the flange rating shall be class 300 minimum.

For pressure-temperature rating of globe body control valves reference should be made to IPS-M-PI-110/2.

7.1.6 All globe body control valve manifolds and by pass valves shall follow the piping class and ratings. The dimensions however, shall be in accordance with the recognized standard such as ANSI/ISA RP-75.06.

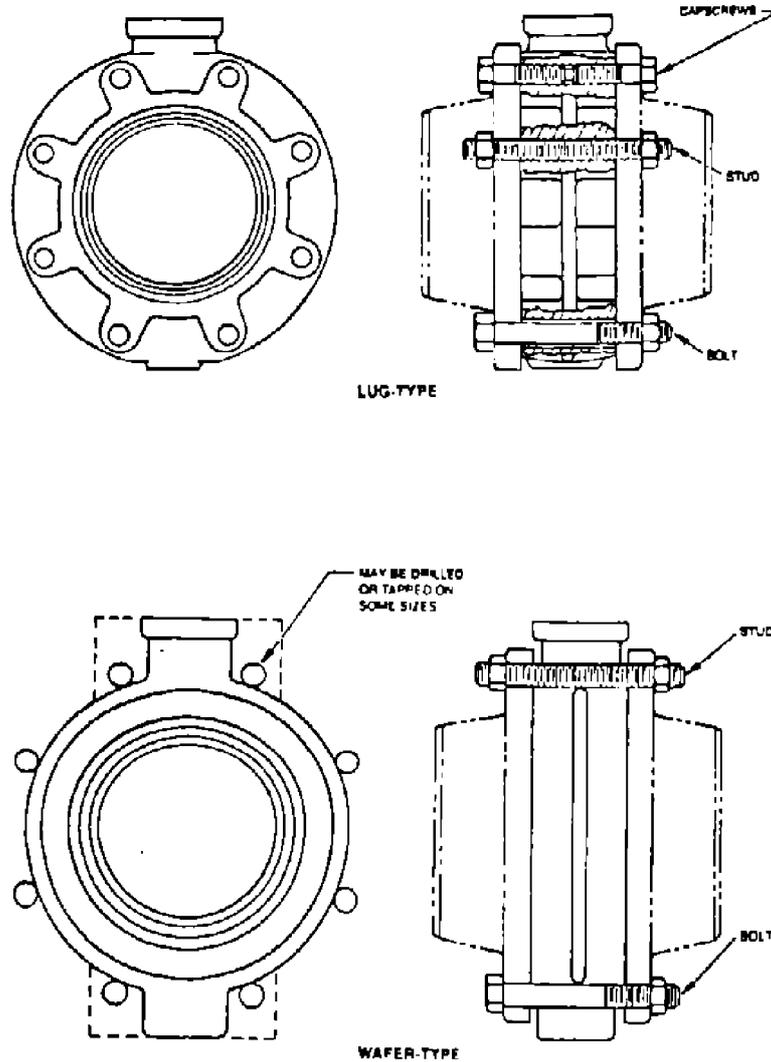
7.2 Butterfly Body Valves

7.2.1 Lug-type and wafer-type butterfly valves shall have body pressure-temperature ratings for the selected American Society of Testing and Materials (ASTM) material specification in accordance with the applicable ANSI B-16 standard as listed in 2., this Standard.

7.2.2 The wafer type butterfly valves, other than lugged type, shall be provided with or without holes for the passage of bolts securing the connecting flanges dependent up on valve design.

Lugged type, wafer valves shall be supplied with threaded or drilled holes the lugs to the size, nominal pressure rating and type of connecting flange.

7.2.3 The end flanges of double flanged steel butterfly control valves shall be cast or forged integral with the body.

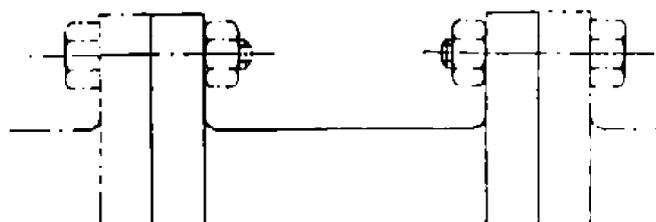


ILLUSTRATIONS OF END TYPES AND EXTERNAL BOLTING OPTIONS
Fig. 13

7.2.3 For other types of valves such as eccentric rotating plug valves or Butterfly valves flanges shall be wafer type, i.e., suitable for installation between flanges.

7.2.4 Butterfly valves shall be one of the following types shown in Figs. 14 to 17, with metal or resilient seating or linings:

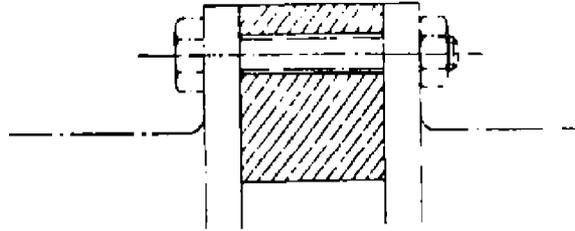
- a) Double flanged:** A valve having flanged ends for connection to pipe flanges by individual bolting.



BUTTERFLY VALVE: DOUBLE FLANGED TYPE
Fig. 14

b) Wafer: A valve primarily intended for clamping between pipe flanges using through bolting:

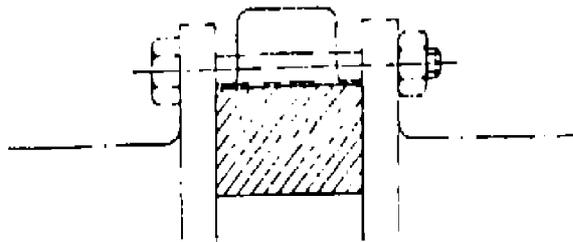
- 1) single flange;
- 2) flangeless;
- 3) u-section.



BUTTERFLY VALVE: SINGLE FLANGE WAFER TYPE
Fig. 15

Note:

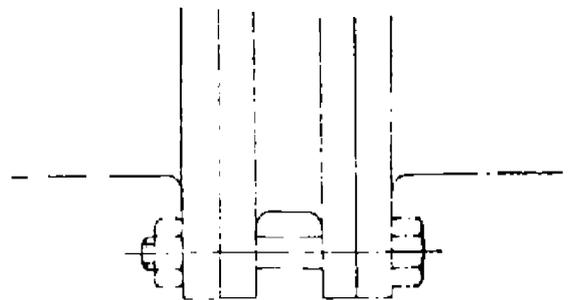
This type of valve when supplied with threaded holes may be suitable for terminal connections.



BUTTERFLY VALVE: FLANGELESS WAFER TYPE
Fig. 16

Note:

This type of valve when supplied with threaded lugs may be suitable for terminal connections.



BUTTERFLY VALVE: U-SECTION WAFER TYPE
Fig. 17

Notes:

- 1) This type of valve may be suitable for the individual bolting of each flange to the pipework, but this cannot be assumed.
- 2) This type of valve may be suitable for terminal connections.

7.3 Face-to-Face Dimensions

7.3.1 Face-to-face dimensions of flanged-bodied globe style control valves shall comply with the recognized standard such as ANSI/ISA-S 75.03, (Table 2).

7.3.2 Face-to-face dimensions of Butterfly valves shall be in accordance with the recognized standard such as BS-5155, (Table 3).

7.3.3 Tolerances on Face-to-Face dimensions for Butterfly valves shall be in accordance with BS-5155 standard, (Table 4).

7.3.4 Flange dimensions of Butterfly valves Class 125 shall be in accordance with the recognized standard such as BS-5155, (Table 5, if flange type is specified).

7.3.5 Flange dimensions of Butterfly body control valves shall be in accordance with the recognized standard such as of BS-1560: Part 2.

For pressure-temperature rating of Butterfly control valves reference should be made to IPS-M-PI-110/5.

TABLE 2 - FACE-TO-FACE DIMENSIONS FOR FLANGED GLOBE-STYLE CONTROL VALVES

NOMINAL VALVE SIZE	(ANSI CLASSES 150)		(ANSI CLASSES 300)		(ANSI CLASS 600)		TOLERANCE	
	DIMENSION "A"		DIMENSION "A"		DIMENSION "A"			
INCHES	mm	INCHES	mm	INCHES	mm	INCHES	mm	INCHES
½	184	7.25	190	7.50	203	8.00	±1.6	±0.062
¾	184	7.25	194	7.62	206	8.12	±1.6	±0.062
1	184	7.25	197	7.75	210	8.25	±1.6	±0.062
1½	222	8.75	235	9.25	251	9.88	±1.6	±0.062
2	254	10.00	267	10.50	286	11.25	±1.6	±0.062
2½	276	10.88	292	11.50	311	12.25	±1.6	±0.062
3	298	11.75	318	12.50	337	13.25	±1.6	±0.062
4	352	13.88	368	14.50	394	15.50	±1.6	±0.062
6	451	17.75	473	18.62	508	20.00	±1.6	±0.062
8	543	21.38	568	22.38	610	24.00	±1.6	±0.062
10	673	26.50	708	27.88	752	29.62	±1.6	±0.062
12	737	29.00	775	30.50	819	32.25	±3.2	±0.125
14	889	35.00	927	36.50	972	38.25	±3.2	±0.125
16	1016	40.00	1057	41.62	1108	43.62	±3.2	±0.125



TABLE 3 - FACE-TO-FACE DIMENSIONS OF BUTTERFLY VALVES

1	2	3	4	5	6	7
NOMINAL SIZE (INCHES)	DOUBLE FLANGED SHORT	DOUBLE FLANGED LONG	WAFER SHORT	WAFER MEDIUM	WAFER LONG	WAFER
	FACE-TO-FACE DIMENSION FOR NOMINAL PRESSURES NOT EXCEEDING		FACE-TO-FACE DIMENSIONS FOR NOMINAL PRESSURES NOT EXCEEDING			CLASS 300
	CLASS 150	CLASS 300	CLASS 150	CLASS 150	CLASS 150	
	mm	mm	mm	mm	mm	mm
1½	106	140	33	—	—	—
2	108	150	43	—	—	—
2½	112	170	46	—	—	—
3	114	180	46	—	64	49
4	127	190	52	—	64	56
5	140	200	56	—	70	64
6	140	210	56	—	76	70
8	152	230	60	—	89	71
10	165	250	68	—	114	76
12	178	270	78	—	114	83
14	190	290	—	92	127	127
16	216	310	—	102	140	140
18	222	330	—	114	152	160
20	229	350	—	127	152	170
24	267	390	—	154	178	200
28	292	430	—	—	229	—
32	318	470	—	—	241	—
36	330	510	—	—	241	—
40	410	550	—	—	300	—
48	470	630	—	—	350	—
56	530	710	—	—	390	—
64	600	790	—	—	440	—
72	670	870	—	—	490	—
80	760	950	—	—	540	—

Note:

Wafer type valves may not be available in all combinations of materials and face-to-face dimensions.

TABLE 4 - TOLERANCES ON FACE-TO-FACE DIMENSIONS OF BUTTERFLY VALVES

FACE-TO-FACE DIMENSION	TOLERANCE
mm	mm
Up to and including 200	±1
Above 200 up to and including 400	±2
Above 400 up to and including 600	±3
Above 600 up to and including 800	±4
Above 800	±5

TABLE 5 - DIMENSIONS OF CLASS 125 (CAST IRON) FLANGES OF BUTTERFLY VALVES

1	2	3	4	5	6	7	
NOMINAL SIZE OF VALVE		DIAMETER OF FLANGE	MINIMUM THICKNESS OF FLANGE	DIAMETER OF BOLT CIRCLE	NUMBER OF BOLTS	DIAMETER OF BOLT HOLES	
	inch	mm	mm	mm		mm	inch
	1½	127	14.3	98.4	4	15.9	5/8
	2	152	15.9	120.6	4	19.0	¾
	(2½)*	178	17.5	139.7	4	19.0	¾
	3	190	19.0	152.4	4	19.0	¾
	4	229	23.8	190.5	8	19.0	¾
	5	254	23.8	215.9	8	22.2	7/8
	6	279	25.4	241.3	8	22.2	7/8
	8	343	28.6	298.4	8	22.2	7/8
	10	406	30.2	362.0	12	25.4	1
	12	483	31.8	431.8	12	25.4	1
	14	533	34.9	476.2	12	28.6	1 1/8
	16	597	36.5	539.8	16	28.6	1 1/8
	18	635	39.7	577.8	16	31.8	1 ¼
	20	698	42.9	635.0	20	31.8	1 ¼
	24	813	47.6	749.3	20	34.9	1 3/8

Note:

This size has been retained only for the purpose of replacing existing valves. Its use for new construction on piping systems using BS 1560: Part 2 flanges, should be avoided.

Class 125 (cast iron) valves shall be used on special applications such as slurry and utility services.

8. CONTROL VALVE SIZING AND CHARACTERISTICS

8.1 Control Valve Sizing

8.1.1 Control valve sizing is necessary to optimize operation, provide sufficient rangeability, and minimize cost. The key to correct control valve sizing is the proper determination of the required valve capacity coefficient (C_V).

By definition (C_V) is the number of gallon per minute of water at 15°C that will pass through a given flow restriction with a pressure drop of 1 pound per square inch. For example, a control valve that has a maximum flow coefficient (C_V) of 12 has an effective port area in the full open position such that it passes 12 gallons per minute of water with a pressure drop of 1 pound per square inch.

Determination of required (C_V) for a given application may be accomplished through formula or slide rule methods. For detailed information regarding control valve sizing equations refer to ISA-S-75.01 or see Appendix C of this Standard.

8.1.2 Working equations are derived from the fundamental hydraulic equation and is converted to customary engineering units, then, equation becomes,

$$Q = C_V \sqrt{\frac{\Delta P}{G}}$$

Where C_V is the experimentally determined coefficient, ΔP is the differential pressure across the valve, and G is the specific gravity of the liquid, and Q is the quantity of liquid.

8.1.3 The equations of this Standard are based on the use of experimentally determined capacity factors obtained by testing control valve specimen according to the procedures of ANSI/ISA S75.02 "Control Valve Capacity Test Procedure".

8.1.4 The equations are used to predict the flow rate of fluid through a valve when all factors, including those related to the fluid and its flowing condition, are known. When the equations are used to select a valve size it is often necessary to use capacity factors associated with the fully open or rated condition to predict an approximate required valve flow coefficient (C_V).

8.1.5 In using these methods, full knowledge of actual flowing conditions is essential. The primary factors that should be known for accurate sizing are:

- 1) The upstream and downstream pressures at the flow rates being considered.
- 2) The generic identity of process fluid.
- 3) The temperature of the fluid.
- 4) The fluid phase (gas, liquid, slurry and so forth).
- 5) The density of the fluid (specific gravity, specific weight, molecular weight).
- 6) The viscosity (liquids).
- 7) The vapor pressure (liquids).

8.1.6 Valve sizing shall be based on a maximum sizing capacity of 1.3 times the normal maximum flow or 1.1 times the absolute maximum flow, whichever is greater. The sizing pressure drop (ΔP sizing) shall be sufficient to obtain good regulation at the normal maximum case, maintain maximum quantity as well as the normal minimum quantity within the rangeability of the selected valve.

If in primary design stage maximum flow is not available, then valves shall be selected to have twice the C_V required for normal design flow at specified conditions.

8.1.7 Control valves with inherent high pressure-recovery characteristics can cause cavitation when fluid pressure and temperature conditions would indicate. Valves with low pressure recovery, special trim should be used to minimize or prevent cavitation.

8.1.8 Flashing, like cavitation, can cause physical damage and decreased valve capacity. Manufacturers should be consulted for recommendations.

8.1.9 The pressure drop across the control valve at maximum process flow shall be at least 20% of the pressure drop across the control valve at normal flow.

- a) The control valve shall be sized such that the C_V value of the control valve for maximum process flow with the pressure drop across the control valve at maximum process flow is approximately 80% of the maximum C_V value for that control valve. Furthermore, the control valve shall never have less than 25% lift for minimum process flow at the specified pressure drop.

If neither a maximum nor a minimum process flow is stated, these flows shall be assumed to be 120% and 80% respectively of the normal process flow.

Sizing calculations should be checked for at both extremes to assure controllability over the entire range of the flow rates and pressure drop.

8.1.10 Butterfly valves shall be sized for maximum angle operating of 60 degrees. Proposals to use angles greater than 60 degrees shall be submitted to the purchaser for approval.

8.1.11 Shafts of rotary actuated valves shall be sized for pressure drop equal to maximum upstream pressure.

8.1.12 Control valve body size normally shall not be less than half that of normal line size.

8.1.13 Control valves in flashing services shall be sized using valve recovery coefficient (K_m) and critical pressure correction factor (r_c) and are defined as follows:

$$K_m = \frac{4 P_m}{4 P_{vc}} = \frac{4 P_m}{P_1 P_{vc}}$$

and

$$4 r_c = \frac{P_{vc}}{P_v}$$

Where:

- ΔP_m = Pressure drop across the valve body required to produce choked flow in Psi.
- ΔP_{vc} = Pressure drop between valve inlet and vena contracta at choked flow in Psi.
- P_1 = Valve inlet pressure in Psia.
- P_{vc} = Vena contracta pressure at choked flow in Psia.
- Δr_c = Theoretical critical pressure ratio.
- P_v = Vapor pressure of fluid in Psia.

For more details, reference should be made to ISA Handbook of control valves (Chapter 6) or equivalent methods.

8.1.14 Cavitation effects on flow in control valves due to reduction of the calculated liquid flow coefficient of a valve C_V , will be observed if pressure drop is increased beyond a certain limit at a constant up-stream pressure.

The cavitation index, K_c , defines the first point where reduction of C_V can be observed from experimental data. The recovery coefficient k_m approximates the second point where flow becomes choked.

$$K_{sc} = \frac{4 P}{P_1 P_v}$$

Where:

- K_{sc} = System cavitation parameter
- ΔP = Pressure drop across the valve, Psi
- P_1 = Absolute upstream pressure, Psia
- P_v = Absolute vapor pressure of fluid flowing, Psia

K_m and K_c can be considered as two values of the system cavitation parameter K_{sc} .

8.2 Control Valve Characteristics

Control valve flow characteristics are determined principally by the design of the valve trim. The three inherent characteristics available are quick opening, linear, and equal percentage. These are shown in Fig. 18. A modified percentage characteristic generally falling between the linear and equal percentage characteristics is also available.

The three inherent characteristics can be described as follows:

1) Quick Opening

As the name implies, this characteristic provides a large opening as the plug is first lifted from the seat, with lesser flow increase as the plug opens further. This type is most commonly used where the valve will be either open or closed with no throttling of flow required.

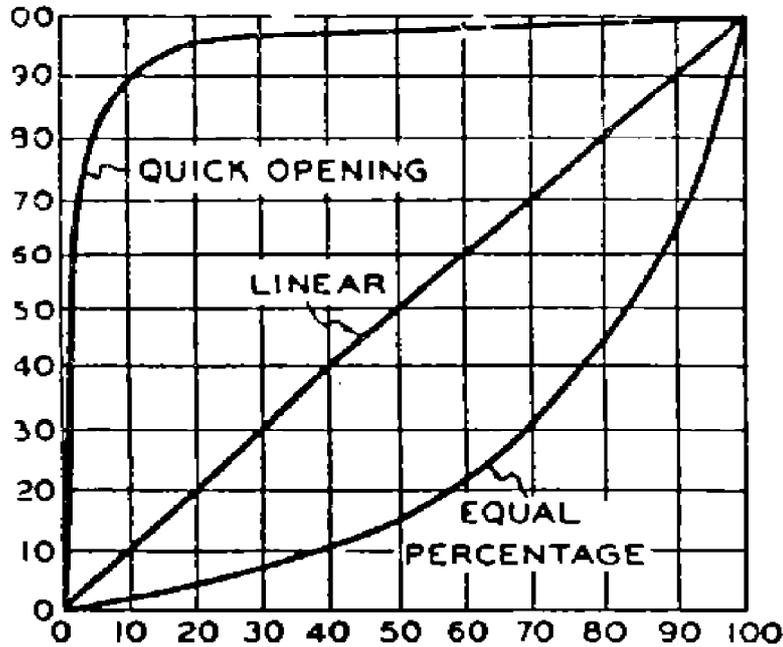
2) Linear

Linear trim provides equal increases in C_V for equal increases in stem travel. Thus the C_V increase is linear with plug position throughout its travel.

3) Equal Percentage

Equal percentage trim provides equal percentage increases in C_V for equal increments of stem travel. This is accomplished by providing a very small opening for plug travel near the seat and very large increases toward the more open position. As a result, a wide rangeability of C_V is achieved.

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



PERCENT OF VALVE OPENING REPRESENTATIVE
INHERENT FLOW CHARACTERISTIC CURVES

Fig. 18

- 8.2.1 Characteristic of the inner valve shall normally be equal percentage except where system characteristics indicate otherwise. Linear and quick opening characteristics shall be used where required. In general linear trim shall be used only for Split-Range service or where control valve pressure drop remains constant over the range of 10% to 100% of flow capacity.
- 8.2.2 Shut off valves should normally have quick closing or equal percentage characteristic, but another characteristic (such as modified equal percentage) may be required for special cases, e.g. to avoid or reduce the consequence of hydraulic shock.
- 8.2.3 Characteristics of valves may change due to particular requirements.
- 8.2.4 Butterfly and angle valves and characterized ball valves ("V-Ball") shall normally have equal percentage characteristics.
- 8.2.5 Three-way valves in control services shall normally have linear characteristics.
- 8.2.6 Valves with shut-off function shall be single seated.
- 8.2.7 The pressure drop across the control valve at maximum flow shall be at least 25% of the pressure drop across the control valve at normal flow.
- 8.2.8 Three-way valve shall be capable of operating against the maximum differential pressure that can exist across a single port. Each 3-way valve shall be specified as flow-mixing or flow splitting in accordance with the intended application.
- 8.2.9 The action of the valves on failure of the operating medium shall be determined by process requirements with regard to safe operation and emergency shut-down.

8.2.10 Extension Bonnets shall be provided on services above 232°C and below -6.7°C or in accordance with the manufacturer's recommendation.

8.2.11 Pressure Balanced Valves of the double diaphragm type shall be considered for use on fuel gas to heaters in temperature control systems. When a single diaphragm type is used, a pneumatic ratio relay shall be installed in the control air line with the input-output ratio as required.

8.2.12 Control valves installed in pipe lines should normally be at least one pipe size smaller than the computed line size. This is to allow margin for future expansion and a better controllability of the process.

8.2.13 Where it is necessary to reduce from line size to control valve size, swaged reducers shall be used between the block valves and the control valve. Sufficient spacing between block valves shall allow for installation of larger size control valves.

8.2.14 Over sized bodies with reduced trims shall be used for valves in severe flashing or cavitating service. Angle type or multiple seat type valves may be considered for this service.

8.2.15 Valves used in pairs, as 3 way valves, including rotary actuated valves such as Ball or Butterfly types, shall have linear characteristics. Characterized positioners may be used to meet this requirement. In this case calibration for the required characterization must be done by the valve manufacturer.

8.2.16 Gas compressor recycle control valves shall have linear characteristics.

8.2.17 Valves in pressure reducing service, where the pressure drop is constant, shall have linear characteristics.

9. CONTROL VALVE MANIFOLD DESIGN

9.1 Control valves and bypass valves are mostly manifolded in piping systems to allow manual manipulation of the flow through the systems in those situations when the control valve is not in service. For more information, reference should be made to IPS-C-IN-160.

9.2 For application information and guidance reference shall be made to ISA Handbook of control valves, API RP 550 or other relevant publications.

9.3 Dimensions for flanged globe control valves shall be used as per ANSI/ISA-S75.03 standard.

9.4 Control valve body nominal size covered by the designs are 1, 1½, 2, 3, 4, and 6 inches.

9.5 Reference should be made to ISA RP 75.06 "CONTROL VALVE MANIFOLD DESIGN" for additional information and dimensions for all ANSI classes.

10. CONTROL VALVE BLOCK AND BYPASS VALVES

10.1 Where significant future expansion is not anticipated, a less flexible but more economical approach that gives a minimum acceptable design is to make the block valves one size larger than the control valve (but not larger than line size).

