ENGINEERING STANDARD

FOR

PROCESS DESIGN OF VALVES

AND

CONTROL VALVES

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0. INTRODUCTION

Valves are the components in a fluid flow or pressure system which regulate either the flow or the pressure of the fluid. This duty may involve stopping and starting flow, controlling flow rate, diverting flow, preventing back flow, controlling pressure, or relieving pressure.

The equations of this Standard are used to predict the flow rate of a fluid through a valve when all the 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 rate condition to predict an approximate required valve flow coefficient (C_v).

"Process Design of Valves & Control Valves, and Steam Traps" are broad and contain variable subjects of paramount importance. Therefore, a group of process engineering standards are prepared to cover the subject.

This group includes the following Standards:

STANDARD CODE	STANDARD TITLE
IPS-E-PR-830	"Process Design of Valves & Control Valves"
IPS-E-PR-845	"Process Design of Steam Traps"

This Engineering Standard Specification covers:

"PROCESS DESIGN OF VALVES AND CONTROL VALVES"

The valves discussed here are manually operated valves for stop and starting flow, controlling flow rate and diverting flow. The manual valves are divided into four groups according to the way the closure member moves into the seat. The many types of check valves are likewise divided into groups according to the way the closure member moves onto the seat. The basic duty of these valves is to prevent back flow. Predicting the flow of compressible and incompressible fluids through control valve, and cavitation are covered as parts of this Engineering Standard Specification.

1. SCOPE

This Engineering Standard Specification is intended to cover minimum requirements for process design of manual valves, and control valves as well as field of application, selection of types, control valve sizing calculations, and cavitation in design consideration for valves and control valves.

The application of this Engineering Standard Specification shall be exercised, only in combination with the relevant Piping & Pipelines and Instrument Standards, i.e., IPS-M-PI-110/I-VI, "Valves", and IPS-G-IN-160, "Control Valves", respectively.

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/ANSI (INSTRUMENT SOCIETY OF AMERICA/AMERICAN NATIONAL STANDARDS INSTITUTE)

"Flow Equations for Sizing Control Valves", ANSI/ISA-S 75.01-1985, Approved August 15, 1986

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-M-PI-110/I-VI	"Material and Equipment Standard for Valves"
IPS-G-IN-160	"Engineering and Material Standards for Control Valves"

3. SYMBOLS AND ABBREVIATIONS

ANSI	American National Standards Institute.
C_d	Required 6.45 C_v/d^2 at a specified flow condition.
C_f	Critical factor, (dimensionless).
C_{fr}	Reducer critical factor, dimensionless.
C_v	Valve flow coefficient.
d	Valve inlet diameter.
D	Internal diameter of the pipe.
Eq	Equation.
F_d	Valve style modifier (see Table A.3 in Appendix A).
F_F	Liquid critical pressure ratio factor, dimensionless.
F_k	Ratio of specific heats factor, dimensionless.
F_L	Liquid pressure recovery factor of a valve without attached fittings, dimensionless.
F_{LP}	Product of the liquid pressure recovery factor of a valve with attached fittings (no symbol has been identified) and the piping geometry factor, dimensionless.