The bypass line and valve should normally have a capacity at least equal to the calculated or required C_V of the control valve, but not greater than twice the selected C_V of the control valve.

10.2 Bypass valves in sizes of 4 inches or less are usually globe valves that allow throttling. For larger sizes, because of cost, gate valves are normally used.

10.3 Where block valves are provided, vent valves shall be fitted between them so that pressure may be relieved and the control valve drained when the block valves are closed. Suitable drain lines shall be provided where necessary.

10.4 Vent and drain connections shall not be less than ¾ inch nominal bore.

10.5 A by-pass connection and valve shall be installed around each control valve unless other means are available for manual control when the control valve is out of service.

10.6 Consideration shall be given to the elimination of by-pass and block-valves around control valves sizes 2 inches and over, but this shall be by agreement with the user.

10.7 Block and by-pass valve assemblies should be avoided in the following instances:

10.7.1 On hydrogen service.

10.7.2 Around three-way valves.

10.7.3 Around self-acting steam pressure reducing valves.

10.7.4 Around control valves forming part of a protective system.

10.8 Block and by-pass valve assemblies shall be provided in the following instances:

10.8.1 Where a valve controls a service common to a number of plants.

10.8.2 Where valves are in continuous operation and there is not sufficient assurance of reliability over the anticipated period between plant overhauls, e.g., on erosive or corrosive service or where the temperature is below 0°C. or above 180°C. The cost of a failure shall also be taken into account.

10.8.3 Where failure of the control valve would necessitate continuous operator attention, e.g., on the fuel control to heaters.

10.9 Where by-pass valves are not provided, a permanent side-mounted hand wheel shall be fitted to the control valve. Where the cost of the hand wheel is greater than the cost of block and by-pass valves, the latter shall be provided except on hydrogen service and protective service.

10.10 Where block and by-pass valves are not fitted initially adequate space should be allowed for possible future installation.

10.11 When control valves are placed in pre-stressed lines they shall be in a by-pass assembly to the main pipeline.

11. CONTROL VALVE PACKING AND SEALING

11.1 All valves shall be drilled and tapped to accept a gland lubricator except when otherwise specified in data sheet.

11.2 The bottom flange or the bottom of the body of a control valve shall not be drilled and tapped.

11.3 For special duties as specified in data sheet, e.g., toxic, control valve stems should be bellows sealed, with an independent gland seal, the enclosed space being monitored for bellows leakage.

11.4 When sealing by bellows is not possible, a purge should be used, monitored for flow failure. Bellows seals may also be required to prevent leakage of penetrating liquids.

11.5 On clean fluids, interlocking self lubricating gland packings with spring followers may be used.

11.6 On higher temperature duties or where carbon or other deposits may settle on the stem, special packing should be used.

11.7 If dangerous fluids are encountered, horizontal lines shall be fitted with suitable drains on the under side. This does not replace the vent.

11.8 Packing materials for butterfly valves shall be suitable for the specified service conditions.

11.9 Where the controlled liquid contains particles or materials which would damage the valve guide, stem or packing, a purge system shall be considered.

12. CONTROL VALVE NOISE AND VIBRATION CAUSED BY SONIC FLOW

12.1 Sonic flow occurs when the velocity of the fluid reaches the speed of sound in that medium.

At subsonic velocities the flow is characterized by turbulent mixing and this is responsible for the noise produced. This noise best described as a "hiss" for small jets or as a roar for larger jets has no discrete dominating frequency. Its spectrum is continuous with a single, rather flat maximum.

As pressure ratio increases past the critical ratio and the fluid reaches its sonic velocity, the sound emanating undergoes a fundamental change, while the roaring noise due to the turbulent mixing is still present, it may be almost completely dominated by a very powerful "whistle" or "serooch" of a completely different character. This noise is rather harsh and of a confused nature, becoming much more like a pure note.

At sonic flow, vibration can be caused in various, frequency bands due to vertical/horizontal movement of control valve components (20-80 KHz), impingement of fluid on control valve internals at high velocities (400-1600 Hz) aerodynamic noise from shock waves by the sonic velocities, (1200-4000 Hz), internal components vibrating at their natural frequencies (3000-6000 Hz) and high pressure drop gas services (above 8000 Hz). For guidance in specifications the permissible noise exposure, is noted below:-

<u>Duration hours per day</u>	<u>Sound level dB slow response</u>
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

12.2 Cause of Noise and Vibration

High pressure drop gives rise to sonic flow. Sonic flow generates shock waves which in turn produce high frequency noise and vibration (1.2 to 4.8 KHz). The noise has a characteristic whistle or scream at its peak frequency, is directional in nature when discharged into the atmosphere and even more dependent upon fluid jet pressure than the turbulent mixing noise of subsonic flow.

The most dangerous vibration occurs in frequency band 3 to 7 KHz and is the result of resonance by the valve parts. This can lead to failure due to metal fatigue.

12.3 The most effective method of solution is to remove the cause, that is the high pressure drop. Values of safe pressure drop may be taken from:-

$$\begin{array}{ll} \text{for subsonic conditions } \Delta P < 0.5 & Cf^2 P_1 \\ \text{for sonic conditions, } \Delta P \geq 0.5 & Cf^2 P_2 \end{array}$$

- ΔP = Pressure drop across valve, (P₁-P₂) bar
- P_1 = upstream pressure, bar Abs.
- P_2 = downstream pressure, bar Abs.
- Cf = critical flow factor for valve, dimensionless (obtained from valve manufacturer).

The absence of sonic flow means an absence of its effects of noise and vibration. In cases where pressure drop must remain high, a special type of "low-noise" control valve is recommended.

If the calculated sound pressure level (SPL) value of a reducing valve under maximum load exceeds the stated limit by only 5 to 10 dB, then one of the following simple cures must be considered:-

- a) Increase the pipe wall thickness downstream (doubling the wall thickness will decrease the SPL by 5 dB).
- b) Use acoustical isolation downstream. This will reduce SPL by 0.2 to 0.5 dB per mm of insulation, depending on the density of the insulating material.

12.4 If the valve noise is 10 dB above the selected limit, then one must choose a different approach such as the use of downstream, in line silencers. The silencers generally attenuate between 10 to 20 dB depending on the frequency range. The silencers must be installed directly adjacent to the valve body and that the valve outlet velocity is below sonic; (Say 1/3 Mach). Otherwise the silencer will act as a pressure-reducing device for which it is not suitable.

12.5 The use of expansion plates downstream of valves is recommended. The primary function of these plates is not to attenuate the valve noise, but to absorb some of the pressure reduction over the whole system. In this way the pressure across the control valve can be kept below critical. In a typical installation the expansion plate downstream flow area must be increased to compensate for the changes in the density due to pressure drop. For more information see IPS-E-SF-900.

13. CONTROL VALVE ACTUATORS

13.1 General

Definitions

For the purpose of this standard the following definitions apply:

Actuator

Any device designed for attachment to a general purpose industrial valve in order to provide the operation of valve.

The device is designed to operate by using motive energy which can be electrical, pneumatic, hydraulic etc. or a combination of these. The movement is limited by travel, torque or thrust.

Multi-Turn actuator

An actuator which transmits to the valve a torque for at least one revolution and shall be capable to withstand the thrust.

Torque

A turning moment transmitted through the mounting flanges and couplings.

Thrust

An axial force transmitted through the mounting flanges and couplings.

13.2 Control valve actuators should be selected, so that; on failure of the operating medium, the valve will automatically take a position (open, closed or locked) that will result in the safest configuration for the operating unit.

13.3 Actuator Travel Limit - In the opening direction, a stop shall be engaged before the valve plug reaches its travel limit. The stop shall have sufficient contact area to absorb any force transmitted to it. In the closing direction, the valve plug shall seat before the actuator reaches its travel limit.

13.4 Valve connection to the actuator shall be adjustable, with positive locking of the adjustment.

- 13.5** Rotary actuated valves (such as butterfly, ball) shall have shaft keyways that allow the action of the valve to be changed.
- 13.6** For Rotary actuated valves in cryogenic service, shaft thrust bearings shall be provided.
- 13.7** Standard spring range shall be 0.2-1 barg.
- 13.8** Handwheels, when specified, shall be mounted and designed to operate in the following manner:
- a) For globe valves, hand wheels shall be mounted on the yoke, arranged so that the valve stem can be jacked in either direction.
 - b) Neutral position shall be clearly indicated.
 - c) Handwheel operation shall not add friction to the actuator.
 - d) Clutch/Linkage mechanisms for handwheels on rotary valves shall be designed such that control of valve position is not lost when engaging the handwheel.
- 13.9** Pneumatic actuators should have as low as an operating pressure is practicable in order to minimize the need for spare capacity in the instrument air system. In no case may the operating pressure exceed 4 bar.
- 13.10** For shut-off valves, the actuators shall be capable of opening the valve against the full upstream pressure, with the downstream pressure assumed to be atmospheric.
- 13.11** For butterfly valves, the actuators shall have sufficient force for coping with all operating conditions from the fully closed position to the fully open position, and for coping with all pressure drop and torque requirements.
- 13.12** The stroking time of control valves shall be evaluated on the basis of the process control requirements. For critical analogue control systems such as surge control of compressors, the stroking time shall be less than 5 seconds. For other analogue control systems, longer stroking times may be acceptable.
- 13.13** For valves having spring-to-close action, the stroking time is determined by the spring force, the diameter of air exhaust ports in the actuator and solenoid valve, and the mechanical inertia of moving parts.

14. TYPES OF CONTROL VALVE ACTUATORS

There are many types of actuators for stroking control valves. These actuators may be classified into four (4) general types:

- a) Pneumatically operated diaphragm actuators.
- b) Piston (cylinder) actuators.
- c) Electro-Hydraulic actuators.
- d) Electro-Mechanical (Motor) operated actuators.

14.1 Pneumatically Operated Diaphragm Actuators

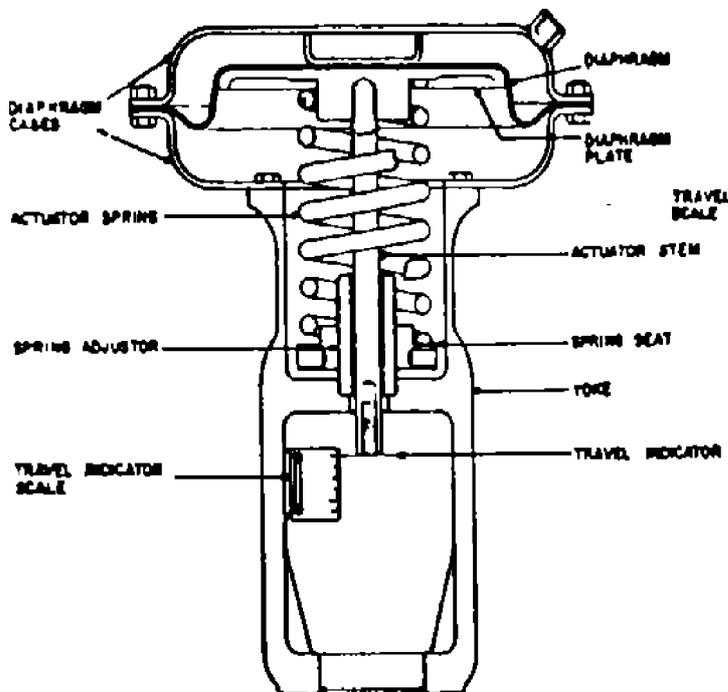
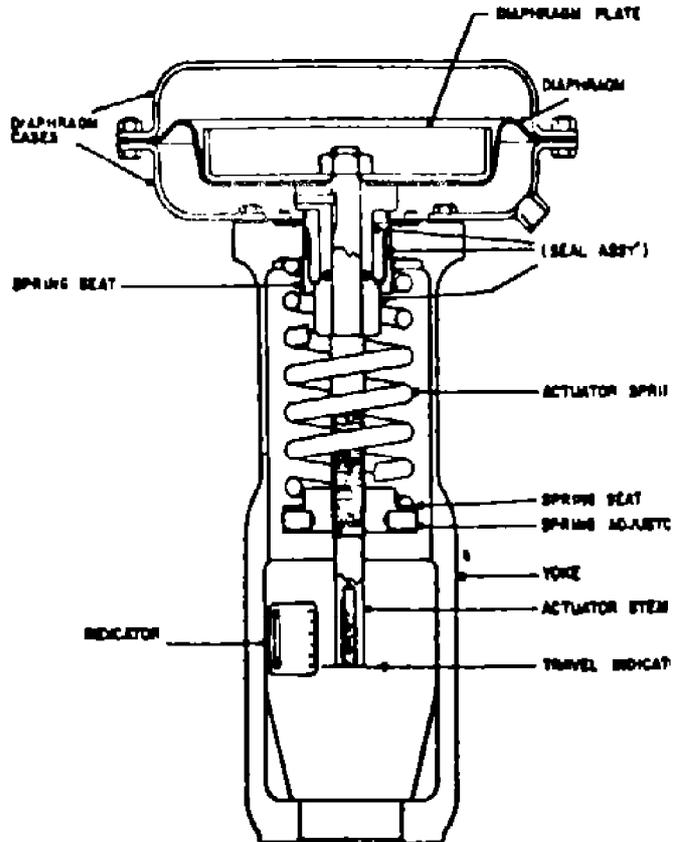
Control valves shall normally be operated by pneumatic diaphragm actuators. The actuator shall normally be operated between 0.2-1.0 bar, and 0.4-2.0 bar may be used as specified for full stroke. Where the control signal is electric, the electro-pneumatic convertor shall be used.

14.1.1 There are two types of diaphragm actuators:

- Direct acting
- Reverse acting

The actuator shall be designed to provide dependable on-off or throttling operation of automatic control valve.

Reverse acting diaphragm actuators using seals or glands are permitted only for those applications where the direct acting type of actuator is unsuitable (typical spring diaphragm actuators are shown in Figs. 19 and 20).



DIRECT-ACTING
DIAPHRAGM ACTUATOR
Fig. 19

REVERSE-ACTING
DIAPHRAGM ACTUATOR
Fig. 20

14.1.2 The air pressure required for stroking the valve may vary from the operating spring range. The maximum air pressure allowable on spring diaphragm actuators shall not exceed 4 bar.

14.2 Pneumatic and Hydraulic Cylinder or Piston Actuators

14.2.1 Cylinder actuators shall be used where a long stroke and high force is required, such as for dampers and louvers in large ducting for combustion air or flue gas services.

14.2.2 Piston actuators may be pneumatically or hydraulically operated.

14.2.3 The cylinders shall be connected directly to the valve as an integral part. Actuator may also be purchased separately and mounted at site.

14.2.4 For throttling applications the cylinder actuator shall be provided with a positioner mechanism and, where necessary, with a position transmitter. A pair of oil filter with isolating valves shall be installed as close as possible to the positioner.

14.2.5 Cylinder actuators on valves with provisions for manual (local) control shall be provided with external bypass valves if these are not integral with the actuator. Fourway valves are often require in the piping of the cylinder to allow local operation.

14.2.6 For hydraulic cylinders, the following points should be considered:

- a) If the hydraulic manifold is rigidly piped, it should be connected to the hydraulic fluid supply and return headers by flexible metallic hose.
- b) To assure a continuous supply of hydraulic to actuators, it is advisable to provide both an oil filter or strainer and a spare suitably valved and piped so that either unit may be removed and cleaned without shutting off the supply.
- c) Vent valve should be provided at high points in the hydraulic fluid system.
- d) Depending upon whether the valve served by the actuator will move if the hydraulic oil pressure is lost, it may be necessary to use automatic fluid trapping valves that lock the hydraulic fluid in the cylinders upon failure of the hydraulic system.

14.3 Electro-Hydraulic Actuators

14.3.1 Electro-hydraulic actuators may be used to operate a large rotary and sliding stem valves. Electrical signal of 4-20 mA or 10-50 mA d.c. may be used.

14.3.2 Electro-hydraulic actuators shall be used for an electronic control loop, where fast stroking speeds, high thrust, and long stroke are required.

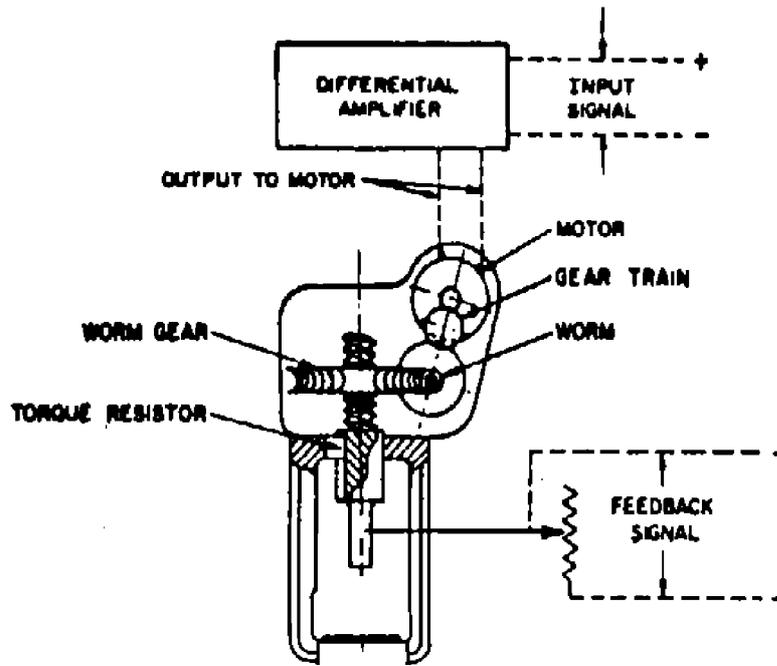
14.3.3 Electro-hydraulic actuators may be used at locations where a suitable air supply is not available.

14.4 Electro-Mechanical Actuators

14.4.1 The electro-mechanical valve actuator has essentially the same advantages as the electro-hydraulic actuator with respect to field use. It is capable of being used over long distances with only inconsequential signal transmission delays. It is also immune from the pneumatic system problem of freeze-up in extremely cold ambient conditions. Electro-mechanical actuators are still, however, generally more expensive, although more efficient, than electro-hydraulic units.

14.4.2 An Electro-Mechanical valve actuator is composed of a motorized gear train and screw assembly which drives the valve stem or rotary shaft valves. A typical example is shown schematically in Fig. 21. The varying input signal, whose magnitude corresponds to the required position of the inner valve stem, is fed into the positioner (usually a differential amplifier) and produces a voltage to actuate the motorized gear train and screw.

The resultant movement of the stem and the take-off attached to it and to a potentiometer or linear differential transformer, produces a voltage that increases with stroke, and is sent into the positioner. When the input signal voltages and feed back voltages are equal, the output voltage to the motor goes to zero and the motor stops with the valve stem at the required position. Conversely, when the voltages are not equal, the motor is run in the direction to make them equal.



AN ELECTRO-MECHANICAL VALVE ACTUATOR
Fig. 21

14.5 Motor Operated Actuators

14.5.1 The actuator shall consist of a motor driven, reduction gearing, thrust bearing where applicable, handwheel and local position indicator, together with torque and limit switches, space heaters terminals, control power transformer, and integral motor starter controls, all furnished as a self-contained, totally enclosed unit.

14.5.2 Motor starter for remote mounting shall be specified.

14.5.3 The motor shall be sized for torque requirement according to the valve size, operating differential pressure and temperature, and speed operation.

14.5.4 The actuator terminal box should be double-sealed in such a way that when the actuator terminal box cover is removed for the connection of incoming cables, the remaining electrical components are still protected by the watertight enclosure.

14.5.5 The valve and actuator mounting bracket must be capable of withstanding the stall torque of the actuator, with torque and limit switches disconnected.

14.5.6 The actuator shall provide both torque and position limitation in both directions. An automatic over-ride shall be provided to prevent the torque switches from tripping the motor on initial valve unseating.

14.5.7 The actuator shall be capable of operating at any mounting angle.

- 14.5.8** The actuator shall be designed so that there will be no release of high stem thrust or torque reaction spring forces when covers are removed from actuator gear box, even when the valve is under full line pressure conditions.
- 14.5.9** Failure of the motor, power, or motor gearing shall not prevent manual operation of the valve through the use of the handwheel. When the motor drive is declutched, the handwheel drive shall be engaged safely, with the motor running or stopped.
- 14.5.10** A means of locking the actuator in either the manual or motor condition shall be provided. If not locked in either position, starting of the motor shall automatically restore the power drive.
- 14.5.11** The actuator shall be capable of functioning within the ambient temperature range as specified in the job specification, but in any case not less than -15°C to $+80^{\circ}\text{C}$.
- 14.5.12** Clockwise rotation of the actuator handwheel shall close the valve. The handwheel drive must be mechanically independent of the motor drive, and gearing should be such as to permit emergency manual operation in a reasonable time.
- 14.5.13** The motor shall be of sufficient size to open and close the valve against maximum cold working pressure when voltage to motor terminals is within 10% of rated voltage. Motor nameplate rating shall be 380 volts, 3 phase, 50 Hz, unless otherwise specified.
- 14.5.14** Local pushbuttons shall be provided for "Open-Stop-Close" control of valve, with a lockable selector switch providing positions "local control only", "local and remote", "remote plus local stop" and "off" position.
- 14.5.15** Provision shall have made for the addition of extra sets of limit switches in each actuator. Each set shall be adjustable to any point of valve position. Each unit shall be provided with auxiliary contacts, rated 5 Amps at 110 V.a.c. for remote position indication. They shall be adjustable continuously in the range of open to close positions.
- 14.5.16** Actuators shall have an output speed of 0.4 rev/s unless otherwise specified on the data sheets (e.g., for high speed emergency isolation). No valve shall required more than two (2) minutes for full operation, i.e., from closed to fully open or open to fully closed.
- 14.5.17** In the case of high speed actuators a pulse timer should be included which will give variable slow down times for fast closing and fast opening, normally set to operate over the last 25% of the valve closure.
- 14.5.18** Provision shall also be made for remote operation through interposing relays supplied with d.c. power of 24 V unless otherwise specified.
- 14.5.19** Mechanical dial indication of valve position shall be incorporated in the actuator. Indication shall be continuous if valve is specified to be in regulating device.
- 14.5.20** Position limit switches shall be provided at each end of travel for remote indication and sequencing.
- 14.5.21** Torque and limit switches shall be easily adjustable without special tools or removal of switch assembly from the actuator. Repeatability of switch actuation shall be $\pm 5\%$ of set point.
- 14.5.22** Control power transformers when used, shall have fuse protection on the secondary. Fuses shall be readily accessible for replacement or deactivation at the terminal board.
- 14.5.23** An electrically and mechanically interlocked motor starter shall be provided in the actuator housing, unless the motor starter is specified for remote mounting.
- 14.5.24** All electrical components shall be prewired by the actuator vendor to a legibly marked terminal strip. Power and control wiring shall be segregated and insulated from each other. All wiring shall be identified by the Vendor, and access for maintenance provided.

- 14.5.25** Motor overload protection shall be provided. One or more winding temperature detectors embedded in the motor winding, or three thermal overload relays in the motor controller are acceptable. Either must be capable of being deactivated at the terminal board.
- 14.5.26** All motor operators shall be explosion proof approved in accordance with the requirements of the National Electrical Code latest edition (NFPA No. 70) for use in the hazardous area classification, or unless otherwise specified in individual data sheets.
- 14.5.27** All electrical equipment and motors shall be totally enclosed for outdoor services and should be water tight to IEC 34.5 and IEC 144-IP 67.
- 14.5.28** All electrical equipment used in hazardous area, shall also meet the electrical area classification requirements as per IPS-E-EL-110, and IPS-E-IN-100/1.
- 14.5.29** Vendor shall supply the valve actuator compatible with the valve. All information required for sizing the actuator shall be obtained from the purchaser and/or Valve Supplier.
- 14.5.30** Torque requirements of valve and torque characteristics of the actuator shall be supplied to the Purchaser for approval.
- 14.5.31** The actuating unit shall include a 3-phase electric motor, reduction gearing geared limit switches, and torque switches, space heaters, terminals, together with a handwheel for manual operation with declutching lever and valve position indicator.
- 14.5.32** All gearing shall be totally enclosed and continuously lubricated. All shafts shall be mounted on ball or roller bearings. Limit switch drive shall be stainless steel or bronze.
- 14.5.33** Power terminals shall be of stud type, segregated by an insulating cover. Four conduit entrance taps shall be provided as a minimum. Each tap will be provided with standard electrical connections in metric type such as M20.
- 14.5.34** The actuator terminal box should be double sealed in such a way that when the terminal box cover is removed for the connection of incoming cables the remaining electrical components are still protected by the watertight enclosure.
- 14.5.35** The actuator shall have an integral motor starter, Local controls and lamp indication. Provide phase discriminator relay.
- 14.5.36** The starter shall include a mechanically and electrically interlocked reversing contactor, with control transformer having a grounded screen between primary and secondary windings. The common point of contactor coils and secondary winding shall also be grounded, so that any ground fault will cause contactors to drop-out. Terminals for remote controls shall be provided.
- 14.5.37** The starter components shall be readily accessible for inspection without disconnecting external cables. Internal wiring shall be number-identified at both ends.
- 14.5.38** Lamp indication of "close" (Green), intermediate (white) and "open" (Red) positions shall be provided.
- 14.5.39** Open and close torque and/or position limit switches, plus two auxiliary limit switches at each end of travel shall be provided. Switch ratings shall be 5 Amps at 115 V.a.c or as specified in data sheet.
- 14.5.40** Internal control wiring of 5 Amp tropical grade PVC cable shall be provided, terminating in a separately sealed housing with stud terminals. The 3 phase leads of the motor shall be brought to separately stainless studs.
- 14.5.41** The motor shall be pre-lubricated and all bearings shall be of anti-frictions type.
- 14.5.42** The motor shall be sized for the torque requirements according to the valve size, operating pressure and temperature, and speed operation.
- 14.5.43** The motor shall have class "B" insulation, short time rated, with burn-out protection provided.

14.5.44 The motor shall be of sufficient size to open and close the valve against maximum differential pressure when voltage to motor terminals is within 10% of rated voltage. Motor name plate rating shall be 380 volts, 3 phase, 50 Hz.

15. ACTUATOR CONSTRUCTION MATERIALS

15.1 Materials of construction shall be manufacturer’s standard for the specified environmental exposure.

15.2 The material of diaphragm housing shall be steel, unless otherwise specified. For piston type actuators aluminum housing are acceptable except for valve on depressurizing or emergency shut-off services. In special cases such as for the larger sizes of butterfly valves, consideration may be given to (long-stroke) cylinder actuators.

15.3 The enclosure housing the electrical components of a valve shall be made of iron, steel, brass, bronze, aluminum, or an alloy containing not less than 85 percent aluminum. A metal such as zinc or magnesium or other alloys shall not be used.

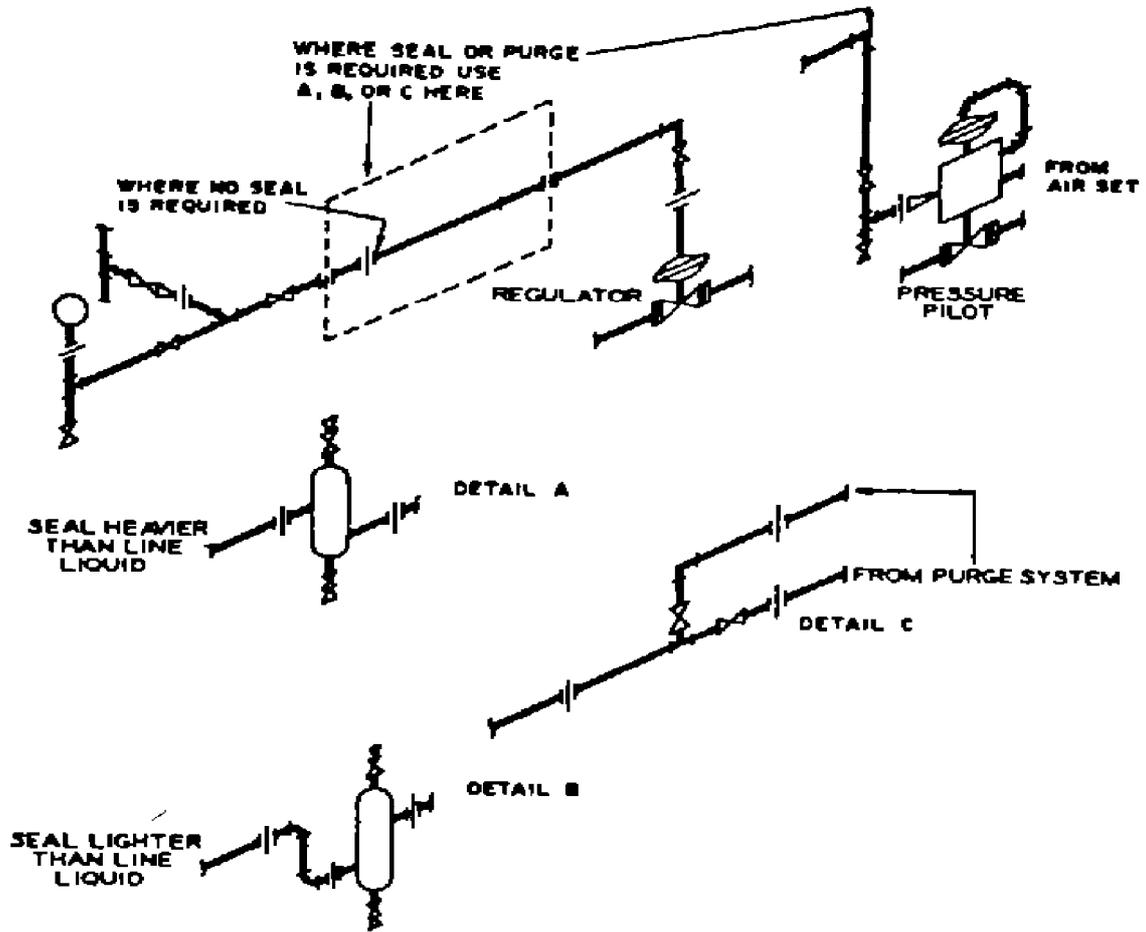
15.4 Copper shall not be used for an enclosure for use in Class I group A locations. A copper alloy shall not be used for an enclosure unless it is coated with tin nickel or other acceptable coating, or unless the copper content of the alloy is not more than 30 percent.

15.5 Construction material of actuators may be considered and selected according to the requirements. The following materials shall be considered for different parts of actuators:

- Diaphragm Casing** : **Steel, cast iron or cast aluminum**
- Diaphragm** : **Nitrile on nylon or nitrile on polyester**
- Diaphragm plate** : **Cast iron, cast aluminum or steel**
- Actuator spring** : **Alloy steel**
- Spring adjuster** : **Steel**
- Spring seat** : **Steel or cast iron**
- Actuator stem** : **Steel**
- Travel indicator** : **Stainless steel**
- O-Rings** : **Nitrile**
- Seat bushing** : **Brass**
- Stem connector** : **Steel zinc plated**
- Yoke** : **Iron or steel**

16. SELF-ACTUATED REGULATORS

The self-actuated regulator is a variation of the diaphragm actuator and normally uses the process fluid as the operating medium. For pressure applications, some self-actuated regulators use bellows instead of diaphragms for the actuator. For temperature applications, bellows with a filled system and bulb shall be used instead of diaphragms. Piping arrangements are shown in Fig. 22.



PIPING AT REGULATOR VALVE OR PRESSURE PILOTS
Fig. 22

16.1 Definitions

A regulator is a very simple control device in which all of the energy to operate it is derived from the controlled system. Consider using a regulator first whenever you have a requirement for:

- Pressure control
- Level control
- Flow control

All regulators, whether they are being used for pressure, level of flow control, fit into one of the following two basic categories:

- 1) Direct-operated
- 2) Pilot-operated

16.1.1 Characteristically, direct-operated regulators are adequate for narrow-range control, and where the allowable change in outlet pressure can be 10 to 20 percent of the outlet pressure setting.

16.1.2 Pilot-Operated regulators are preferred for broad-range control, or where the allowable change in outlet pressure is required to be less than 10 percent of the outlet pressure setting. They are also commonly used when remote set point adjustment is required for a regulator application.

16.1.3 The globe-style pilot operated backpressure regulators or relief valves are used in gas or liquid service to maintain pressure on oil and gas separators and in pressure relief application in gas distribution systems.

With the pilot, pressure can be controlled, and set pressure is varied to individual requirement by the adjusting screw on the pilot. Pilot exhaust can be piped into the down-stream line or vented to the atmosphere on gas service, but must always be piped downstream on liquid service.

16.1.4 Direct-Operated regulators are used to provide constant reduced pressure to pneumatic instrumentation and other control equipments.

16.1.5 Pilot-Operated service regulators are ideal for applications involving pressure factor measurement.

16.1.6 Construction material shall be selected according to the process requirement, and indicated as per data sheet.

- **Body material and spring case** : Cast iron, steel or stainless steel.
- **Major metal internal parts** : Brass or stainless steel.
- **Valve plug seating surfaces and diaphragm** : Neoprene or stainless steel.

16.2 Self-Actuated Pressure Regulator Characteristic

16.2.1 All regulators should be installed in accordance with local and international standards and regulations.

16.2.2 Adequate over pressure protection should be installed to protect the regulator from over pressure, and also to protect all downstream equipment in the event of regulator failure.

16.2.3 Downstream pressures significantly higher than the regulator pressure setting, may damage soft seats and other internal regulator parts.

16.2.4 The recommended selection for port diameter shall be the smallest port diameter that will handle the flow.

16.2.5 Spring cases must be protected against the accumulation of water caused by condensation or other sources.

16.2.6 Control line connections (where required) should be made in a straight run of pipe 8 to 10 pipe diameters downstream of any area of turbulence such as elbows or block valves.

16.2.7 Regulator body size should never be larger than pipe size. In many cases, the regulator body shall be one size smaller than the pipe size.

16.2.8 The self-operated regulators generally have faster response to quick flow change than pilot-operated regulators.

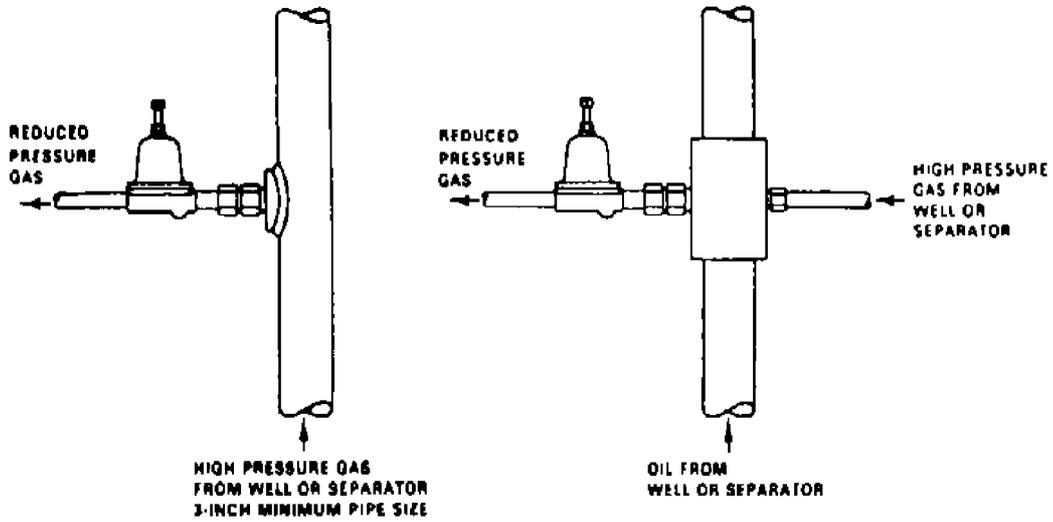
16.2.9 Materials and temperature capabilities of the regulators must be checked to conform with process requirement. Stainless steel diaphragms and seats shall be used for higher temperatures such as steam services.

16.2.10 Self-operated regulating valves may only be used for services where fixed gain control is acceptable. Where failure of the mechanism may give rise to a dangerous situation, e.g., heating of tanks the application of such valves shall be discussed with user.

16.3 Anti Freeze-Up Regulators

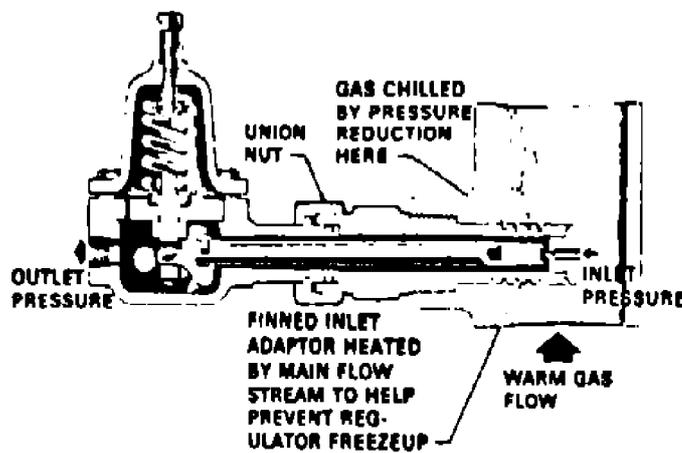
These regulators are self operated, pressure reducing regulators that resist hydrate formation and regulator freeze up. These regulators are suitable for service with natural gas, air, propane, and other gases compatible with the internal parts. They are used on high pressure lines from wellheads and separators.

Regulator freeze-up resistance occurs as the pipe line gas warms the finned inlet adaptor and the seat ring area. As the gas cools within the inlet adaptor due to pressure drop and volume expansion, the warm inlet adaptor helps keep the gas temperature above the freezing point of water and the hydrate formation temperature (see Figs. 23, 24, 25).



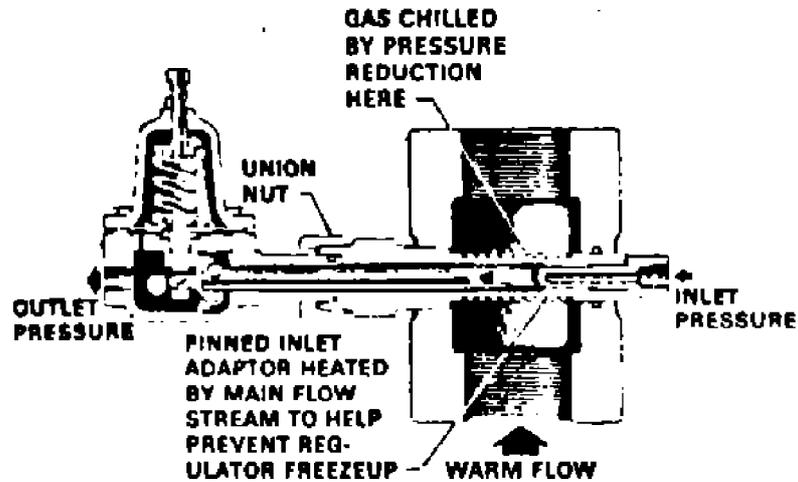
TYPICAL REGULATOR INSTALLATIONS

Fig. 23



TYPE 1 - REGULATOR

Fig. 24



TYPE 2 - REGULATOR
Fig. 25

16.4 Self-Actuated Temperature Regulators

16.4.1 For temperature applications, bellows with a filled system and bulb are used.

16.4.2 The tube system assembly consist of the sensitive bulb, capillary tubing and the bellows assembly, the indicated dial thermometer and the cap.

16.4.3 Self-operating temperature regulators are generally used on installations that require full pressure drop through the valve, the inlet pressure should not exceed the maximum allowable pressure drop.

16.4.4 The regulator should be suitable for installing in an accessible location on horizontal piping. Possible damage from moving parts, splashing of corrosive liquids, vibration, heat etc., should be considered in deciding the location.

16.4.5 Similar consideration should also be given the capillary tubing and bulb. The capillary tubing on high range instruments should be located where the temperature is at least (6.7°C) cooler than the control point.

16.4.6 Self operating regulators are regularly furnished with the most sensitive temperature range unless otherwise specified. The most sensitive range span (approximately 10°C) may be changed to the corresponding wide span range (approx. 32°C) by replacing the sensitive range spring with the wide span range spring.

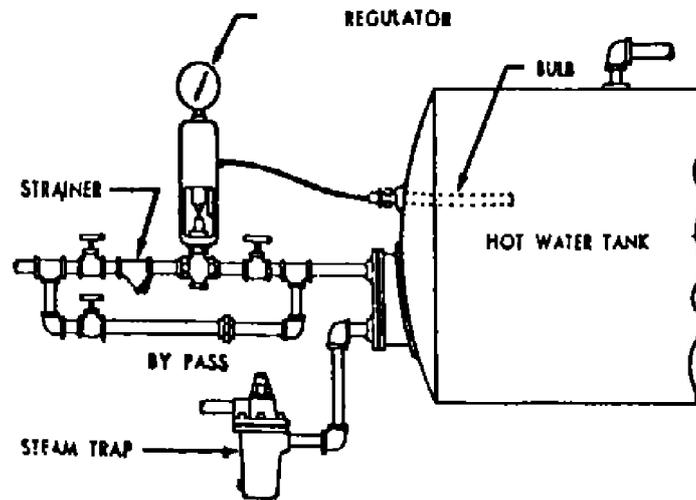
16.4.7 The maximum external pressure allowed on standard bulbs and sockets are 35 bar for copper or brass, and 70 bar for steel or stainless steel, or unless otherwise specified by data sheets.

16.4.8 Stainless steel trim valves are recommended on installation having pressure over 35 bar.

16.4.9 The material of tube system assembly consist of the sensitive bulb, capillary tubing and the bellows assembly, the indicating dial thermometer and the cap shall be specified in data sheets.

16.4.10 Packing gland for the regulators shall be teflon v ring (or graphite asbestos for high temperature applications) packing sets with male and female adapters used as end rings, and a stainless steel compression spring. The spring loading of the packing shall maintain proper compression of the rings and also compensate for wear that occur at the seals.

**INSTALLATION OF TEMPERATURES
REGULATOR IN STORAGE TYPE
H.W. HEATER**



TYPICAL APPLICATION OF SELF ACTUATED TEMPERATURE REGULATOR
Fig. 26

17. CONTROL VALVE ACCESSORIES

The most common types of pneumatic control valve accessories which may be supplied with the control valve are, Solenoid Valves, Convertors, Positioners, Electropneumatic Positioners, Booster Relays, Extension Bonnets, Handwheels, Air Filter, Limit Switch and etc.

Since the positioner is often considered to be the most important of them, it is covered first.

17.1 Positioners

17.1.1 Definition

A pneumatic valve positioner is a device which precisely positions, by the use of air, the moving part (or parts) of a pneumatically operated valve in accordance with a pneumatic signal.

17.1.2 The valve positioner compares the valve stem position with the demand generated by the controller. If the valve stem is incorrectly positioned, the positioner either increases or decreases the air in the actuator until the correct valve stem position is obtained. The following is a list of six functions a positioner can accomplish:

- 1) Provide for split-range operation.
- 2) Improve transmission line speed of response to accommodate large actuator volumes at the end of signal transmission lines.
- 3) Reverse the valve action without changing the "fail-safe" action of the spring in the actuator.

(Note that this may also be done with a reversing-type relay.)

- 4) Increase the thrust in spring diaphragm actuators for use in high pressure-drop applications, and allow the same linearity in the installed characteristic as in the "bench setting" characteristic.
- 5) Change the control valve flow characteristic (cam-type positioner).
- 6) Improve the resolution or sensitivity of the actuator where high-precision valve control is required. Precision is enhanced by the availability of positioners with various gains, and by the fact that modern packings generally have equal static and dynamic coefficients of friction which eliminate the stick/slip behavior.

In the past a positioner was thought to reduce control loop stability for fast acting loops. Modern positioners with volume or pressure boosters, where required, can be made faster than any actuator without a positioner.

17.1.3 Pneumatic control valves may be operated over only part of the controller output range. This can be accomplished by either changing or adjusting the input spring of the positioner. A common arrangement is to have one valve and positioner operate over 0.2 to 0.6 barg of the controller output, while another valve and positioner operates over 0.6-1 barg of the controller output (split range operation). In the above, it is only necessary to modify the positioner springs.

17.1.4 Valve positioners shall be provided with an integral pneumatic switch to bypass the positioner. The bypass may not be recommended where the valve will not operate without the positioner.

17.1.5 Valve positioners shall be supplied with the requisite number of pressure gages, the controller output pressure, positioner output pressure, and supply pressure to the positioner.

17.1.6 Piston operators shall be provided with positioners to ensure that the control valve position is always proportional to the control signal. The positioner shall have a weather proof enclosure.

17.2 Solenoid Valves

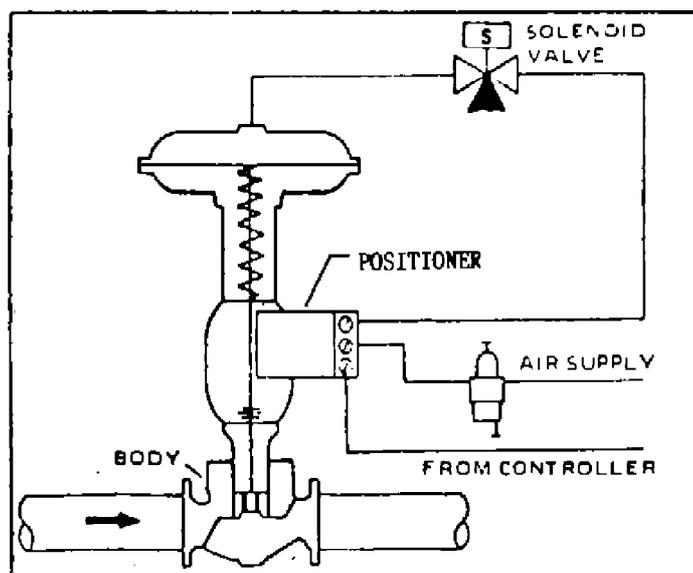
17.2.1 A solenoid valve is a combination of two basic functional units:

- a) A solenoid (electro-magnet) with its core.
- b) A valve body containing one or more orifices.

Flow through an orifice is shut off or allowed by the movement of the core when the solenoid is energized or deenergized.

17.2.2 A common application of a solenoid valve to a diaphragm control valve is illustrated in Fig. 27. In an emergency the solenoid valve can be switched, causing the control valve to go to the preselected position.

The solenoid valve is normally open and allows the positioner output to pass into the diaphragm case. Upon a power loss, the solenoid valve closes the port to the valve positioner and bleeds pressure from the diaphragm case of the control valve.



TYPICAL APPLICATION OF A SOLENOID VALVE
Fig. 27

17.2.3 Where solenoid valves are installed in control air supplies to pneumatically operated valves to seal-in diaphragm pressure, in the event of an electrical failure, the solenoid valves shall incorporate a time delay and hand re-set to prevent operation resulting from transient interruptions of the electrical supply.

For more information on solenoid valves, reference should be made to Section 18 of this Standard.

17.3 Convertors (Transducers)

17.3.1 Definition

A convertor is a device that converts one form of energy into another. This conversion may be pressure to movement, an electric current to a pressure, a liquid level to a twisting movement on a shaft or any number of other combinations.

17.3.2 There are two basic types of sensors, one that produces an output proportional to a change in parameter is described as an analog device, one that produces an ON/OFF type of output is described as a digital device.

17.3.3 Electro-Pneumatic transducers convert the electrical output signal from electronic controllers into pneumatic signal that may be used to operate diaphragm control valves.

17.3.4 Electro-Pneumatic convertors shall not be mounted on control valves. Sufficient capacity must be allowed in the pneumatic circuit to prevent interaction between convertors and valve positions. Where there is no possibility of local vibration ruining the valve positioner, consideration shall be given to the use of valve mounted electro-pneumatic valve positioner.

17.3.5 An I/P convertor operating a single valve shall be mounted such that the length of tubing between the convertor and valve does not exceed 3 meters. If a single I/P convertor is used to operate two or more valves, such as in split range service, the valves and convertor shall be mounted such that the total length of tubing from the convertor to the valves does not exceed 3 meters. Where this is not practical, a separate convertor shall be supplied for each valve.