F_P	Piping geometry factor, dimensionless.
F_{Re}	Reynolds number factor, dimensionless.
F_s	Laminar, or streamline, flow factor, dimensionless.
g	Local acceleration of gravity, (9.806 m/s^2).
G	Relative density (specific gravity).
G_f	Liquid relative density (specific gravity) at upstream conditions [ratio of density of liquid at flowing temperature to density of water at 15.5°C (60°F)], dimensionless.
G_g	Gas relative density or specific gravity (ratio of density of flowing gas to density of air with both at standard conditions, which is equal to the ratio of the molecular mass of gas to the molecular mass of air), dimensionless.
IPS	Iranian Petroleum Standards.
ISA	Instrument society of America..
K	Flow characteristic of valve.
K_B	Bernoulli coefficient, dimensionless.
K_{B1}	Bernoulli coefficient for an inlet fitting, dimensionless.
K_{B2}	Bernoulli coefficient for an outlet fitting, dimensionless.
K_c	Coefficient of incipient cavitation, $\mathbf{K_c} = \dfrac{\textbf{change in flow}}{\textbf{change in lift}}$ **(Eq. 1)**
K_i	Velocity head factors for an inlet fitting, dimensionless.
K_1	Resistance coefficient for inlet fitting.
M	Molecular mass (weight), atomic mass units.
MPa	Megapascal = 1- bar.
N_1, N_2 etc.	Numerical constants for units of measurement used.
P_1	Upstream absolute static pressure, measured two nominal pipe diameters upstream of valve-fitting assembly.
P_2	Downstream absolute static pressure, measured six nominal pipe diameters downstream of valve-fitting assembly.
ΔP	Pressure differential, $\Delta P = P_1 - P_2$., in (bar).
ΔP_{crit}	Critical pressure drop, $\Delta P_{crit.} = C_f^2 (P_1 - P_v)$
P_c	Absolute thermodynamic critical pressure.
P_r	Reduced pressure, dimensionless.
P_R	Valve Pressure drop ratio; is the ratio of valve Pressure drop to total dynamic pressure drop.
P_v	Absolute vapor pressure of liquid at inlet temperature.
P_{vc}	Apparent absolute pressure at vena contracta.

R	Sub-critical flow capacity correction factor, dimensionless.
q	Volumetric flow rate.
q_{max}	Maximum flow rate (choked flow conditions) at a given upstream condition.
Re_v	Valve Reynolds number, dimensionless.
T	Absolute temperature, in kelvin (K).
T_1	Absolute upstream temperature, in kelvin (K).
U_c	Velocity in the inlet pipe that will create critical cavitation in the valve, in (m/s).
U_i	Velocity in the inlet pipe that will create incipient cavitation in the valve, in (m/s).
V	Specific volume, in (m^3/kg) . $V = \frac{1}{\gamma}$
W	Mass or (weight) flow rate (mass fraction), in (kg/h).
W_f	Mass flow rate of fluid, in (kg/h).
W_g	Mass flow rate of gas, in (kg/h).
X	Ratio of pressure drop to absolute inlet pressure, ($X = \Delta P/P_1$), dimensionless.
X_T	Pressure drop ratio factor, dimensionless.
X_{TP}	Value of X_T for valve-fitting assembly, dimensionless.
Y	Expansion factor, ratio of flow coefficient for a gas to that for a liquid at the same Reynolds number, dimensionless.
Z	Compressibility factor, dimensionless.
γ **(gamma)**	Specific mass (weight), in (kg/m^3).
γ_1 **(gamma)**	Specific mass (weight), upstream conditions, in (kg/m^3).
γ_f **(gamma)**	Specific mass (weight) of liquid, in (kg/m^3).
μ **(mu)**	Viscosity, absolute.
ν **(nu)**	Kinematic viscosity, in centistokes (cSt).
ρ **(rho)**	Density (mass density).

Subscripts:

1	Upstream conditions.
2	Downstream conditions.
s	Non-turbulent.
t	Turbulent.

4. UNITS

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

5. GENERAL

5.1 Manual Valves

Manual valves serve three major functions in fluid handling systems:

a) stopping and starting flow;
b) controlling flow rate;
c) diverting flow.

5.1.1 Grouping of valves by method of flow regulation

Manual valves may be grouped according to the way the closure member moves onto the seat. Four groups of valves are thereby distinguishable:

5.1.1.1 Closing-down valves

A stopper-like closure member is moved to and from the seat in direction of the seat axis.

5.1.1.2 Slide valves

A gate-like closure member is moved across the flow passage.

5.1.1.3 Rotary valves

A plug or disc-like closure member is rotated within the flow passage, around an axis normal to the flow stream.

5.1.1.4 Flex-body valves

The closure member flexes the valve body.