17.3.6 Electro-Pneumatic convertor shall be explosion proof or intrinsically safe and suitable for Electrical area classification as indicated in data sheet.

17.3.7 Housing shall be IP 54 (IEC-529) or, NEMA-3R weather proof.

17.3.8 Reference accuracy shall be $\pm 0.5\%$ of full scale as detailed in ISA Standard S 51.1.

17.3.9 Input signals of: 4 - 20 mA d.c or unless otherwise specified.

17.3.10 Output signals: 0.2 - 1.0 bar, 0.4 - 2 bar, as required by data sheet.

17.3.11 Supply pressure: 1.4 bar (Recommended). 3.5 bar maximum.

The supply pressure medium must be clean, dry and filtered.

17.3.12 An air filter-regulator with an output pressure gage for the air supply to each convertor shall be provided. Filter-regulator shall be mounted on actuator.

17.3.13 Connection

- Supply pressure : 1/4 inch NPT female
- Output pressure : 1/4 inch NPT female
- Vents : 1/4 inch NPT female
- Electrical : 3/4 inch female conduit connector, or M 20 x 1.5.

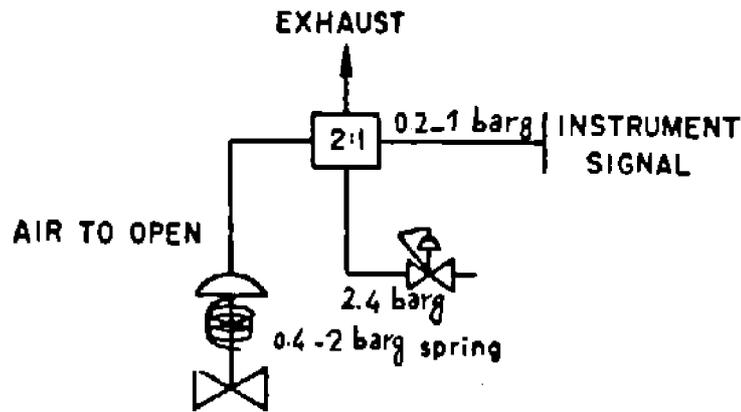
17.3.14 Pressure gage

On filter regulator : 2½ inch diameter, dial with brass movement.

17.3.15 Construction material of housing and relay body shall be die cast aluminum.

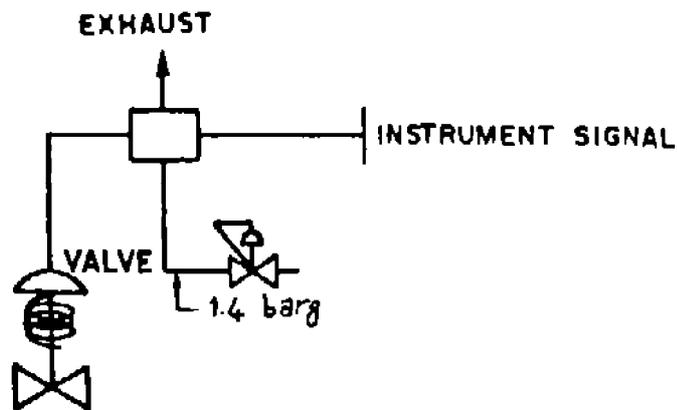
17.4 Booster Relays

Booster relays may be used to increase the speed of response of the control valve and are especially useful when the valve is remotely located from the controller. The function of the pressure booster is to amplify the signal from the controller to above 1.4 barg in certain applications.



PRESSURE BOOSTER IN A CONTROL VALVE LOOP
Fig. 28

Volume boosters are used to increase the speed of response of the control valve. An application of a booster relay is that on modern positioners with volume or pressure boosters, where required, can be made faster than actuator without a positioner.

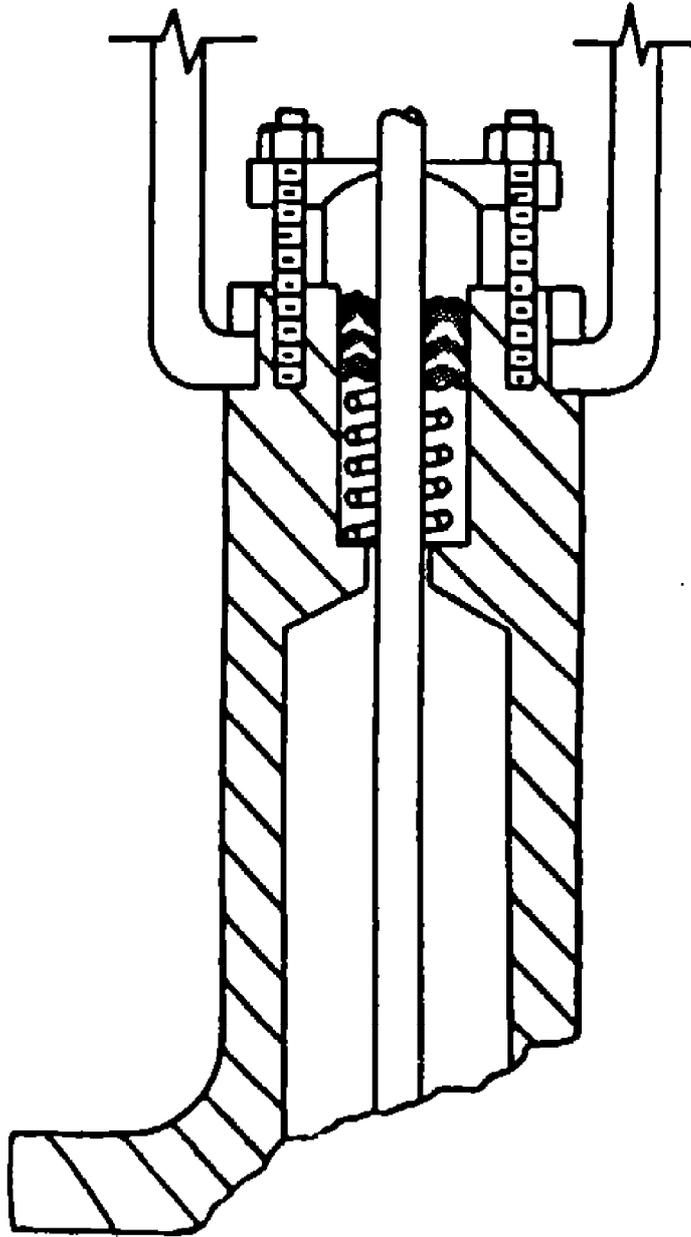


VOLUME BOOSTER IN A CONTROL VALVE LOOP
Fig. 29

17.5 Extension Bonnets

The standard control valve bonnet, with the packing area relatively near the bonnet flange connection, is usually limited to temperatures not exceeding 232°C. For higher temperatures an extension bonnet containing sufficient area to provide radiating heat loss may be used. In no case should such a bonnet be covered with thermal insulating material (Fig. 30).

A similar bonnet design is employed on low-temperature applications (-29°C and below). This extension bonnet places the packing far enough away from the cold area of the valve to prevent freeze-up of the packing.



EXTENSION BONNET
Fig. 30

17.6 Handwheels

17.6.1 Handwheels can be supplied with most types of valves. They provide the operator with the means to override the control system and to operate the valve manually. Various designs are available, including those that can stroke the

valve in either direction and those that stroke the valve in one direction, relying on the valve spring for the return stroke. Some handwheels are continuously connected. Others use a clutch, pin, or other means of engagement, and must be disengaged when not in use or damage may result.

17.6.2 Handwheels when specified, shall be mounted and designed to operate in the following manner.

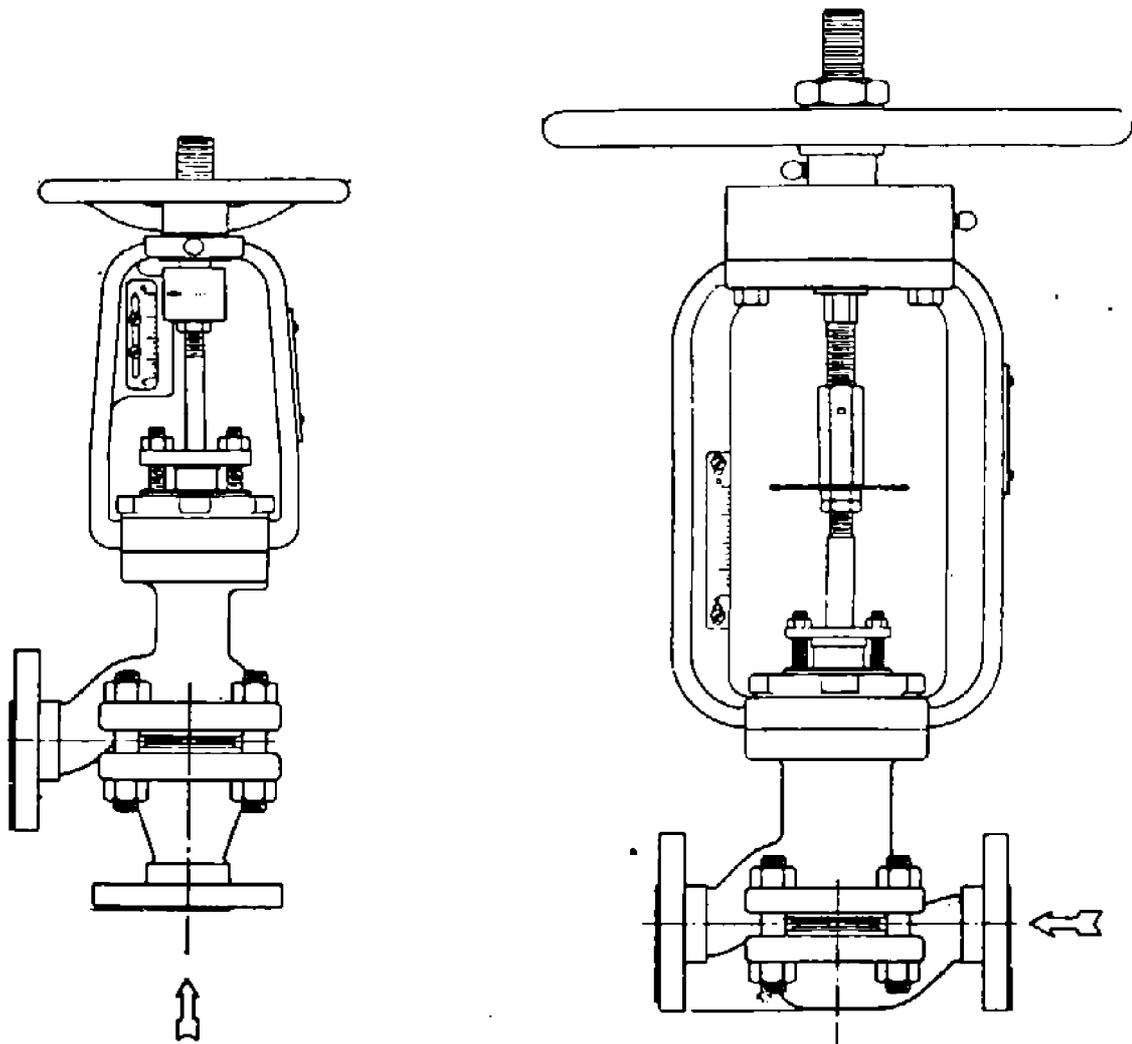
- a)** For globe valves, handwheels shall be mounted on the yoke, arranged so that the valve stem can be jacked in either direction.
- b)** Neutral position shall be clearly indicated.
- c)** Handwheel operation shall not add friction to the actuator.
- d)** Clutch/Linkage mechanisms for handwheels on rotary valves shall be designed such that control of valve position is not lost when engaging the handwheel.

17.6.3 Top mounted handwheels shall be for the valves mounted relatively low (Fig. 31).

17.6.4 Side mounted handwheels should be chosen for valves at higher elevations.

17.6.5 The side mounted handwheels may also be operated by a chain fall plus chains to release and rest the locking levers.

Both of these operators can be used to facilitate the start-up of a control system (i.e., to preposition a valve to a given flow). They can also be used as devices to shut off the valve, eliminating the need in some systems for costly bypass valve arrangements.



A TOP-MOUNTED HANDWHEEL CONTROL VALVE

Fig. 31

17.6.6 The actuator shall be equipped with a permanently attached handwheel of the automatic declutching type that precludes mechanical engagement of the handwheel while the drive is in operation.

The declutching device shall:

- a) Allow power-override of the handwheel operation at all times.
- b) Permit manual handwheel operation of the valve in the event of a frozen or seized drive.

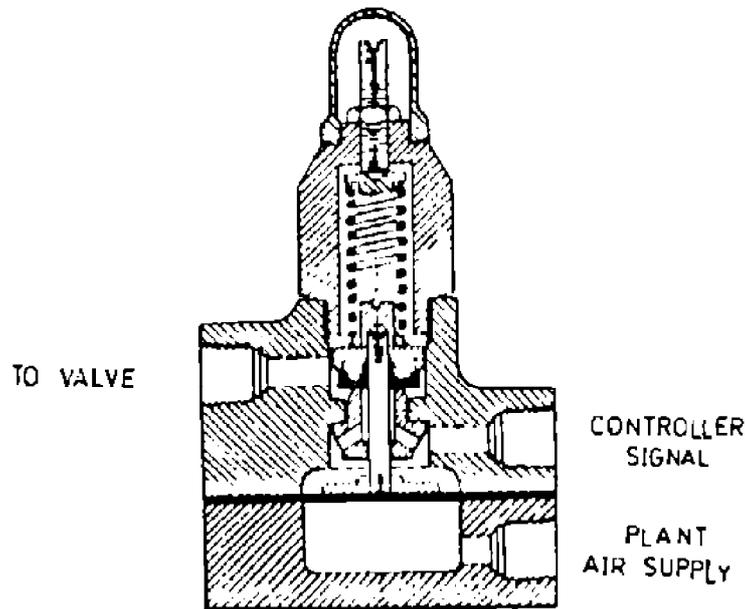
17.6.7 Handwheel drive shall permit the valve to be stroked open or closed in 15 minutes or less.

17.6.8 Handwheel clockwise rotation shall close the valve.

17.7 Air Locks

An air lock device is used for applications that require a control valve to hold its position in the event that the plant air supply pressure falls below a given level. One type is shown in Fig. 32. The plant air supply is fed into a chamber sealed

by a spring-opposed diaphragm. In the event that the plant air decreases to a predetermined lower limit, the spring closes the connection to the actuator and locks the existing controller-signal pressure in the line connecting the valve operator.



AIR LOCK
Fig. 32

17.8 Pressure Sensing Trip Valves

17.8.1 Pressure-sensing trip valves are for control applications where a specific valve/actuator action is required when supply pressure fails below a specific point.

When supply pressure fails below the trip point, the trip valve causes the actuator to fail in up position, lock in the last position, or fail in down position. When the supply pressure rises above the trip point, the trip valve automatically resets, allowing the system to return to normal operation.

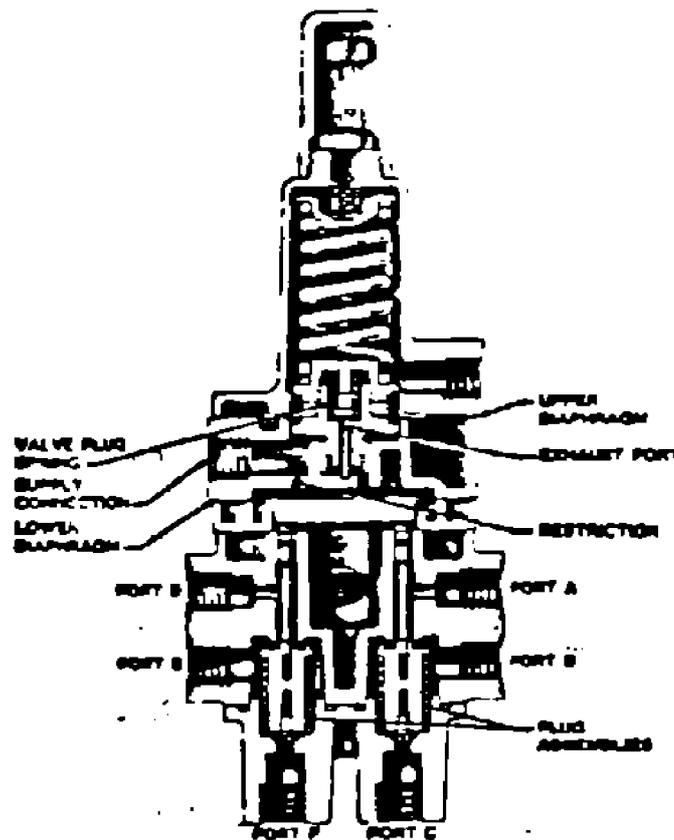
17.8.2 The trip valve can be top-mounted on a manifold, yoke-mounted, or bracket-mounted to match the application requirements. Simplified sectional view of typical trip valve can be seen in Fig. 33.

17.8.3 Trip valve pressure connections

Read the following information before making pressure connections:

- a)** Trip valve port A must receive the operating pressure that is intended for the top of the actuator cylinder. Depending on the actuator type and accessories being used, this operating pressure will be from a valve positioner or switching solenoid.
- b)** Trip valve port B must provide operating pressure to the top of the actuator cylinder. Depending on the actuator type and accessories being used, this port should be connected to the manifold assembly to the top of the cylinder, or to the cylinder connection on the hydraulic snubber (if one is used).
- c)** Trip valve port C must provide a fail-mode outlet for the operating pressure to or from the top of the actuator cylinder. For the fail-down mode, this port should be connected to the volume tank. For the fail-up mode, this port should vent to atmosphere. For the lock-in-last-position mode, this port should be plugged.

- d) Trip valve port D must receive the operating pressure that is intended for the bottom of the actuator cylinder. Depending on the actuator type and accessories being used, this operating pressure will be from a valve positioner or switching solenoid.
- e) Trip valve port E must provide operating pressure to the bottom of the actuator cylinder. This port should always be connected to the bottom of the actuator cylinder.
- f) Trip valve port F must provide a fail-mode outlet for the operating pressure to or from the bottom of the actuator cylinder. For the fail-down mode, this port should vent to the atmosphere. For the fail-up mode, this port should be connected to the volume tank. For the lock-in-last-position mode, this port should be plugged.



SIMPLIFIED SECTIONAL VIEW OF TRIP VALVE
Fig. 33

18. SOLENOID VALVES

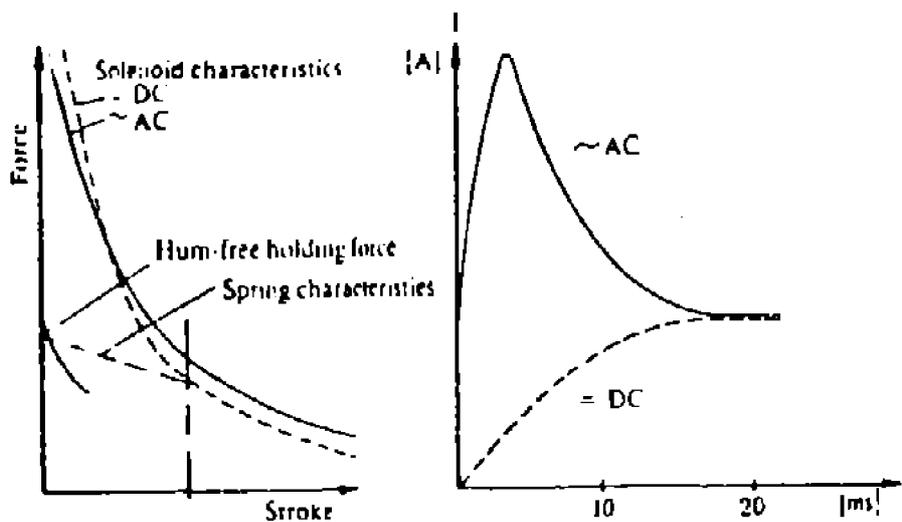
18.1 General

The solenoid valve is basically a valve operated by a built-actuator in a form of an electrical coil (or solenoid) and a plunger. The valve is thus opened and closed by an electrical signal, being returned to its original position (usually by a spring) when the signal is removed. Solenoid valves are produced in two modes—normally-open or normally-closed (referring to the state when the solenoid is not energized).

18.1.1 d.c. or a.c. solenoids

The d.c. solenoids are generally preferred to a.c. because d.c. operation is not subject to peak initial currents which can cause overheating and coil damage with frequent cycling or accidental spool seizure. a.c. solenoids are preferred, however, where fast response is required, or where relay-type electric controls are used. Response time with a.c. solenoid-operated valves is of the order of 8 to 15 milliseconds, compared with the 30 to 40 milliseconds typical for d.c. solenoid operation.

There is an appreciable difference in the working characteristics of a solenoid supplied with d.c. and a.c. d.c. coils are slow in response time and can handle only low pressures. a.c. coils are quicker in response time and can handle higher pressures initially (see Fig. 34). They can thus be cycled at faster rates, if required. Electrical losses are higher, however, and proportional to a.c. frequency. (The power losses in a solenoid operated by a.c. of 60 Hz frequency, for example, is higher than that of the same coil on a 50 Hz supply).



FORCE/STROKE CHARACTERISTICS FOR A TYPICAL SOLENOID VALVE (LEFT); AND A TIME - BASED COMPARISON OF SOLENOID ENERGIZATION BY a.c. AND d.c. (RIGHT)
 Fig. 34

18.1.2 Return spring effect

With a two-way normally closed valve both the spring force and the fluid inlet pressure act to close the valve. As a consequence the return spring can be made relatively weak, and in some designs eliminated entirely. The latter would require mounting the valve so that the solenoid was vertical, return action being by gravity plus fluid pressure.

With a two-way normally-open valve the spring holds the valve open, assisted by fluid pressure. The solenoid force must be sufficient to overcome both spring pressure and inlet pressure to close the valve.

Three-way valves require an upper and a lower spring. The lower spring presses the valve against its seal opened by inlet pressure. The upper spring acts in a direction to force the valve open. The following are the combination of spring strengths required:

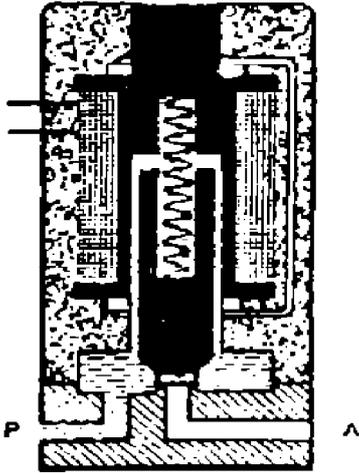
Three-way normally-closed
 Three-way normally-open
 Mixer valve
 Divider valve

LOWER SPRING

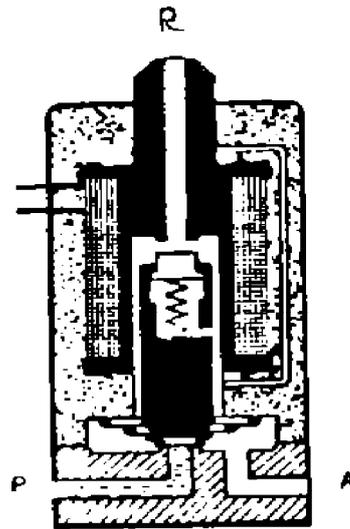
Strong
 Weak
 Medium
 Strong

UPPER SPRING

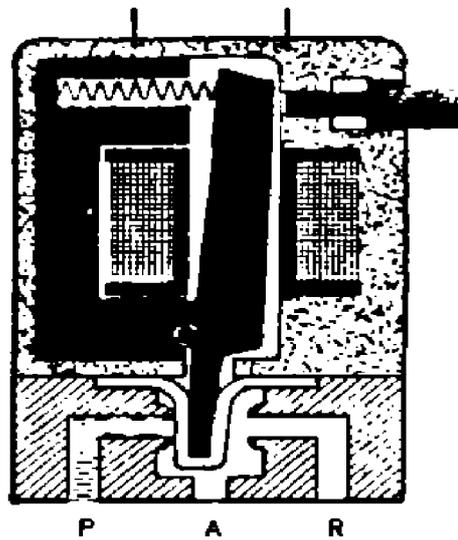
Weak
 Strong
 Medium
 Weak



**DIRECT-ACTING
 TWO-WAY VALVE**



**DIRECT-ACTING
 THREE-WAY VALVE**



PIVOTED-ARMATURE THREE-WAY VALVE

Fig. 35

- P. Pressure point
- A. Supply port
- B. Second supply port
- R. Exhaust port.

18.2 Special Types of Solenoid Valves

18.2.1 Pilot-Operated valves

In general, direct solenoid operation is restricted to smaller sizes of valves, i.e. up to about in bore size as a maximum. Larger solenoids needed for operating larger valves consume high levels of electricity and generate considerable heat. The pilot-operated valve offers a much more attractive proposition in such cases where a small solenoid is retained to operate a pilot valve, which in turn admits inlet pressure to an appropriate part of the valve to open the main valve. The pilot valve may be accommodated internally (internal pilot-operated) or externally (external pilot-operated).

For a pilot-operated valve to work there must be some differential pressure existing across the main valve for it to operate properly. It will then operate against higher pressures with low electrical input, with the pressure rating of the main valve the same as the pressure rating of the pilot valve, since both are subjected to the same line pressure. Pilot-operated valves have slower response time than direct-acting solenoid valves, although in many designs this is adjustable.

There is a further general class of solenoid-operated valve known as a semibalanced valve. This is a double sealed valve with two plugs mounted on a common stem. The lower plug is slightly smaller than the upper plug. Line pressure is introduced below the lower plug and above the upper plug, creating a differential pressure to hold the valve on its seals, assisted by a spring if necessary. The solenoid force required to open the valve is then only that due to the differential pressure (and the spring force, if present).

18.2.2 Solenoid-Operated hydraulic valves

Preference for the design of a solenoid-operated hydraulic valve is to use the solenoid for a 'push' operation, utilizing spring action for 'pull' motions. The solenoid must be powerful enough to override inertia and friction and also the spring and hydraulic forces. The latter may be extremely variable and not completely predictable, calling for a generous margin in the power of the solenoid and springs.

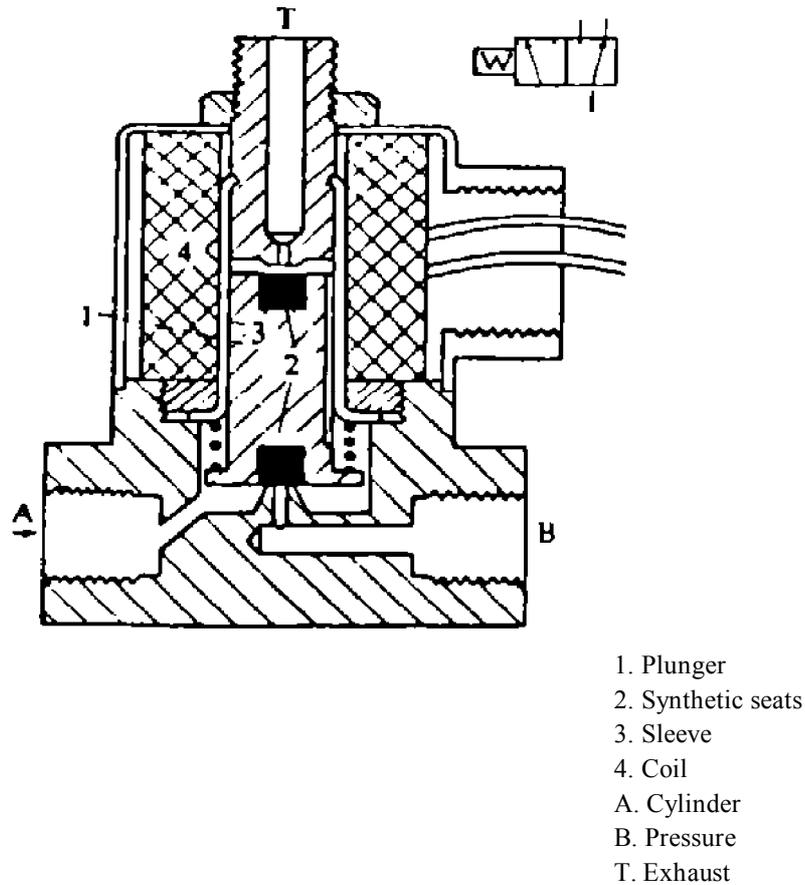
Solenoids may be of the 'dry' or 'wet' type. In general, 'wet' solenoids can be smaller for the same duty because of their lower static and dynamic friction. They also have the advantage that all moving parts are enclosed and lubricated, and seals between the solenoid and valve body are eliminated. They are also described as glandless valves.

The size of directly operated solenoid valves is generally restricted to flow rates up to about 45 l/min - i.e., (1/8 in) and (1/4 in) nominal valve sizes. Many of these valves can be switched directly from static systems, the outputs usually being 24 V d.c. and 20 to 65 W, depending on the system.

18.2.3 Glandless solenoid valves

By arranging the solenoid armature to work in a sealed tube with the solenoid coil enveloping it, the sealing glands can be dispensed with, so simplifying the construction and eliminating one possible point of leakage.

This principle has been applied extensively to the smaller valves. A typical type is shown in Fig. 36.



- 1. Plunger
- 2. Synthetic seats
- 3. Sleeve
- 4. Coil
- A. Cylinder
- B. Pressure
- T. Exhaust

Fig. 36

Glandless valves can be installed in any position and will withstand appreciable shock loads. Response time is extremely short, 5 milliseconds on a.c. and 10 to 15 milliseconds on d.c. and it is said that speeds of up to several hundred cycles per minute are possible.

For hazardous atmospheres most manufacturers supply explosion-proof materials which are slightly heavier and bulkier than the standard type.

18.3 Solenoid Valves Characteristics

18.3.1 Valve body for solenoid valves shall follow the instrument piping specifications when used in process lines. Manufacturer's standard bronze material shall normally be used on air service.

18.3.2 Valve body connection sizes shall be 1/8", 1/4" and 3/8" or as required by data sheet.

18.3.3 Coils for solenoid valves shall be molded and encapsulated and specified continuous duty Class E, and F insulation at rated voltage and frequency. (Reference IEC-85, thermal insulation and classification of electrical insulation.)

18.3.4 The solenoid itself may be operated by d.c. or a.c. supply. Electrical rating of standard voltages shall be 24 Volts a.c. or d.c., 110 Volts a.c. 50 Hz or as specified in data sheet.

18.3.5 Solenoid coil shall operate the valves by 10% of voltage variation, unless otherwise specified in data sheet.

18.3.6 A variety of body materials are available to choose. Valve seat material shall be selected to suit the requirement. Materials available are Buna N, and stainless steel discs, viton, teflon etc. Reference must be made to the specification detailed in data sheet for this selection.

18.3.7 External parts of solenoid construction in contact with fluid shall be stainless steel.

18.3.8 Three-Way and four-way packless solenoid valves which are direct acting and require no minimum operating pressure, may be installed on control valves. Both miniature and standard size solenoid valves are available along with both general purpose enclosure to protect from indirect splashing and dust, or explosion-proof and watertight enclosures. The requirement shall be specified by user in the relevant data sheet.

18.3.9 The enclosure shall be suitable for area classification as specified in data sheet. The weatherproof housing shall be min IP 55 and explosionproof housing shall be EEx-'d' gas group, as per IEC-144 recommendation.

18.3.10 Specification form for solenoid valves extracted from ISA, can be seen in Appendix A.

19. INSPECTION, TEST AND REPAIR OF DEFECTS

19.1 Inspection and Tests

19.1.1 When inspection is specified in the purchase order by purchaser, then inspection shall be in accordance with API standard 598. If inspection is not specified, control valves shall meet the requirements for visual examination described in API standard 598.

19.1.2 Each control valve shall be hydrostatically tested by the manufacturer and the certified test reports shall be provided confirming that the control valve have been tested in accordance with the test standard outlined in ANSI/ISA-S 750.1 or ANSI B16.37 test requirements.

19.1.3 The test requirement and the test procedure for obtaining the control valve various coefficients shall be in accordance with ANSI/ISA-S 75.02 (control valve capacity test procedure).

19.1.4 After testing, each valve shall be drained of test liquid, cleaned of any extra matter and suitably protected in preparation for storage and transportation.

19.2 Repair of Defects

The user reserves the right to reject individual valves for bad workmanship or defects.

19.2.1 The repair of defects in cast iron or ductile iron castings, by welding, brazing, plugging, pinning or impregnation is not permitted.

19.2.2 Defects in the body of carbon steel or alloy steel valve revealed by inspection or test may be repaired as permitted by the most nearly applicable ASTM material specification listed in Table 1 of ANSI/B16.34.

20. SPECIFIED MAXIMUM LEAKAGE

20.1 The maximum allowable leakage rate in terms of percent of valve maximum C_v value shall be specified.

20.2 Another method of calculating the leakage rate is to specify the leakage rate per inch of valve seat orifice diameter per pound of differential pressure to compare with water or air leakage test specifications. These specifications are given in ISA recommended practice RP-39.6 (Fig. 37) lists leakage rate for various valve types.

Select a valve type having a lower leakage rate than the maximum process leak rate allowed.

The given rates are based on factory tests of new valves so an allowance must be made for leakage to increase with service usage.

20.3 Seat tests shall be conducted as per ANSI/FCI 70-2 or ISA RP-39.6 (Fig. 37) metal to metal seated valve.

Note:

Tests conducted under factory test conditions with 50 psig air to atmosphere.

20.4 Body tests: Test pressure for steel bodies shall be per ANSI B-16.34 cold pressure rating at 38°C ratings. For cast Iron, brass, or bronze bodies, test pressure shall be two times primary pressure rating.

LEAKAGE CLASS ISA 879.6	ALLOWABLE LEAKAGE RATE: AIR OR WATER	VALVE TYPES	REMARKS
CLASS I	CATEGORY II, III OR IV, BUT NOT TEST REQUIRED BY AGREEMENT BETWEEN USER AND SUPPLIER.	VALVE TYPES LISTED IN CATEGORY II, III & IV	QUALITY OF $m\bar{g}$ IMPLIES THAT THESE VALVES DO NOT EXCEED LEAKAGE CLASSES II, III & IV, BUT NO GUARANTEE IS STIPULATED.
CLASS II	0.5% RATED VALVE CAPACITY. (MAXIMUM C_v)	GLOBE, DOUBLE SEATED, GLOBE, SINGLE SEATED, BALANCED WITH STEPPED METAL PISTON SEAT. BUTTERFLY, METAL LINED.	
CLASS III	0.1% OF RATED VALVE CAPACITY	HIGH QUALITY GLOBE DOUBLE SEATED, GLOBE, SINGLE SEATED, BALANCED WITH CONTINUOUS METAL PISTON SEALS.	
CLASS IV	0.1% OF RATED VALVE CAPACITY	GLOBE, SINGLE SEATED, GLOBE, SINGLE SEATED, BALANCED WITH ELASTOMER PISTON SEALS. ROTARY ECCENTRIC CAM TYPE. BALL VALVES WITH METAL SEAT.	
CLASS V	5×10^{-4} cc/min. OF WATER PER INCH OF ORIFICE DIAMETER PER μ DIFFERENTIAL PRESSURE	GLOBE VALVES IN CLASS IV WITH HEAVY DUTY ACTUATORS TO INCREASE SEATING FORCE.	FEW VALVES CONTINUE TO REMAIN THIS TIGHT IN SERVICE UNLESS THE SEAT PLASTICALLY DEFORMS TO MAINTAIN CONTACT WITH THE PLUG.
CLASS VI	MAXIMUM PERMISSIBLE LEAKAGE ASSOCIATED WITH RESILIENT SEATING VALVES. EXPRESSED AS BUBBLES PER MIN. AS PER RP 79.6.1	GLOBE WITH RESILIENT SEAT. BUTTERFLY, ELASTOMER LINED. ROTARY ECCENTRIC CAM WITH ELASTOMER SEAT. BALL WITH RESILIENT SEAT. SOLID BALL TYPE. DIAPHRAGM, WEIR TYPE. PLUG VALVES, ELASTOMER SEATED OR SEALANT INJECTION SEALING SYSTEM.	ELASTOMER SEALED VALVES REMAIN THIS TIGHT FOR MANY THOUSANDS OF CYCLES UNTILL THE SEAL IS WORN OR CUT.

VALVE LEAKAGE RATES

Fig. 37

1 Example-0.46 cc/min for a 2 inch port orifice diameter in a globe, butterfly or ball valve with 50 psi differential pressure air. Equivalent to 3 bubbles per minute from a ¼ inch O.D., 0.032 inch wall tube, ¼ inch under water surface.

Note:

The terms bubble tight and drop tight are meaningless unless some leakage rate is specified. Lack of visible air bubbles using soap solution indicates leakage of less than 1×10^{-3} , 1×10^{-4} cc/sec.

21. HYDROSTATIC TESTING OF CONTROL VALVES

21.1 Control valves having bodies, bonnets and cover plates made of carbon steel, low alloy and high alloy (stainless) steel, cast Iron and ductile Iron shall be hydrostatically tested as per recognized standard ANSI B-16.37.

21.2 Pressure measuring instruments used in testing shall be of the indicating or recording type.

21.3 It is recommended that gages and recording instruments have a range of approximately double but not more than 4 times the test pressure.

22. PRESSURE TEST REQUIREMENTS FOR BUTTERFLY VALVES

22.1 All Butterfly Valves, completely assembled, shall be pressure tested by the manufacturer before dispatch, and in accordance with the recognized standard such as BS-5155 (pressure testing).

22.2 Testing shall be carried out before valves are painted or otherwise externally coated with materials that are capable of sealing against leakage. Internal linings and external non-pressure sealing anticorrosion treatments shall be permitted for the purposes of testing.

22.3 No valve undergoing pressure testing shall be subject to shock loading.

22.4 Valves and connections shall be purged of air prior to pressure testing.

22.5 The test fluid for all pressure tests shall be either water with the addition of a suitable inhibitor, or another liquid whose viscosity at ambient temperature is equal to or less than that of water.

Note:

Attention is drawn to the need to control the chloride content of test water in contact with austenitic stainless steel components.

22.6 Test pressures shall be determined by the following relationships:

a) Shell test: $1.5 \times$ maximum permissible, working pressure at 20°C.

b) Disk strength test (applicable to valves 14 inches and larger): $1.5 \times$ maximum permissible working pressure at 20°C.

c) Seat test: $1.1 \times$ maximum permissible working pressure at 20°C.

22.7 Test procedures for shell, Disk and seat of Butterfly valves shall be in accordance with the recognized standard such as BS-5155.

22.8 Test durations for Butterfly valves shall be conducted as per Table 10 of BS-5155.

22.9 After test carried out by Table 10 above, the maximum permissible leakage shall be given in Table 11 of BS-5155 for each valve type.

23. SOLENOID VALVES TEST REQUIREMENT

23.1 Solenoid valves shall be tested by the manufacturers before dispatch according to UL specification and approvals or other recognized testing organizations.

23.2 Test approvals by third party is only necessary for equipment used in hazardous areas, which should be certified in accordance to any approved bodies such as BASEFA, UL, FM, PTB etc.

23.3 Solenoid valves are used in hazardous areas shall meet the electrical area classification requirements.

24. MARKING

24.1 Nameplate

The nameplate should be 316 stainless steel and 70 × 50 mm and should be marked with the following information:

- a) Tag No.
- b) Body material
- c) Trim material
- d) Body/trim sizes
- e) Actuator air to open/close
- f) Actuator operating pressure
- g) Manufacturers name and model No. and serial No.
- h) Pressure rating
- i) Maximum differential pressure
- j) A tag, indicating type of packing and lubricant
- k) The arrow indicating direction of valve flow on the body.
- l) Bench set pressure
- m) Valve characteristics.

25. PACKING AND SHIPPING

Equipment must be carefully protected and packed to provide adequate protection during transit to destination and shall be in accordance with any special provision contained in the specification or order. Special attention must be given to protection against corrosion during transit. All bright and machined parts must be painted with a rust preventative.

Ancillary items forming an integral part of the equipment should be packed preferably in a separate container if the equipment is normally cased or crated.

Alternatively the ancillary items should be fixed securely to the equipment and adequate precaution taken to ensure that the items do not come loose in transit or be otherwise damaged.

25.1 Unless export packaging is specified in the purchase order, valves shall be shipped or packed in wooden boxes or crates, and fastened, so that prevent shifting within the package.

25.2 Threaded openings of the valves shall be plugged with suitable protective device to prevent entrance of dirt and to prevent damage to threads.

25.3 Flanged faces shall be coated with rust-ban or other suitable rust preventive substance. Flanged faces shall be protected by covers securely bolted to the flanges to prevent dirt from entering the valve interior.

25.4 Valves shipped with mounted actuators shall be packed in a manner that will prevent damage while in transit.

25.5 Butterfly valves shall be shipped with the shaft packing installed.

25.6 Butterfly valves shall be shipped with the disk positioned so that the disk edges are within the body contact faces to prevent damage during normal handling.

25.7 After the receipt of the inspection report, the control valve should be prepared for shipment either to the plant area for installation, or to storage. The valve body's air or electrical connections should be plugged to keep-out dirt. If the control valve is to be stored for any length of time it should be packed for protection against environmental adverse effects.

26. DOCUMENTATION/LITERATURE

26.1 At Quotation Stage

Suppliers are to provide the following in the numbers requested at the time of quotation:

- a) Comprehensive descriptive literature.
- b) List of recommended commissioning spares with prices.
- c) Details of any special tools required with prices.
- d) Calculation, including C_v noise etc.

26.2 At Ordering Stage

Suppliers are to provide the following in quantities and at times as detailed on the order:

- a) List of recommended spares for two years continuous operation.
- b) Illustrated comprehensive spare parts manual with part numbers suitable for warehouse stocking.
- c) Illustrated installation and operating instructions.
- d) Maintenance manuals.

Notes:

The above shall include identification of all proprietary items. All drawings and literature shall be in the English language and show all dimensions, capacities, etc., in metric units. The order number must be prominently shown on all documents.

Drawings are to be properly protected and packed and negatives must be dispatched in a strong cardboard cylinder. Drawings must be rolled not folded.

27. GUARANTEE

27.1 The manufacturers shall guarantee equipment performance as specified for a warranty period of 18 months from delivery or 12 months after installation, whichever comes first. Manufacturers shall also guarantee all equipment furnished against defects in design, materials, and workmanship and will bear the entire cost of correcting such defects which would develop during the specified warranty period.

27.2 The manufacturers/suppliers shall guarantee the supply of min. 10 years spare parts for the quoted equipment.

APPENDICES**APPENDIX A
SPECIFICATION FORMS FOR PROCESS MEASUREMENT AND
CONTROL INSTRUMENTS**

- 1) Specification forms for control valves.
- 2) Specification forms for pressure control valves pilots and regulators.
- 3) Specification forms for self-actuated temperature regulators.
- 4) Specification forms for solenoid valves.

SPECIFICATION FORM FOR CONTROL VALVES

		PROJECT _____				DATA SHEET _____ of _____	
		UNIT _____				SPEC _____	
		P.O. _____				TAG _____	
		ITEM _____				DWG _____	
		CONTRACT _____				SERVICE _____	
		MFR SERIAL # _____					
1	Fluid _____					Crit Pres PC _____	
2	SERVICE CONDITIONS	Flow Rate	Units	Max Flow	Norm Flow	Min Flow	Shut-Off
3		Inlet Pressure					
4		Outlet Pressure					
5		Inlet Temperature					
6		Spec Wt/ Spec Grav/ Mol Wt					
7		Viscosity/Spec Heats Ratio					
8		Vapor Pressure P_v					
9		*Required C_v					
10		*Travel	%				0
11		Allowable/*Predicted SPL	dBA	/	/	/	-
12							
13	LINE	Pipe Line Size In _____					
14		& Schedule Out _____					
15		Pipe Line Insulation _____					
16	VALVE BODY/BONNET	*Type _____					
17		*Size _____ ANSI Class _____					
18		Max Press/Temp _____					
19		*Mfr & Model _____					
20		*Body/Bonnet Matl _____					
21		*Liner Material/ID _____					
22		End In _____					
23		Connection Out _____					
24		Flg Face Finish _____					
25		End Ext/Matl _____					
26	*Flow Direction _____						
27	*Type of Bonnet _____						
28	Lub & Iso Valve _____ Lube _____						
29	*Packing Material _____						
30	*Packing Type _____						
31							
32	TRIM	*Type _____					
33		*Size _____ Rated Travel _____					
34		*Characteristic _____					
35		*Balanced/Unbalanced _____					
36		*Rated C_v F_L _____ X_T _____					
37		*Plug/Ball/Disk Material _____					
38		*Seal Material _____					
39	*Cage/Guide Material _____						
40	*Stem Material _____						
41							
42							
43	SPECIALS/ACCESSORIES	Class _____ Group _____ Div _____					
44							
45							
46							
47							
48							
49							
50							
51							
52							
53	ACTUATOR	*Type _____					
54		*Mfr & Model _____					
55		*Size _____ EH Area _____					
56		On/Off _____ Modulating _____					
57		Spring Action Open/Close _____					
58		*Max Allowable Pressure _____					
59		*Min Required Pressure _____					
60		Available Air Supply Pressure _____					
61		Max _____ Min _____					
62		*Bench Range _____/_____					
63	Act Orientation _____						
64	Handwheel Type _____						
65	Air Failure Valve _____ Set at _____						
66							
67	Input Signal _____						
68	POSITIONER	*Type _____					
69		*Mfr & Model _____					
70		*On Incr Signal Output Incr/Decr _____					
71		Gauges _____ By-pass _____					
72		*Cam Characteristic _____					
73							
74	SWITCHES	Type _____ Quantity _____					
75		*Mfr & Model _____					
76		Contacts/Rating _____					
77		Actuation Points _____					
78							
79	AIR SET	*Mfr & Model _____					
80		*Set Pressure _____					
81		Filter _____ Gauge _____					
82							
83	TESTS	*Hydro Pressure _____					
84		ANSI/FCI Leakage Class _____					
85							
86							
	Rev	Date	Revision	Orig	App		

*Information supplied by manufacturer unless already specified.