5.1.2 Valve guides

The main parameters concerned in selecting a valve or valves for a typical general service are:

a) Fluid to be handled

This will affect both type of valve and material choice for valve construction.

b) Functional requirements

Mainly affecting choice of valve.

c) Operating conditions

Affecting both choice of valve type and constructional materials.

d) Flow characteristics and frictional loss

Where not already covered by (b), or setting additional specific or desirable requirements.

e) Size of valve

This again can affect choice of type of valve (very large sizes are only available in a limited range of types); and availability (matching sizes may not be available as standard production in a particular type).

f) Any special requirements-quick-opening, free draining

In the case of specific services, choice of valve type may be somewhat simplified by following established practice or selecting from valves specifically produced for that particular service.

Table B.1 in Appendix B summarizes the applications of the main types of general purpose valves.

Table B.2 in Appendix B carries general selection a stage further in listing valve types normally used for specific services.

Table B.3 in Appendix B is a particularly useful expansion of the same theme relating the suitability of different valve types to specific functional requirements.

5.1.3 Selection of valves

a) Valves for stopping and starting flow

Such valves are slide valves, rotary valves and flex-body valves.

b) Valves for control of flow rate

c) Valves for diverting flow

Such valves are plug valves and ball valves.

d) Valves for fluids with solids in suspension

The valves best suited for this duty have a closure member which slides across a wiping motion.

5.1.4 Globe valves

The sealing of these valves is high.

Applications

Duty:

- Controlling flow.
- Stopping and starting flow.
- Frequent valve operation.

Service:

- Gases essentially free of solids.
- Liquids essentially free of solids.
- Vacuum.
- Cryogenic.

5.1.5 Piston valves

Applications

Duty:

- Controlling flow.
- Stopping and starting flow.

Service:

- Gases.
- Liquids.
- Fluids with solids in suspension.
- Vacuum.

5.1.6 Parallel gate valves

Parallel gate valves are slide valves with a parallel-faced gate-like closure member. The advantages of these valves are as follows:

- Their low resistance to flow.

- Capable of handling fluids which carry solids in suspension.

- With closure member if a single disc or twin discs with a spreading mechanism in-between. Limitation to the operation of parallel gate valves.

- If fluid pressure is low, the seating force may be insufficient to produce a satisfactory seal between metal-to-metal seating.

- Frequent valve operation may lead to excessive wear of the seating face. For this reason, parallel gate valves are normally used for infrequent valve operation only.

- Flow control from a circular disc traveling across a circular flow passage becomes satisfactory only between the 50% closed and the fully closed positions. Therefore they are normally used for on-off duty only.

Applications

Duty:

- Stopping and starting flow.
- Infrequent operation.

Service:

- Gases.
- Liquids.
- Fluids with solids in suspension.
- Knife gate valve for slurries, fibers, powders, and granules.
- Vacuum.
- Cryogenic.

5.1.7 Wedge gate valves

Wedge shape is to introduce a high supplementary seating load against high but also low fluid pressures.

Applications

Duty:

- Stopping and starting flow.
- Infrequent operation.

Service:

- Gases.
- Liquids.
- Rubber-seated wedge gate valves without bottom cavity for fluids carrying solids in suspension.
- Vacuum.
- Cryogenic.

5.1.8 Plug valves (cocks)

Applications

Duty:

- Stopping and starting flow.
- Moderate throttling.
- Flow diversion.

Fluids:

- Gases.
- Liquids.
- Non-abrasive slurries.
- Abrasive slurries for lubricated plug valves.
- Sticky fluids for eccentric and lift plug valves.
- Sanitary handling of pharmaceutical and food stuffs.
- Vacuum.

5.1.9 Ball valves

Applications

Duty:

- Stopping and starting flow.
- Moderate throttling.
- Flow diversion.

Service:

- Gases.
- Liquids.
- Non-abrasive slurries.
- Vacuum.
- Cryogenic.

5.1.10 Butterfly valves

Butterfly valves are available for wide range of pressures and temperatures based on variety of sealing principles.