EXPLANATION OF TERMS AND DEFINITION OF CONTROL VALVES

Line	Explanation of Terms and Definitions	Examples	Line No.	Explanation of Terms and Definitions	Examples
PROJECT	Specify project name for which control valve is intended.		3	Specify inlet pressure (gauge or absolute).	20 bar
UNIT	Specify unit within project.	#1	4	Specify outlet pressure (gauge or absolute).	1000 psig 400 kPa gauge
P.O.	Specify purchase order number from purchaser to control valve manufacturer.	P.O. 12345	5	Specify inlet temperature in °F, °R, °C or K. Must agree with state of fluid and its inlet pressure.	200° C
ITEM	Specify item number of purchase order.	3	6	Specify specific weight (kg/m ³), specific gravity, or molecular weight of fluid. Identify the appropriate term.	61.9 kg/m ³ 1.03 44.01
CONTRACT	Specific contract number of project for purchaser's reference.	96-V-32510	7	Specify viscosity in appropriate units for liquids or specific heats ratio for gases.	20 centipoise 17.8 centistokes 1.27
MFR SERIAL	This line may show the valve manufacturer's serial number(s) and is normally filled in at the time of shipment of the valve. Serial numbers often contain the manufacturer's shop order number.	C12650-3	8	Specify vapor (saturation) pressure at inlet temperature in absolute units. Only required for liquid flow.	46.9 bar abs.
DATA SHEET	Specify data sheet number. Normally assigned by purchaser.	3 of 12	9	Specify required C _v as calculated for each condition per ANSI/ISA S75.01-1986. No additional safety (oversize) factor should be included at this point.	760
SPEC	Specify number of technical specification on which valve selection is based.	FL-13265-A	10	Specify travel of the valve in percent of rated travel calculated from required C _v , rated C _v of the valve, trim selected, and characteristic (see lines 33, 34, and 36). 0% is full closed, 100% is full open.	78%
TAG	Specify tag number, if any, used to designate location of valve.	FV-103	11	Specify laboratory-measured allowable and predicted sound pressure levels, both normally in dBA as measured per ISA-S75.07-1987.	90/87 dBA
DWG	Specify piping and instrumentation diagram number, loop diagram number, engineering flow diagram number, etc.	17-453	12	Extra line for information not covered in lines 1 through 11.	Compressibility factor Z Ambient temperature Base pressure and temperature
SERVICE	Describe service of control valve and/or pipe line number.	Feedwater control Reheat spray 2" MA 1051 WA7	13 & 14	Specify size and schedule (or wall thickness if nonstandard) of pipe line into which valve is installed.	8" SCH 40 15" OD x 0.500" wall
NOTE: The above lines are suggested only and may be modified to fit the individual company's needs. If the provided space is insufficient, add an additional sheet and refer to it.			15	Specify pipe line insulation. This information is required for predicted sound pressure level calculations.	2" thermal None
Line No.	Explanation of Terms and Definitions	Examples	16	Specify type of valve body.	Globe (through, angle) Split body Double port Butterfly Ball Pinch
1	Describe fluid flowing into valve and its state. Indicate corrosive or erosive service and the corrosive or erosive agents. Specify thermodynamic critical pressure of the fluid.	Superheated steam Saturated water Crude oil and natural gas 6 bar			
2	Specify volumetric or mass flow rate at inlet or standard conditions. Maximum flow condition, if greater than normal flow condition, is the condition for which the valve is sized.	600 std. m ³ /h 300 kg/h			

EXPLANATION OF TERMS AND DEFINITION OF CONTROL VALVES

Line No.	Explanation of Terms and Definitions	Examples	Line No.	Explanation of Terms and Definitions	Examples
17	Specify nominal size of valve body. Specify ANSI class in accordance with ANSI B16.34-81	4" 600 2500 SPECIAL	34	Specify inherent flow characteristic of installed trim	Linear Equal % Modified parabolic Quick-opening
18	Specify maximum pressure and temperature of the valve	in bar & °C	35	Specify whether trim is balanced or unbalanced. Semi-balanced trim should be considered as balanced	Balanced Unbalanced
19	Specify manufacturer and model number		36	Specify rated C_v , F_L , and X_T of installed trim. Refer to ANSI/ISA-S75.01-1986	260 0.9 0.68
20	Specify body and bonnet material.	Steel, ASTM A216, WCB	37	Specify closure member, i.e., plug, ball, or disk material as applicable.	17-4 PH, H-1150 316
21	Specify body liner material, if any, and its inside diameter.	Polyurethane, 3.9"	38	Specify seat material	420 hardened 316 hardened
22 & 23	Specify end connection. May be integral or welded onto body.	6" RTJ Class 1500 flange Butt weld end 2" FNPT	39	Specify cage, bearing, or guide material	410 hardened
24	Specify flange face finish per ANSI B16.5-81 or special finish as required	ANSI B16.5-81 Special finish 32 RMS	40	Specify stem material	17-4 PH H-1150 316
25	Specify end extensions, if any. Normally, refers to sections of pipe or reducers welded to the body by the valve manufacturer	6" long, SCH 80, A106, GR. B	41 & 42	Extra lines for additional trim requirements not covered in lines 32 through 40	Chrome-plate Pilot-operated
26	Specify direction of the flow through the body. FTO = flow-to-open, FTC = flow-to-close valve NOTE: The descriptors "FTO" and "FTC" refer to the direction of fluid forces on the closure member. If immaterial, leave blank. When FTO and FTC are not applicable, specify direction as appropriate	FTO FTC	43	Specify hazardous location classification per the <i>National Electrical Code</i> ®, ANSI/NFPA 70-1987.	Class I Div. 1, Group C
27	Specify type of bonnet	Standard Cooling fin Extended	44 - 52	Specify special requirements and/or accessories not covered elsewhere.	Solenoid valves E. P. transducer NACE MR-01-75 Seismic Net weight = 275 lb
28	Specify whether a lubricator and isolation valve are required. Specify lubricant.	Yes Silicone	53	Specify type of actuator	Diaphragm, pneumatic Hydr. piston, double-acting Pneumatic rotary vane
29	Specify packing material.	Graphite impreg asbestos TPE Non-asbestos	54	Specify manufacturer and model number	
30	Specify type of packing	Braided Molded V-ring Laminated filament Pressure-Vacuum	55	Specify nominal size and effective diaphragm/piston area	8" 0.2 m ²
31	Extra line for special body or bonnet not covered in lines 16 through 30.	Body drain Separable flanges Flangeless	56	Specify whether actuator is for on/off or modulating service.	Modulating On/off
32	Specify type of trim.	Single seat cage-guided Multi-stage Multi-hole Top- and bottom-guided Double seat	57	Specify whether spring, if any, acts to open or to close valve	Open Close None
33	Specify nominal size and rated travel of installed trim	2" 50 mm	58	Specify maximum pressure for which the actuator is designed	100 psig 6 barg
			59	Specify minimum pressure required to fully stroke the installed valve under specified conditions	4.5 barg

EXPLANATION OF TERMS AND DEFINITION

Line No.	Explanation of Terms and Definitions	Examples	Line No.	Explanation of Terms and Definitions	Examples
60 & 61	Specify limits of available air or hydraulic supply pressure. If upper limit is greater than line 58, a reducing valve (air set) should be furnished. Lower limit or reducing valve setting must be higher than pressure shown on line 59.	in barg	71	Specify whether air pressure gauges and positioner are required.	No Yes
62	Specify the pressures in the actuator when valve starts travel and at its rated travel position without fluid forces acting on the valve.	in barg " " " "	72	Specify cam characteristic, if positioner has a cam. Normally linear.	Linear Square root
63	Specify orientation of actuator as "VERT UP" or "VERT DOWN" (vertical) or "HORIZ." (horizontal). For rotary valves, also specify whether mounting is "RH" (right-hand) or "LH" (left-hand) as viewed from valve inlet, if appropriate. Specify additional information as appropriate or provide sketch.	VERT. UP HORIZ RH LH	73	Extra line for positioner requirements.	Aluminum-free
64	Specify type and orientation of handwheel (manual override), if any.	Top-mounted Side-mounted/LH	74	Specify type and quantity of limit switches.	Mech. (lever arm) Proximity Pneumatic 2
65	Specify if air failure valve (actuator air lock-up valve) is required and at what supply pressure it shuts.	Yes in barg	75	Specify manufacturer and model number.	
66	Extra line for additional actuator requirements not covered in lines 53 through 65. .	Hydraulic damper Stroking speed 1"/sec. Stainless steel tubing	76	Specify electrical rating and number of contacts and action.	10A, 600 VAC, DPDT
67	Specify input signal range for full travel.	.2 to 1 barg	77	Specify valve travel at which switches are to actuate.	Full open/full closed
68	Specify type of positioner.	None Single acting Double acting	78	Extra line for additional limit switch requirements not covered in lines 74 through 77.	NEMA 4 IP 65
69	Specify manufacturer and model number.		79	Specify manufacturer and model number of air set (pressure regulator).	
70	Specify whether an increasing signal increases or decreases output pressure in actuator.	Incr. Decr.	80	Specify output pressure setting.	in barg
			81	Specify whether filter and/or output pressure gauge is required.	Yes No
			82	Extra line for additional air set requirements not covered in lines 79 through 81.	Mount separate from valve
			83	Specify pressure of hydrostatic test. Normally per ANSI B16.37-80 or API 6A-83.	3350 in barg
			84	Specify leakage class per ANSI FCI 70-2-76.	Class IV
			85 & 86	Extra lines for additional test requirements not covered in lines 83 and 84.	Hydro for 30 minutes Helium leak test Stroking time test Dead hand test

PRESSURE CONTROL VALVES-PILOTS AND REGULATORS

		PRESSURE CONTROL VALVES PILOTS AND REGULATORS				SHEET ____ OF ____	
		NO		REVISION		SPEC NO	REV
		BY	DATE			CONTRACT	DATE
						REQ. NO	
		BY	CHK'D	APPR			
GENERAL	1.	Tag No.					
	2.	Service					
	3.	Line No./Vessel No.					
	4.	Line Size/Sched. No.					
	5.	Function					
BODY	6.	Type of Body					
	7.	Body Size	Port Size				
	8.	Guiding	No. of Ports				
	9.	End Conn. & Rating					
	10.	Body Material					
	11.	Packing Material					
	12.	Lubricator	Use Valve				
	13.	Seal Type					
	14.	Trim Form					
	15.	Trim Material					
	16.	Seat Material					
	17.	Required Seat Tightness					
	18.	Max. Allow Sound Level dBA					
ACTUATOR/ PILOT	19.	Type of Actuator					
	20.	Pilot					
	21.	Supply to Pilot					
	22.	Self Cont.	Ext. Conn.				
	23.	Diaphragm Material					
	24.	Diaphragm Rating					
	25.	Spring Range					
	26.	Set Point					
	27.						
ACCESSORIES	28.	Filt. Req.	Supply Gage				
	29.	Line Strainer					
	30.	Housing Vent					
	31.	Internal Relief					
	32.						
	33.						
SERVICE	34.	FLOW UNITS	LIQUID	STEAM		GAS	
	35.	Fluid					
	36.	Quant. Max.	Cv				
	37.	Quant. Oper.	Cv				
	38.	Valve Cv	Valve P.				
	39.	Norm. Inlet Press.	ΔP				
	40.	Max. Inlet Press.					
	41.	Max. Shut Off	ΔP				
	42.	Temp. Max.	Operating				
	43.	Oper. to gr.	Mol. Wt.				
	44.	Oper. Visc.	% Flash				
	45.	% Superheat	% Solids				
	46.	Vapor Press.	Crit. Press.				
47.	Predicted Sound Level dBA						
48.	Manufacturer						
49.	Model No.						
Notes:							

PRESSURE CONTROL VALVES-PILOT AND REGULATORS

1-4. Identification and service or location. It is assumed that each tag number is for a single valve.

5. Pressure reducing, back pressure control, or differential pressure regulator.

6. Globe, angle, or Manufacturer's Standard (MFR. STD.).

7. Body connection size and inner valve size.

8. Guiding may be top, top and bottom, skirt, or MFR. STD. Select single or double port, if applicable.

9. Specify screwed (NPT), flanged, or weld end; and flange rating, such as 150 lb ANSI.

10-11. Specify materials.

12. Write in "yes" or use check mark if required.

13. Quick open, equal percent, linear, etc.

State Characteristic:

- L = Linear
- LV = Linear V Port
- EP = Equal Percentage
- EPT = Equal Percentage Turned
- EPB = Equal Percentage Balanced
- Q = Quick Opening

Or use your own code and identify in notes.

14. Refers to seal between body and top works, such as diaphragm, stuffing box, etc.

15. Refers to seat, plug, stem, in general, all internal wetted parts.

16. Use only to specify soft seat, otherwise material will be same as trim specified in line 14.

17. Use if required.

18. Max allowable sound level dBA 3 ft from pipe and 3 ft downstream of the valve outlet.

19. Actuator may be spring type or springless pressure balanced.

20. The pilot is an integral or external auxiliary device which amplifies the force available through an operating medium, usually air.

21. Give pressure available and specify medium.

22. Refers to valve pressure sensing system. Specify whether controlled pressure is sensed internally or by means of an external line requiring an additional piping connection.

23-24. Specify diaphragm material and pressure or temperature limits, if applicable.

25. Range over which pressure setting can be made.

26. Specification of set pressure does not apply to factory setting. This must be called for specifically, if required.

27. Specify filter regulator, with or without gage, if required for air supply to pilot. Write "yes" or use check mark.

28. Specify if strainer is to be furnished with valve. Write "yes" to check off; or give style or model number.

30-31. Options available in gas regulators. On line 30 specify "bug-proof" if required.

34. State liquid, steam, gas units gpm, lb/hr ft³/min, etc.

35. Name of fluid and state whether vapor or liquid if not apparent.

36. State maximum quantity required by process and corresponding Cv.

37. State operating quantity required by process and corresponding Cv.

38. The manufacturer shall fill in the valve Cv and F_L (Liquid Pressure) Recovery Factor without reducers or other accessories.

39. Operating inlet pressure and pressure differential with units (psia, psig, inches H₂O or Hg). Note at this point that one might consider how minimum conditions will fit the sizing.

40. Maximum inlet pressure if different from normal.

41. State the maximum pressure drop in shut-off position to determine proper actuator size. This is actual difference in inlet and outlet pressure stated in psi, inches of H₂O or Hg, etc.

42. State °F or °C.

43. State operating specific gravity and molecular weight.

44. State operating viscosity and its units. State flash at valve outlet, i.e., of max flow that will be flashed to vapor because of the valve pressure drop.

45. In the case of vapors, state superheat and in the cases of liquids, state the solids, if present.

46. Note vapor pressure of fluid as well as the critical pressure.

47. Give manufacturers predicted sound level dBA.

48. Complete when available.

SELF ACTUATED TEMPERATURE REGULATORS

		SELF ACTUATED TEMPERATURE REGULATOR				SHEET ____ OF ____		
		NO		REVISION		SPEC NO.	REV.	
		BY	DATE			CONTRACT	DATE	
						REQ. NO.		
						BY	CHK'D	APPN.
GENERAL	1	Tag No.						
	2	Service						
	3	Line No./Vessel No.						
	4	Line Size/Sched. No.						
	5	Function						
VALVE	6	Body Size	Trim Size					
	7	Number of Ports						
	8	End Conn. and Rating						
	9	Body Material						
	10	Trim Material						
	11	Plug Form						
	12	Seat Material						
	13	Action On Temp. Rise						
	14							
	THERMAL SYSTEM	15	Fill SAMA Class					
16		Bulb Type						
17		Bulb Material						
18		Extension Length						
19		Insertion Length						
20		Bulb Connection						
21		Capillary Material						
22		Armor						
23		Capillary Length						
24		Wall Material						
25		Wall Connection						
26		U" Dimension	"F" Dim.					
27		Adjustable Range						
ACC	28							
	29	Integral Thermometer						
	30							
	31							
	32							
	33							
SERVICE	34	FLOW UNITS		LIQUID	STEAM	GAS		
	35	Fluid						
	36	Quant. Max. Cv						
	37	Quant. Oper. Cv						
	38	Valve Cv	Valve FL					
	39	Norm. Inlet Press.	ΔP					
	40	Max. Inlet Press.						
	41	Max. Shut Off	JP					
	42	Temp. Max.	Operating					
	43	Oper. to g	Mol. Wt.					
	44	Oper. Visc.	% Flash					
	45	% Superheat	% Solids					
	46	Vapor Press.	Crit. Press.					
	47	Predicted Sound Level	dB(A)					
	48	Manufacturer						
	49	Model No.						
Notes								

SELF ACTUATED TEMPERATURE REGULATORS

1. Identification of item by tag number.
2. Process area or function.
3. Stream description and/or pipe size or vessel number with which valve is used.
- 4.
5. Function heating or cooling.
6. Specify nominal size of body and trim in inches.
7. 1 - single port (SP); 2 - double port (DP); 3 - three-way.
8. Specify screwed or flange rating and facing.
9. Specify material of body such as bronze, carbon steel, cast iron, etc.
10. Specify material of trim such as bronze, 316 stainless steel, etc.
11. State Characteristic:

L - Linear	B - Blending
LV - Linear V Port	D - Diverting
EP - Equal Percentage	
EPT - Equal Percentage Turned	
EPB - Equal Percentage Balanced	
Q - Quick Opening	

Or use your own code and identify in notes.

12. Specify seat material such as 316 stainless steel, Buna N, etc.
13. Specify open or close.
15. Filled thermal system instruments are classified as follows:
 - Class IA: Liquid filled, uniform scale, fully compensated.
 - Class IB: Liquid filled, uniform scale, case compensated only.
 - Class IIA: Vapor pressure, increasing scale, with measured temp. above case and tubing temp.
 - Class IIB: Vapor pressure, increasing scale, with measured temp. below case and tubing temp.
 - Class IIC: Vapor pressure, increasing scale, with measured temp. above and below case and tubing temp.
 - Class IID: Vapor pressure, increasing scale, above, at, and below case and tubing temp.
 - Class IIIA: Gas filled, uniform scale, fully compensated.
 - Class IIIB: Gas filled, uniform scale, case compensated only.
 - Class VA: Mercury filled, uniform scale, fully compensated.
 - Class VB: Mercury filled, uniform scale, case compensated only.
16. State whether plain, averaging, sanitary bulb.
17. Give material and type of bulb and extension; such as 316 SS.

18. Write in length of extension, followed by "ben" for bendable, "adj" for adjustable or "rgd" for rigid.
19. The bulb insertion length should be given if no well data are shown.
20. Specify size of jam nut or union connector, or part number.
21. Specify material of capillary tubing.
22. Specify material of armor (Bronze, 316 SS, etc.) or write "None."
23. Specify length in feet.
24. Specify well material such as bronze, 304 stainless steel, 316 stainless steel, monel, etc.
25. Specify process connection size and type, such as 1/4 in. NPT, 1 1/2 in. 150 lb RF, etc.
26. Specify "U" dimension from face of flange or bottom of thread to tip of well. Specify "T" (lagging extension) dimension in inches.
27. Note adjustable range available from the manufacturer.
29. Specify range, or write in "None."
34. State liquid, steam, gas units gpm, lb./hr., ft³/min, etc.
35. Name of fluid and state whether vapor or liquid if not apparent.
36. State maximum quantity required by process and corresponding C_v.
37. State operating quantity required by process and corresponding C_v.
38. The manufacturer shall fill in the valve C_v and F_L (Liquid Pressure) Recovery Factor without reducers or other accessories.
39. Operating inlet pressure and pressure differential with units (psia, psig, inches H₂O or Hg). Note at this point that one might consider how minimum conditions will fit the sizing.
40. Maximum inlet pressure if differential from normal.
41. State the maximum pressure drop in shut-off position to determine proper actuator size. This is actual difference in inlet and outlet pressure stated in psi, inches of H₂O or Hg, etc.
42. State °F. or °C.
43. State operating specific gravity and molecular weight.
44. State operating viscosity and its unit. State flash at valve outlet, i.e., of max flow that will be flashed to vapor because of the valve pressure drop.
45. In the case of vapors, state superheat and in the cases of liquids, state the solids, if present.
46. Note vapor pressure of fluid as well as the critical pressure.
47. Give manufacturers predicted sound level dBA.
48. Complete when available.

SOLENOID VALVES

		SOLENOID VALVES				SHEET ____ OF ____			
		NO		BY		DATE	REVISION	SPEC NO.	REV.
								CONTRACT	DATE
								REQ	P.O.
								BY	CHK'D
VALVE BODY	1.	Tag Number							
	2.	Service							
	3.	Line No./Vessel No.							
	4.	Quantity							
	5.	Type							
	6.	Size - Body/Port							
	7.	Rating & Type Conn.							
	8.	Material - Body							
	9.	Material - Seat							
	10.	Material - Diaphragm							
	11.	Operation Direct/Pilot							
	12.	Packless or Type Packed							
	13.	Manual Re-Set							
	14.	Manual Operator							
	15.								
	16.								
	WHEN DE ENERGIZED	17.	2-Way Valve Opens/Close						
		18.	3-Way						
19.		Vent Port Opens/Close							
20.		Press Port Opens/Close							
21.		4-Way							
22.		Press to Cyl. 1/Cyl 2							
23.		Exh. from Cyl 1/Cyl 2							
24.									
25.									
SOLENOID	26.	Enclosure							
	27.	Voltage/Hz							
	28.	Style of Coil							
	29.	Single or Double Coil							
	30.								
	31.								
SERVICE CONDITIONS	32.	Fluid							
	33.	Qty. Maximum							
	34.	Oper. Diff. Min/Max							
	35.	Allow. Diff. Min/Max							
	36.	Temp. Norm/Max.							
	37.	Oper. sp. g.							
	38.	Oper. Viscosity							
	39.	Required C _v							
	40.	Valve C _v							
	41.								
42.									
43.									
44.									
45.	Manufacturer								
46.	Model Number								
Notes									

SOLENOID VALVES

1. Identification by tag number.
2. Process service.
3. Identification of line and vessel.
4. Number of identical valves.
5. Indicate whether 2-way, 3-way, or 4-way.
6. Specify body and port size in inches.
7. Maximum pressure rating and type of connections such as screwed or FLANGE rating.
 8. Specify material such as bronze, aluminum or stainless steel.
 9. Specify seat such as bronze or stainless steel, synthetic rubber, teflon, etc.
10. If diaphragm is used, specify material such as synthetic rubber, teflon.
11. Designate whether direct operated, self pilot type or with pilot requiring auxiliary operating medium.
12. Specify packless or type packing.
13. State whether no voltage release or electrically lapped.
14. Specify if required.
- 15,16. Blanks for special requirements i.e., manifold valves etc.
- 17-23. State whether open or closed in appropriate places.
- 24,25. Blanks for special requirements.
26. Specify enclosure as general purpose, water tight, explosion proof.
27. State electrical characteristics voltage, ac or dc, and ac hertz.
28. Style of coil to be standard, molded, high temperature.
29. State whether single or dual coil. If dual coil, explain operation in space for notes.
- 30,31. Blanks for special requirements.
32. Name fluid and state whether liquid or gas if not apparent.
33. State maximum required capacity in units of flow such as gpm, lb/hr, SCFH.
34. State actual minimum and maximum differential encountered under operating conditions.
35. Vendor to state minimum operating differential required to operate valve and maximum allowable differential.
- 36-38. State normal operating temperature and maximum possible temperature operating, specific gravity or molecular weight and operating viscosity.
39. State calculated Cv requirement.
40. Vendor to state valve Cv.

APPENDIX B

1. DEFINITIONS OF PARTS COMMON TO MANY TYPES OF VALVES

1.1 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.

1.2 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.

1.2.1 Bonnet types

Typical bonnets are bolted, threaded, or welded to or integral with the body. Other types sometimes used are defined below.

1.2.2 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.

1.3 Closure Member

A movable part of the valve which is positioned in the flow path to modify the rate of flow through the valve.

1.4 Flow Control Orifice

The part of the flow passageway that, with the closure member, modifies the rate of flow through the valve. The orifice may be provided with a seating surface, to be contacted by or closely fitted to the closure member, to provide tight shutoff or limited leakage.

1.4.1 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.

1.4.2 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.

1.4.3 Integral seat

A flow control orifice and seat that is an integral part of the body or cage material or may be constructed from material added to the body or cage.

1.5 Stem

The stem rod, shaft or spindle which connects the valve actuator with the closure member.

1.6 Stem Seals

The part or parts needed to effect a pressure-tight seal around the stem while allowing movement of the stem.

1.6.1 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.

1.6.2 Packing box

The chamber, in the bonnet, surrounding the stem and containing packing and other stem sealing parts.

1.7 Bushing

A fixed member which supports and/or guides the closure member, valve stem and/or actuator stem. The bushing supports the nonaxial loads on these parts and is subject to relative motion of the parts.

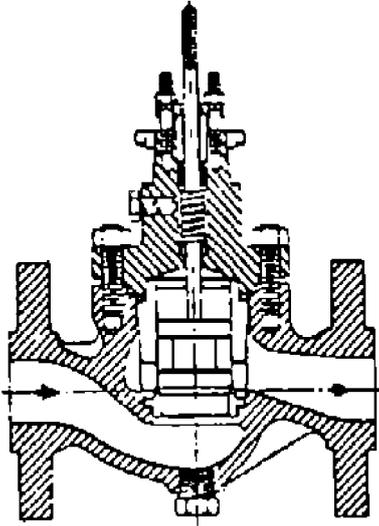
2. LINEAR MOTION CONTROL VALVE TYPES

Types of valves with a closure member that moves with a linear motion to modify the rate of flow through the valve.

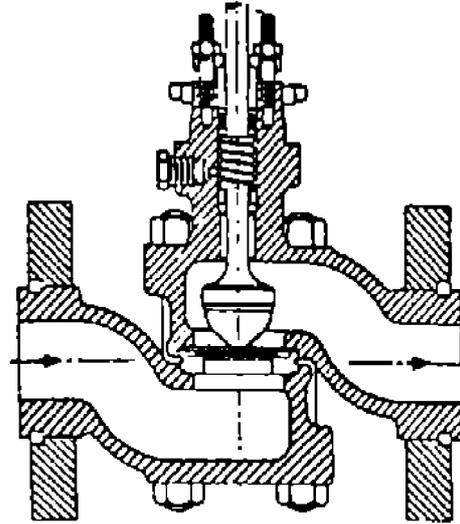
2.1 Globe Valve

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. Typical globe valve types are illustrated below. Flow arrows shown indicate a commonly used flow direction.

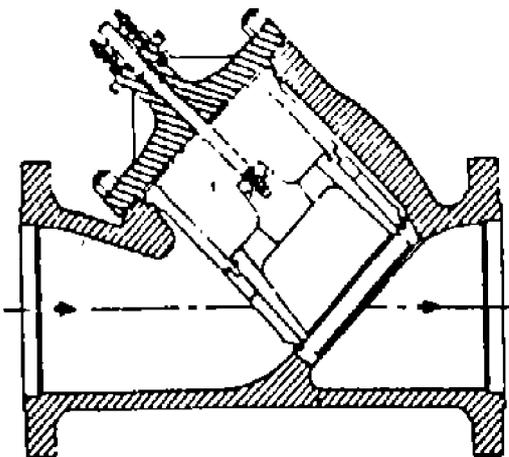
TWO-WAY BODIES



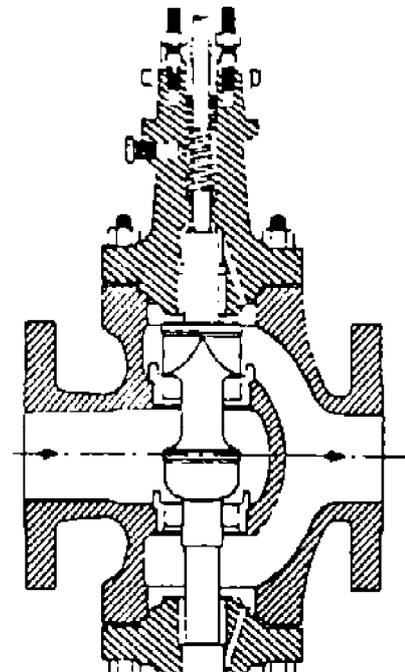
1 a) Cage Guided



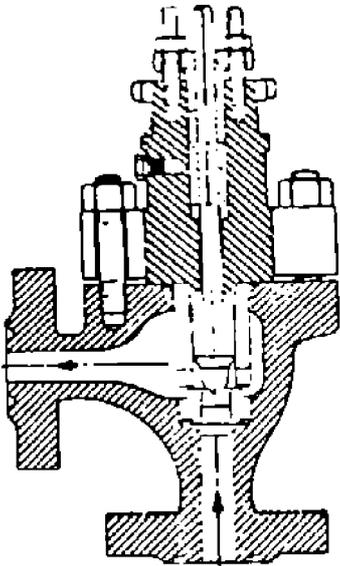
1 b) Split Body Stem Guided



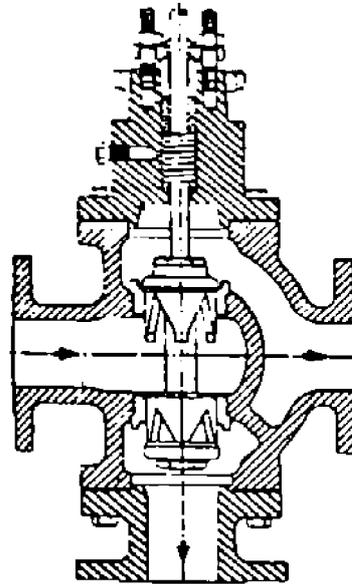
1 c) Y Type Cage Guided



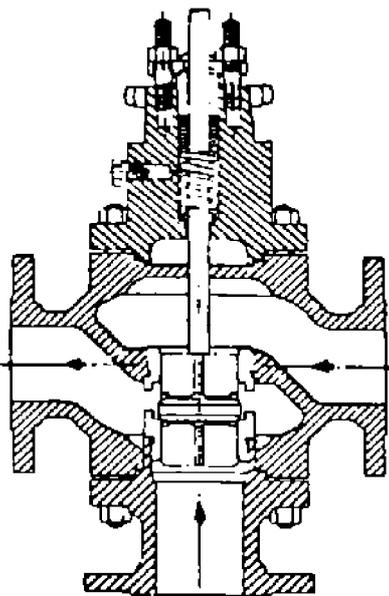
1 d) Double Ported Post or (Top & Bottom) Guided



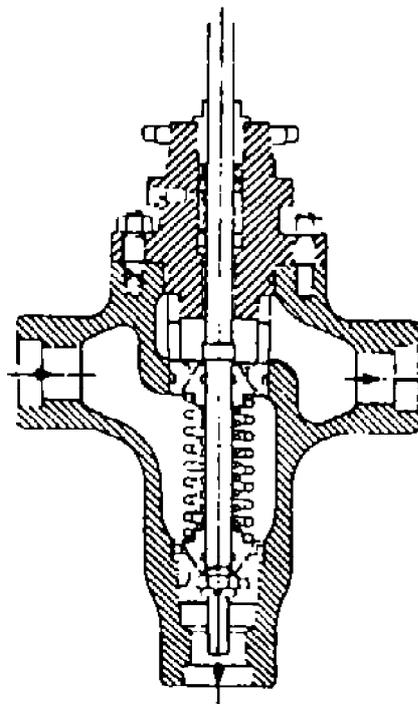
1 e) Angle Body



1 f) Diverging



1 g) Converging



1 h) Three Position

2.1.1 Bottom flange

A part which closes a valve body opening opposite the bonnet opening. It may include a guide bushing and/or serve to allow reversal of the valve action. In three-way valves it may provide the lower flow connection and its seat.

2.1.2 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.

2.1.2.1 Anti-Noise trim

A combination of plug and seat ring or plug and cage that by its geometry reduces the noise generated by fluid flowing through the valve.

2.1.2.2 Anti-Cavitation trim

A combination of plug and seat ring or plug and cage that by its geometry permits non-cavitating operation or reduces the tendency to cavitate, thereby minimizing damage to the valve parts, and the downstream piping.

2.1.2.3 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 stem of a globe valve.

2.1.2.4 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.

2.1.2.5 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.

2.1.3 Globe valve plug guides

The means by which the plug is aligned with the seat and held stable through out its travel. The guide is held rigidly in the body or bonnet.

2.1.3.1 Stem guide

A guide bushing closely fitted to the valve stem and aligned with the seat, (Fig. 1b).

2.1.3.2 Post guide

Guide bushing or bushings fitted to posts or extensions larger than the valve stem and aligned with the seat, (Fig. 1d).

2.1.3.3 Cage guide

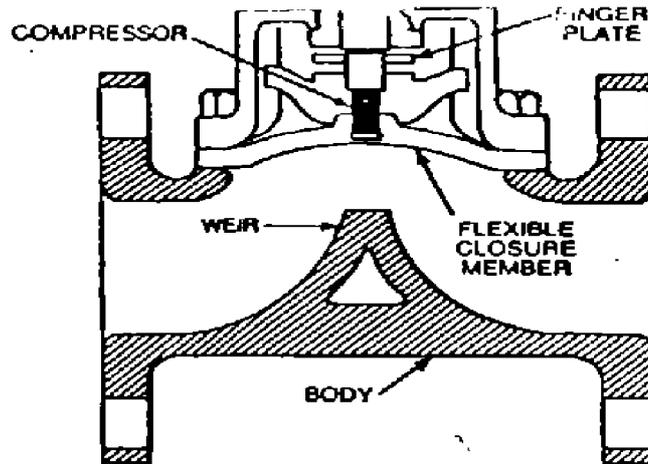
A valve plug fitted to the inside diameter of the cage to align the plug with the seat, (Fig. 1a).

2.1.3.4 Port guide

A valve plug with wings or a skirt fitted to the seat ring bore.

2.2 Diaphragm Valve

A valve with a flexible linear motion closure member that is forced into the internal flow passageway of the body by the actuator.

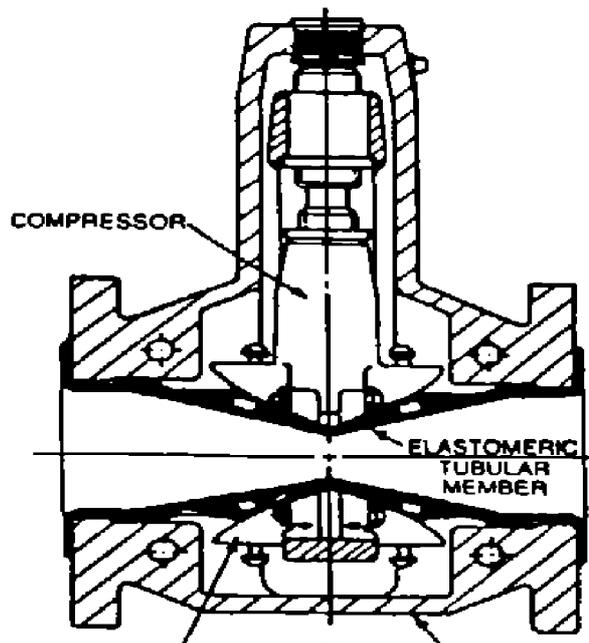


2.2.1 Valve diaphragm

A flexible member which is moved into the fluid flow passageway of the body to modify the rate of flow through the valve.

2.2.2 Compressor

A device which the valve stem forces against the backside of the diaphragm to cause the diaphragm to move toward and seal against the internal flow passageway of the valve body.



2.2.3 Finger plate

A plate used to restrict the upward motion of the diaphragm and prevent diaphragm extrusion into the bonnet cavity in the full open position.

3. ROTARY MOTION CONTROL VALVE TYPES

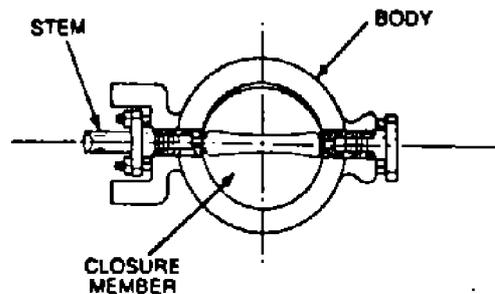
Types of valves with a closure member that moves with a rotary motion to modify the rate of flow through the valve.

3.1 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, (Ref. 6.6.2).

3.2 Butterfly Valve

A valve with a circular body and a rotary motion disk closure member, pivotally supported by its stem.



3.2.1 Body types

3.2.1.1 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.

3.2.1.2 Split body

A body divided in half by a plane containing the longitudinal flow path axis.

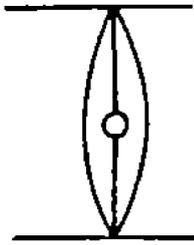
3.2.1.3 Lined body

A body having a lining which makes an interference fit with the disk in the closed position thus establishing a seal.

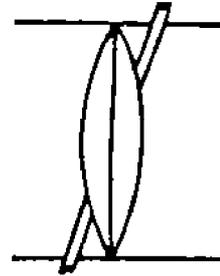
3.2.1.4 Unlined body

A body without a lining.

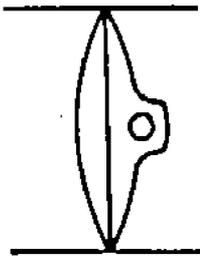
3.2.2 Typical disk orientations



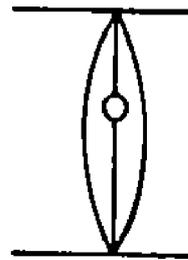
a) Aligned



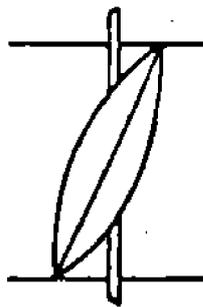
b) Aligned with Canted Stem



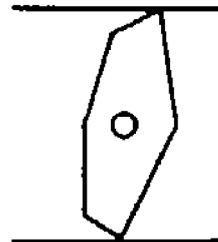
c) Offset



d) Cammed

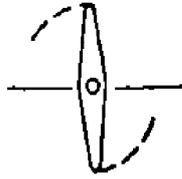


e) Canted Disk

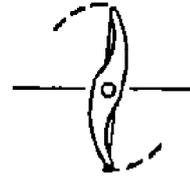


f) Angle Seated

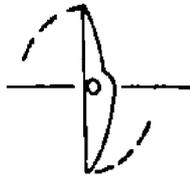
3.2.3 Typical disk shapes



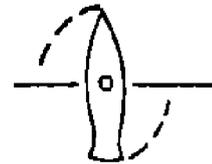
a) Flat



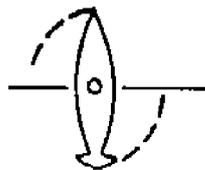
b) Cambered



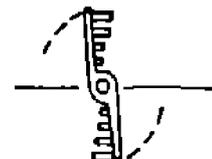
c) Nonsymmetrical Edge



d) Contoured



e) Knife



f) Fluted

3.2.4 Seal on disk

A seal ring located in a groove in the disk circumference. The body is unlined in this case.

3.2.5 Stem bearings

Butterfly stem bearings are referred to as either the outboard or the inboard type, depending on their location, outside or inside of the stem seals.

APPENDIX C

SIZING THEORY AND APPLICATIONS

PART 1: SIZING THEORY AND APPLICATIONS* (L.R. Driskell)

INTRODUCTION

The problem of sizing a control valve may be broken into several more or less distinct parts. The person sizing a valve should carefully consider the effect of these factors on valve size.

1) Flow Application Data:

Flow rate, maximum and minimum.

Pressure upstream and downstream (at both maximum and minimum flows).

Temperature of the stream.

2) Fluid Data:

Name of fluid or its generic identity.

Fluid phase-liquid, gas, slurry, etc.

Density (specific gravity, specific weight, molecular weight, etc.).

Viscosity (liquids).

Vapor pressure (liquids).

3) Piping Influence:

Pressure of reducers or other disturbances at the valve which will change the rated capacity.

4) System Influence:

Control dynamics (is oversizing unimportant?).

Economic factors (is downstream relief valve size affected?).

Safety.

5) Style of Valve-Selection based on application:

Capacity, order of magnitude of size.

Rangeability.

Corrosion or erosion resistance.

Special requirements (tight shut-off, low noise, etc.).

6) Sizing Calculations:

Manufacturer's sizing coefficients.

Sizing formulas, slide rules, nomographs.

7) Judgment:

Based on discriminating analysis of past successes and failures.

* The sizing information and data contained in this chapter is based on the latest ISA Standards S-39.1 and S-39.3.

The first four items can be properly evaluated only by one who is knowledgeable about the whole process; therefore, this is usually the purchaser.

The principal responsibility of the valve manufacturer, in valve sizing, is to publish certified valve sizing coefficients. These values simply state the performance characteristics of his valves, based on standard test data and quality control of production. In some instances a valve manufacturer may assume additional responsibilities. This usually involves sizing the valve based on data provided by the purchaser and may include the selection of valve type and materials as well. This additional engineering on the part of the vendor involves added work and liability on his part and involves some degree of risk on the part of the purchaser. If there is divided responsibility, the application must fly without the last important ingredient—good judgment.

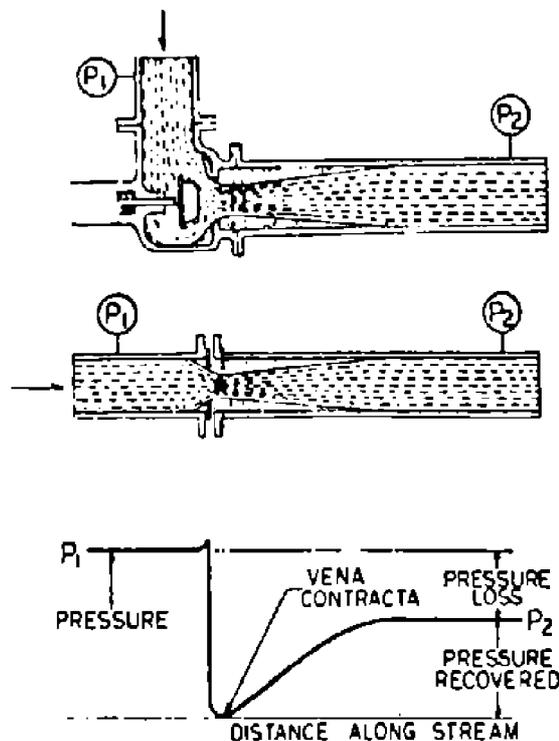
Theory

To be a good aircraft pilot it is necessary to have the seat-of-the-pants feel of the ship. It is also important to know why the ship responds the way it does. For the same reasons, the art of valve sizing goes hand-in-hand with the science of fluid mechanics. It is helpful to know why valves work and what their limitations are, to properly apply the cook-book formulas.

Incompressible Fluids

A fluid flowing through control valves follows the same laws of conservation of mass and energy as expressed in the equations of fluid mechanics. First consider the flow of liquids, which essentially are incompressible fluids. When any fluid flowing inside a pipe, passes through a narrower passage or restriction, it must accelerate. The energy for this acceleration must be taken from the pressure of the fluid, or the static head.

After passing the restriction, the fluid slows down again and part of this head, or pressure, is recovered. The unrecovered part of the pressure has been converted into internal energy by friction. Fig. 1 shows the pressure gradient around a valve or an orifice.



CONTROL VALVE AND ORIFICE PLATE INSTALLATIONS SHOWING REDUCED AREA AT VENA CONTRACTA. THE CURVE DESCRIBES THE PRESSURE GRADIENT AROUND EITHER DEVICE

Fig. 1

Neglecting friction and other non-ideal influences for a moment, Bernoulli's theorem tells us that

$$U_2^2 - U_1^2 = 2gh \tag{1}$$

where U_1 and U_2 are the mean axial speed of the fluid across areas a_1 and a_2 respectively, g is the acceleration of gravity, and h is difference in head (pressure) measured in feet of the fluid.¹

¹ In this part of the discussion of theory all units are in standard absolute units, such as pressures in pounds per square foot, areas in square feet, etc. The working equations discussed later use customary engineering units of pounds per square inches, etc. When metric units are applicable, it will be noted.

If area a_1 is the area of the inlet pipe, and area a_2 is the area of the stream vena contracta, as shown in Fig. 1, Equation (1) can be converted to:

$$q_t = a_2 \sqrt{\frac{P_1 - P_2}{2g}} \phi \sqrt{\frac{1}{1 - \frac{a_2^2}{a_1^2}}} \tag{2}$$

Where q_t is the theoretical flow in cubic feet per second.

Since the actual flow through a restriction is always less than the indicated theoretical rate, and since the area of the vena contracta is less than the orifice area, an additional factor "C," called the discharge coefficient, must be included in the equation. This factor accounts for the contraction of the stream as well as the pressure lost to friction. The fundamental hydraulic equation then becomes:

$$q = a_2 \bar{K} \sqrt{\frac{P_1 - P_2}{2g}}$$

where:

$$\bar{K} = C \sqrt{\frac{1}{(a_2/a_1)^2}} \tag{3}$$

a_2 is the orifice area

It is well to be reminded at this point that the foregoing theoretical development is based on the assumption that p_2 is being measured at the vena contracta, or point of minimum stream area. If p_2 is being measured at a point farther downstream, as is customary in control valve work, another correction factor must be included.

$$FL = \frac{q \sqrt{P_1 - P_2}}{\rho_1 - \rho_{vc}} \tag{4}$$

The relationship expressed by Equation (4) is correct only as long as the fraction of ρ_{vc} recovered remains constant. When flashing or cavitation takes place, for example, this relationship does not hold, and formulas based on p_2 must be modified.

If the fundamental hydraulic Equation (3) is converted to customary engineering units, and p_2 is being measured downstream at a point of full pressure recovery, it then becomes

$$q = \frac{38.0 a \bar{K}}{F_L} \sqrt{\frac{p}{G}} \tag{5}$$

In control valve work the value of the term in parentheses is replaced by an experimentally determined coefficient called C_v ; therefore, Equation (5) becomes:

$$q = C_v \sqrt{\frac{q}{G}} \tag{6}$$

COMPRESSIBLE FLUIDS

Liquids are nearly incompressible and, as they pass through a valve, their specific weight remains constant. Gases and vapors, on the other hand, expand as the pressure drops; therefore, their specific weight decreases as they pass from the valve inlet to the vena contracta within the valve body. The effective specific weight, as far as flow is concerned, is approximately mid-way between the value up-stream at p_1 and the value at the vena contracta.

The most convenient way of accounting for the change of specific weight in sizing formulas for valves, as well as for orifice meters, flow nozzles, and venturis, is by applying an expansion factor "Y" to the formula for liquids. If the basic equation for liquids is converted to weight units it becomes:

$$w = N_6 C_v \sqrt{\frac{P}{i p - 1}} \tag{7}$$

(See Table I, Page 93.)

Where N_6 is the constant for units. If the fluid is compressible, Y must be included; therefore,

$$w = N_6 C_v Y \sqrt{\frac{P}{i p - 1}} \tag{8}$$

The relationship of Y to x for any particular valve fortunately turns out to be an essentially linear curve. The slope of this curve is determined experimentally by methods prescribed by ISA Standard S39.4. With air as the test fluid, the slope of the curve is defined by the pressure drop ratio factor xT , which is the value of x when Y reaches its lower limit of 0.667. Mathematically, when air is the fluid Y has the value: $1 - 0.33 (x/xT)$.

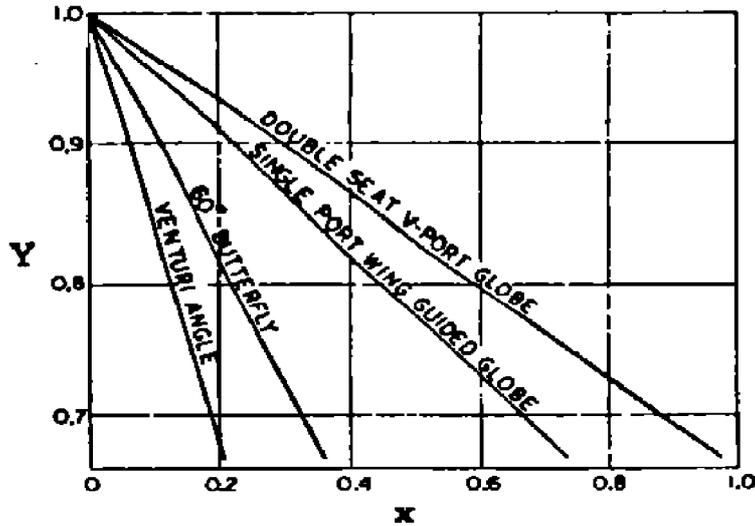
The relationships of Y vs. x for several widely differing styles of valves are shown in Fig. 2. It will be noticed that all of the plots are straight lines and that they terminate at a value of $Y = 0.667$.

Although the true plots may deviate some what from a straight line, the test data to date indicate that the linear representation is within the tolerance of experimental error (about 2%). Termination at $Y = 0.667$ results from the fact that the ultimate flow through a restriction at any selected p_1 must occur when the quantity $Y \sqrt{x}$ reaches a maximum. With the linear relationship of Y to x, it can be demonstrated by differential calculus that $Y \sqrt{x}$ reaches a maximum at $Y = 0.667$.

Nitrogen, oxygen, hydrogen and other diatomic gases behave like air when passing through a valve, but some gases and vapors behave differently and require an adjustment to the slope of the Y curve. The adjustment is brought about by multiplying xT by the correction factor F_k , which is called the ratio of specific heats factor. Table IV lists the values of F_k for a number of common gases, and the value for any gas can be found from Equation (19) if the ratio of specific heats for the gas is known. Taking this effect into account, the resulting formula for Y for any gas or vapor becomes:

$$Y = 1 - 0.33 (x/FK_{xT}) \tag{9}$$

and since the maximum flow is reached when Y attains its minimum value of 0.667, then the maximum useful value of x is FK_{xT} .



EXPANSION FACTOR, Y AS A FUNCTION OF PRESSURE DROP RATIO, X, FOUR WIDELY DIFFERING STYLES OF CONTROL VALVE
Fig. 2

Considering the foregoing, we can now arrange Equation (8) to facilitate the handling of this limitation of x:

$$w = N_6 C_v Y^D \overline{x\rho_1^{-1}} \tag{10}$$

In this form, if x exceeds FK_{xT} , the value of FK_{xT} is used in place of x, and Y becomes 0.667. If x is less than FK_{xT} , then Y is determined by Equation (9).

If U.S. customary units are used, (units based upon the foot and the pound commonly used in the United States of America and defined by the National Bureau of Standards). Equation (10) expresses the weight flow in pounds per hour based on the specific weight in pounds per cubic foot. If SI units are used, the mass flow rate in kilograms per hour and density in kilograms per cubic meter are the units employed. Weight units are customarily used for steam and other vapors.

For a gas, it is common to use volumetric units for flow and specific gravity relative to air instead of density or specific weight. Equation (10) may be restated as:

$$q_g = N_7 C_v p_1 Y^q \frac{\overline{x}}{G_g T_1 Z} \tag{11}$$

Here you will notice the appearance of Z, the compressibility factor, which is now needed because the density term has become a calculated value based on the inlet pressure and temperature, and the specific gravity at base pressure and temperature. If the fluid behaves as a perfect gas, Z will be 1.0, but for real gases Z may vary widely. Compressibility charts¹ show Z ranging from 0.23 to about 4.0 which would change the predicted flow by a factor of 2 in either direction. For most real gases Z usually falls between 0.5 and 1.5, resulting in a flow 40% greater or 20% less than would be predicted if the compressibility factor were omitted. In all cases, if the actual stream density is known, the weight formula will give more accurate results.

¹ See Nelson-Obert Charts.

WORKING EQUATIONS

Liquid Formulas

$$C_v = \frac{q_r}{N_1 F_p F_R} \sqrt{\frac{G_f}{\Delta P}} \quad \text{or}$$

$$q_r = N_1 F_p F_R C_v \sqrt{\frac{\Delta P}{G_f}} \quad (12)$$

$$C_v = \frac{w}{N_6 F_p F_R \sqrt{\Delta P \gamma}} \quad \text{or}$$

$$w = N_6 F_p F_R C_v \sqrt{\Delta P \gamma} \quad (13)$$

At this point it is appropriate to explain why certain factors have been added to the basic equation. The numerical constants N_1 , N_6 , etc. have been introduced to accommodate the transition to metric units. These numerical constants will, of course, have a different value depending upon whether U.S. customary units or SI units are used in the equations. (SI is the official abbreviation for the International System of Units). The factor F_p is introduced to correct for piping geometry differing from that of the standard test manifold. Factor F_R is applied to correct for a non-turbulent flow condition, which can occur with viscous fluids or with low pressure drop across the valve. These new factors will be described in detail in the following pages. The inclusion of all the new factors certainly adds to the complexity of control valve sizing, but they are necessary if reasonable accuracy is desired.

Valve capacity is also affected by vaporization of the flowing liquid at the valve orifice. The conditions where this occurs, called cavitation or flashing, are discussed in Part 2 of this chapter.

The formulas presented in ISA valve sizing standards cannot be used blindly to come up with a properly sized valve. They are intended to be basic mathematical expressions for flow through a valve. The ISA SP 39 Committee recognized that various working equations based on the standards would be developed which may be either more convenient for routine valve sizing, or perhaps more easily handled by digital computer techniques.

Example 1		Liquid Flow	
Given:	Fluid	Brine	
	Specific gravity at F.T.	1.2	
	Flow rate maximum	250 gpm at F.T.	
	Δp at maximum flow	10 psi	
	Flow rate minimum	40 gpm at F.T.	
	Δp at minimum flow	25 psi	

$$C_v = q_r \sqrt{\frac{G_f}{\Delta p}} = 250 \sqrt{\frac{1.2}{10}} = 87 \quad (\text{Equation 6})$$

$$C_v \text{ (minimum)} = 40 \sqrt{\frac{1.2}{25}} = 8.7$$

(Rangeability 10:1)

Gas and Vapor Formulas

$$C_v = \frac{w}{N_6 F_p Y \sqrt{x p_1 \gamma_1}} \quad \text{or}$$

$$w = N_6 F_p C_v Y \sqrt{x p_1 \gamma_1}$$

$$C_v = \frac{q}{N_7 F_p p_1 Y \sqrt{\frac{G T_1 Z}{x}}} \quad \text{or}$$

$$q = N_7 F_p C_v p_1 Y \sqrt{\frac{x}{G T_1 Z}}$$

$$C_v = \frac{w}{N_8 F_p p_1 Y \sqrt{\frac{T_1 Z}{x M}}} \quad \text{or}$$

$$w = N_8 F_p C_v p_1 Y \sqrt{\frac{x M}{T_1 Z}}$$

$$C_v = \frac{q}{N_9 F_p p_1 Y \sqrt{\frac{M T_1 Z}{x}}} \quad \text{or}$$

$$q = N_9 F_p C_v p_1 Y \sqrt{\frac{x}{M T_1 Z}}$$

$$Y = 1 - \frac{X}{3 F_k X T}$$

$$F_k = k/1.40$$

For dry saturated steam (U.S. Customary Units):

$$C_v = \frac{w}{P_1 \left(3 - \frac{x}{x T} \right) \sqrt{x}} \quad \text{or}$$

$$w = C_v P_1 \left(3 - \frac{x}{x T} \right) \sqrt{x}$$

1 Equations (15), (16) and (17) are variations of Equation (14) using conversion factors for customary units.

In all the above formulas the value used for x may not exceed $(F_{K_{xT}})$, regardless of the actual pressure ratio.

Limitations of Equations

Equation (20) is a simplified form for steam. Results will not deviate by more than 6% from the more precise Equation (14) over the range of steam pressures from 0 to 1600 psig.

Mixed phase - For gas-liquid mixtures see the section on "Mixed Phase".

Near critical pressure - Error can become significant when the pressure drop ratio is high and the vapor is near its critical pressure. Steam begins to deviate above 1400 psia.

High Δp - Although the equations are valid for all pressure drops, extremely high outlet velocities may cause excessive noise. Pipe increasers which are normally installed at the valve outlet can cause super-sonic shock waves. To reduce the possibility of excessive noise from this source, it is recommended that the valve outlet velocity be limited to one Mach, preferably as low as one-third Mach. On this basis the valve outlet (increaser inlet) size for one Mach may be determined for a gas by

$$\text{Diam.} = 0.0024 \sqrt{\frac{q}{P_2} \left[\frac{T_1 M}{k} \right]^{1/2}}$$

or

$$\text{Diam.} = 0.047 \sqrt{\frac{w}{P_2} \left[\frac{T_1}{Mk} \right]^{1/2}}$$

For saturated steam -

$$\text{Diam.} = 0.012 \sqrt{\frac{w}{P_2}}$$

For one-third Mach multiply the diameter found above by 1.7.

Example 2		Gas or Vapor Flow
Given:	Fluid	Refrigerant R-12
	Rate, w	20,000 lb/hr.
	Pressure, p₁	114.5 psia
	Pressure, p₂	54.5 psia
	Sp. Vol, v₁	0.355 ft./lb.
	Line size	2 inch

If the valve selected is, for example, a single-seat cage guided type, the value of x_T is about 0.75 and the C_v is about 11d².

$$F_p C_v = \frac{w}{N Y \sqrt{x^3 p_1 \gamma}} \quad 1$$

x = 60/114.5 = 0.524 (by definition)
F_k^{xT} = (0.75) (1.14)/1.40 = 0.610
Y = 1 - 0.524/(3)(0.610) = 0.714 (Eq. 18)

$$F_p C_v = \frac{20,000}{(63.3)(0.714)} \sqrt{\frac{0.355}{(0.524)(114.5)}} = 34$$

If a 2 - inch valve of the style selected has a C_v of 44, it would pass the required amount at 75 to 80% opening, Reducers are not required and F_p is equal to 1.0.

Slide Rules and Nomographs

Many control valve manufacturers provide slide rules and nomographs to be used for valve sizing. When properly designed and used, the results of these tools are as accurate as direct calculations. They, of course, have their advantages and disadvantages. Generally these methods are faster, because all constants in the equations are incorporated into the scales and require no additional settings. The tools must be used frequently in order to avoid re-reading the procedural instructions. The units of measurement used must conform to those employed by the slide rule or nomograph.

The chances of error for the various methods depends upon the calculator. Usually no record is preserved when these devices are used; therefore, checking is difficult.

Low Reynolds Number

The nature of flow in pipes depends upon the combination of four variables (diameter, viscosity, density, velocity) arranged to produce a dimensionless number called the Reynolds number. The value of this number determines whether the flow is laminar or turbulent, and it also affects the coefficient of discharge of an orifice.

The flow coefficient, C_v, is determined at a reasonably high Reynolds number with the fluid in turbulent flow. The C_v changes very little as the Reynolds number is increased. However, as the Reynolds number is decreased, the effective C_v becomes smaller and a correction factor must be applied. At extremely low Reynolds numbers the flow becomes laminar rather than turbulent, and the flow rate is proportional to ΔP rather than √ΔP. This change in flow mechanism is provided for by the correction factor, FR.

The Reynolds criterion is valid only when there is precise mechanical similarity between the devices. For example, in the determination of the friction factor for pipes the "length" dimension used to calculate Reynolds number is the pipe internal diameter, but the relative roughness of the pipe wall must also be the the same as that of the test specimen to validate the method.

TABLE I - NUMERICAL CONSTANTS

SIZING THEORY

N	w	q	P	γ	T	d/D	ω CM ²
N ₁ 0.0986 1.00		m ³ /h gpm	kPa psia				
N ₂ 0.00214 690						mm in	
N ₃ 645 1.00						mm in	
N ₄ 75,000 17,300		m ³ /h gpm				mm in	centistokes centistokes
N ₅ 0.00241 1,000						mm in	
N ₆ 2.73 63.3	kg/h lb/hr		kPa psia	kg/m ³ lb/ft ³			
N ₇ 4.17 1,360		m ³ /h scfh	kPa psia		K R		
N ₈ 0.948 19.3	kg/h lb/hr		kPa psia		K R		
N ₉ 22.4 7320		m ³ /h scfh	kPa psia		K R		
N ₁₀ 1.72 52.3		m ³ /h gpm	kPa psia			mm in	centipoise centipoise

* The standard cubic foot is taken at 14.73 psia and 60°F, and the standard cubic meter at 1.013×10^5 N/m² and 15°C.

TABLE II - VALVE SIZING DATA REPRESENTATIVE VALVE FACTORS

BODY & TRIM TYPE	FLOW DIRECTION	LINE SIZE BODY (D=d)						HALF SIZE (D=2d)			
		C_d	F_L	X_T	F_d^1	F_s	K_c	$\frac{N_3 C_v}{D^2}$	F_{LP}	X_{TP}	F_b
Single Seat Globe Wing Guided V-Skirt Contoured Contoured V-Plug Cage Cage	Either	11	.90	.75	1.0	1.05	c	2.8	.85	.75	1.04
	Either	9	.90	.75	1.5	1.38	c	2.3	.86	.75	1.38
	Open	11	.90	.72	1.0	1.05	.65	2.8	.85	.73	1.04
	Close	11	.80	.55	1.0	1.09	.58	2.8	.78	.57	1.08
	Either	9.5	.90	.75	1.0	1.05	.80	2.4	.86	.75	1.04
	Open	14	.90	.75	1.0	1.06	.65	3.5	.82	.75	1.04
	Close	16	.80	.70	1.0	1.11	c	4.0	.72	.71	1.08
	Double Seat Globe Wing Guided V-Skirt Contoured V-Plug	--	14	.90	.75	.71	0.84	c	3.5	.82	.75
--	13	.90	.75	.71	0.84	c	3.3	.83	.75	0.83	
--	13	.85	.70	.71	0.85	.70	3.3	.79	.71	0.84	
--	12.5	.90	.75	.71	0.84	.80	3.1	.83	.75	0.84	
Angle Full Port Contour Full Port Contour Restricted Contour Restricted Contour 2:1 Tapered Orif. Cage Cage Venturi	Close	20	.80	.65	1.0	1.12	.53	5.0	.69	.68	1.08
	Open	17	.90	.72	1.0	1.08	.64	4.3	.78	.73	1.04
	Close	>6	.70	.55	1.0	1.13	c	1.5	.69	.56	1.13
	Open	>5.5	.95	.80	1.0	1.02	c	1.3	.93	.80	1.02
	Close	12	.45	.15	1.0	1.31	c	3.0	.44	.17	1.31
	Open	12 ^a	.85	.65	1.0	1.08	c	3.0	.80	.68	1.06
	Close	12 ^a	.80	.60	1.0	1.10	c	3.0	.75	.62	1.08
	Close	22	.50	.20	1.0	1.29	.17	5.5	.48	.28	1.28
Ball Std. Bore ^b Characterized	--	30	.55	.15	1.0	1.28	.25	7.5	.47	.24	1.22
	--	25	.57	.25	1.0	1.25	.22	6.3	.50	.33	1.21
Butterfly 60-Deg. Open 90-Deg. Open	--	17	.68	.38	.71	0.92	.3	4.3	.63	.43	0.91
	--	>30	.55	.20	.71	1.01	c	>7.8	.45	.33	0.97

1 The values of F_d are based on limited test data which have not been corroborated by independent laboratories. F_s is computed from F_d . Key: a = Variable, b = Orif. 0.8 d, c = Unavailable.

TABLE III - SUMMARY OF FORMULAS ARRANGED FOR CONVENIENCE

REMARKS	EQUATIONS	VALUE OF N'	
		U.S.	SI
LIQUID Turbulent and Non-Cavitating	$q_f = N_1 F_p C_v \sqrt{\frac{\Delta p}{G_f}}$	1.00	0.0865
	$w_f = N_6 F_p C_v \sqrt{\Delta p \gamma}$	63.3	2.73
Choked	$q_f = N_1 F_{LP} C_v \sqrt{\frac{P_1 - P_{vc}}{G_f}}$	1.00	0.0865
	$w_f = N_6 F_{LP} C_v \sqrt{\frac{P_1 - P_{vc}}{G_f}}$	63.3	2.73
	$P_{vc} = F_F P_v$ $F_F = 0.98 - 0.28 \sqrt{\frac{P_v}{P_c}}$		
	$F_{LP} = \left[\frac{1}{F_L^2} + \frac{K_i}{N_2} (C_d)^2 \right]^{-1/2}$ $K_i = (\text{See Piping Geometry Factor})$	890	0.00214
Laminar	$q_f = N_{10} \frac{\Delta p}{\mu} (F_s F_p C_v)^{3/2}$	52	173
	$F_s = \left(\frac{F_p F_d^2}{F_{LP}} \right)^{1/3} \left[\frac{(F_{LP} C_v)^2}{N_2 D^4} + 1 \right]^{1/8}$	890	0.00214
Transitional	$q_f = N_1 F_R F_p C_v \sqrt{\frac{\Delta p}{G_f}}$	1.00	0.0865

1 U.S. units are: pounds per hour, gallons per minute, pounds per square inch absolute, pounds per cubic foot, °R, and inches.
SI units are: kilograms per hour, cubic meters per hour, kPa, kilograms per cubic meter, °K, and millimeters.

(to be continued)

TABLE III - (continued)

REMARKS	EQUATIONS	VALUE OF N	
		U.S.	SI
Gas or Vapor - (All Equations: $x < F_k x_T$)			
	$w_g = N_6 F_p C_v Y \sqrt{x P_1 V_1}$	83.3	2.73
	$q_g = N_7 F_p C_v P_1 Y \sqrt{\frac{x}{G_g T_1 Z}}$	1360	4.17
Variations for Selected units.	$w_g = N_8 F_p C_v P_1 Y \sqrt{\frac{x M}{T_1 Z}}$	19.3	0.948
	$q_g = N_9 F_p C_v P_1 Y \sqrt{\frac{x}{M T_1 Z}}$	7320	22.4
Expansion factor lower limit = 0.667	$Y = 1 - \frac{x}{3 F_k x_T}$		
Sp. ht. ratio factor	$F_k = W/1.40$		
Mfr's. Factors	$x_T = C_1^2 = \frac{0.84 C_1^2}{1600}$		
x_T with reducers	$x_{TP} = \frac{x_T}{F_p^2} \left[\frac{x_T K_1}{N_5} (C_d)^2 + 1 \right]^{-1} 1000$ $K_1 = (\text{See Piping Geometry Factor})$	0.0024	
Steam (Dry and Saturated)			
For $x < x_{Tp}$	$w = N F_p C_v P_1 \left(3 - \frac{x}{x_{TP}} \right) (\sqrt{x})$	1.0	0.152
For $x \geq x_{Tp}$ (Choked Flow)	$w = N F_p C_v P_1 \sqrt{x_{TP}}$	2.0	0.304

(to be continued)

TABLE III - (continued)

REMARKS	EQUATIONS		VALUE OF N U.S.	SI
Piping Geometry Factor For F_{LP} see "Liquid Choked Flow"	$F_p = \left[\frac{\sum K}{N_2} \left(C_d \right)^2 + 1 \right]^{-0.5}$		890	0.00214
Sum of velocity head coefficients	$\sum K = K_1 + K_2 + K_{B1} - K_{B2}$			
Bernoulli coefficient	$K_{B1} = K_{B2} = 1 - \left(\frac{d}{D} \right)^4$			
Resistance coefficients for abrupt transitions	$K_1 = 0.5 \left[1 - \left(\frac{d}{D} \right)^4 \right]^2$			
Inlet fitting coefficient for F_{LP} and F_{TP}	$K_2 = 1.0 \left[1 - \left(\frac{d}{D} \right)^4 \right]^2$			
	$K_i = K_1 + K_{B1}$			
Line Velocity	Feet/Second	Meters/Second	Range (Ft/Sec.)	
Liquid	$U = \frac{q}{2.45D^2}$	$U = 354 \frac{q}{D^2}$	} 5-10 Norm. 40-60 Max.	
Gas	$U = \frac{qT}{895pD^2}$	$U = 1.24 \frac{qT}{pD^2}$	} 250-400	
Vapor	$U = \frac{w}{19.6\gamma D^2}$	$U = 354 \frac{w}{\gamma D^2}$	} 70 Wet 300 superheated	
Steam	$U = \frac{23w}{pD^2}$	$U = 685 \frac{w}{pD^2}$	}	
Acoustic Velocity (Mach 1.0)				
Gas	$U_a = 223 \sqrt{\frac{kT}{M}}$	$U_a = 91 \sqrt{\frac{kT}{M}}$	} < 0.3 Mach	
Air	$U_a = 49 \sqrt{T}$	$U_a = 20 \sqrt{T}$	}	
Steam, Superheated	$U_a = 60 \sqrt{T}$	$U_a = 24.5 \sqrt{T}$	} < 0.16 Mach	
Steam, Dry Saturated	$U_a = 1850$	$U_a = 500$	} < 0.10 Mach	
Vapor	$U_a = 68.1 \sqrt{kp_v}$	$U_a = 1038 \sqrt{kp_v}$	}	

TABLE IV - REFERENCE DATA FOR STEAM AND GASES

	SP. GRAVITY G	SP. HEATS RATIO k	FACTOR F _k
Acetylene	0.897	1.28	0.914
Air	1.000	1.40	1.00
Ammonia	0.587	1.29	0.921
Argon	1.377	1.67	1.19
Carbon Dioxide	1.516	1.28	0.914
Carbon Monoxide	0.965	1.41	1.01
Ethylene	0.967	1.22	0.871
Helium	0.138	1.66	1.19
Hydrogen Chloride	1.256	1.40	1.00
Hydrogen	0.0695	1.40	1.00
Methane	0.553	1.26	0.900
Methyl Chloride	1.738	1.20	0.857
Nitrogen	0.966	1.40	1.00
Nitric Oxide	1.034	1.40	1.00
Nitrous Oxide	1.518	1.26	0.900
Oxygen	1.103	1.40	1.00
Sulphur Dioxide	2.208	1.25	0.893
Steam (dry saturated)	P ₁		
	0-80	1.32	0.94
	80-245	1.30	0.93
	245-475	1.29	0.92
	475-800	1.27	0.91
	800-1050	1.26	0.90
	1050-1250	1.25	0.89
	1250-1400	1.23	0.88

NOMENCLATURE

- a* Area of orifice or valve opening, in².
- C* Coefficient of discharge, dimensionless. Includes effect of jet contraction and Reynolds number, mach number (gas at high velocities), turbulence.
- Cd* Relative capacity (at rated C_v) $D_d = N_3 C_v / d^2$
- cp* Specific heat at constant pressure.
- c_v* Specific heat at constant volume.
- C_v* Valve coefficient, 38 aK/FL
- d* Valve inlet diameter, inches or mm.
- D* Pipe diameter, inches or mm.
- F* Velocity of approach factor = $\frac{1}{1 - m^2}$
- d* Experimentally determined factor relating valve C_v to an equivalent diameter for Reynolds number.
- f* Weight fraction.
- F_F* Liquid critical pressure ratio factor, $F_F = P_{vc}/pv$
- F_k* Ratio of specific heats factor.
- F_l* Pressure recovery factor. When the valve is not choked:

$$F_L = (P_1 - P_2)/(P_1 - P_{vc})$$
- F_{LP}* Combined pressure loss and piping geometry factors for valve/fitting assembly.
- F_p* Correction factor for piping around valve (e.g., reducers) $F_p C_v =$ effective C_v for valve/fitting assembly.
- F_R* Correction factor for Reynolds number, where $F_R C_v =$ effective C_v .
- F_S* Laminar, or streamline, flow factor.
- g* Acceleration due to gravity.
- G_f* Specific gravity of liquids at flowing temperature relative to water at 60°F or 15°C.
- G_g* Specific gravity of gas relative to air with both at standard temperature and pressure.
- h* Effective differential head, height of fluid.
- K* Flow coefficient = CF, dimensionless.
- ΣK** Sum total of effective velocity head coefficients where $K (U^2/2g)=h$.
- K_B* Bernoulli coefficient = $1-(d/D)^4$.
- K_c* Cavitation indes. Actually the ratio $\Delta P/(P_1 - P_{vc})$ at which cavitation measurably affects the value of C_v .
- K_i* Inlet velocity head coefficient, $K_1 + K_{B1}$.
- K₁* Resistance coefficient for inlet fitting.
- K₂* Resistance coefficient for outlet fitting.

<i>k</i>	Ratio of specific heats of a gas = c_p/c_v , dimensionless.
<i>M</i>	Molecular weight.
<i>m</i>	Ratio of areas.
<i>N</i>	Numerical constant (See Table I).
<i>P</i>	Absolute static pressure.
<i>pc</i>	Thermodynamic critical pressure.
<i>pr</i>	Reduced pressure, p/pc .
<i>pv</i>	Vapor pressure of liquid at inlet.
<i>q</i>	Volume rate of flow.
<i>Re_v</i>	Reynolds number for a valve.
<i>T</i>	Absolute temperature.
<i>T_c</i>	Thermodynamic critical temperature.
<i>T_r</i>	Reduced temperature, T/T_c .
<i>U</i>	Average velocity.
<i>v</i>	Specific volume ($1/\gamma$).
<i>w</i>	Weight rate of flow.
<i>x</i>	Ratio of differential pressure to absolute inlet static pressure, $x=(P_1-P_2)/P_1$.
<i>x_T</i>	Terminal or ultimate value of x , used to establish expansion factor, Y .
<i>x_{TP}</i>	Value of x_T for valve/fitting assembly.
<i>y</i>	Expansion factor. Ratio of flow coefficient for a gas to that for a liquid at the same Reynolds number (includes radial as well as longitudinal expansion effects).
<i>Z</i>	Compressibility factor. (See Nelson-Obert Compressibility Charts.)
<i>γ(gamma)</i>	Specific weight ($1/v$).
<i>Δ(delta)</i>	Difference, (e.g., $\Delta P=P_1-P_2$).