Applications

Duty:

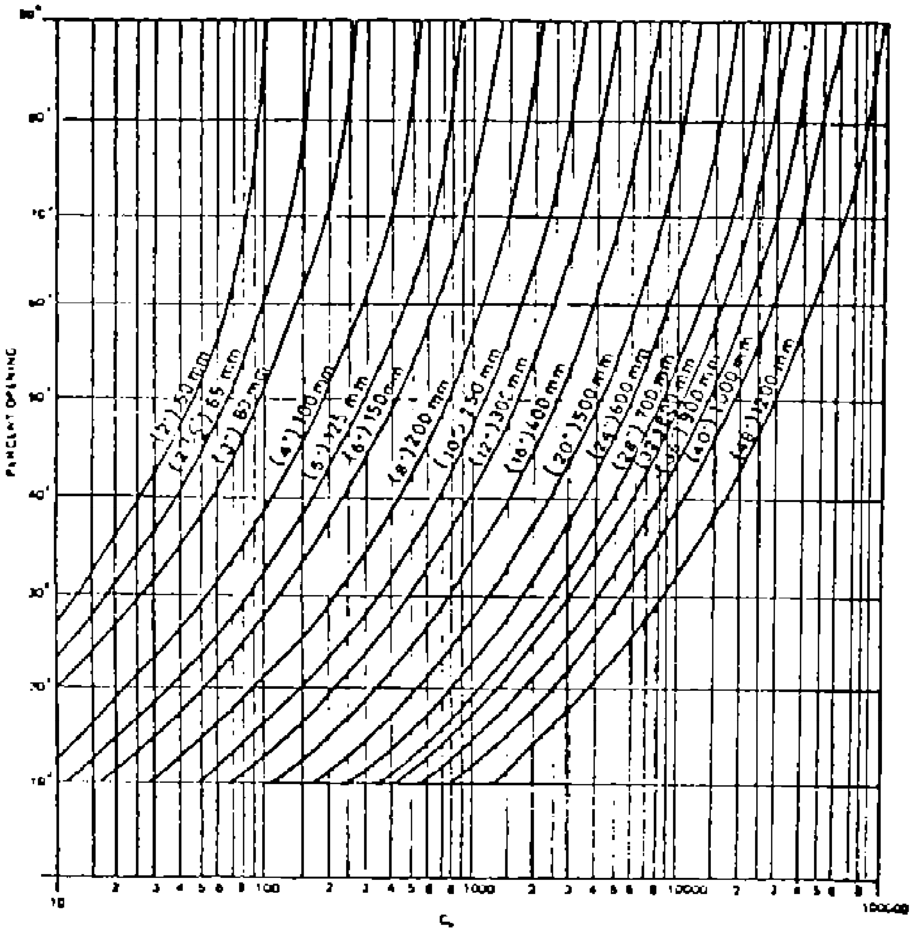
- Stopping and starting flow.
- Controlling flow.

Service:

- Gases.
- Liquids.
- Slurries.
- Powder.
- Granules.
- Sanitary handling of pharmaceuticals and food stuffs.
- Vacuum.

5.1.10.1 Flow characteristic of butterfly valve

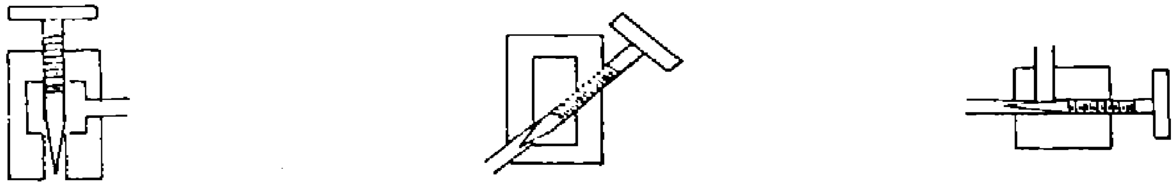
Fig. 1 gives flow coefficients for a series of butterfly valves of similar design but different size, those being representative of good design.



C_V DIAGRAM FOR TYPICAL BUTTERFLY VALVE
Fig. 1

5.1.11 Needle valves

Small sizes of globe valves fitted with a finely tapered plug are known as needle valves:



a) b) c)

Fig. 2

Three basic configurations are shown in Fig. 2, (a) is a simple screwdown valve; (b) is an oblique version, offering a more direct flow path; (c) is another form where the controlled outlet flow is at right angles to the main flow (and may be distributed through one or more passages).

5.1.12 Pinch valves

Pinch valves are flex-body valves consisting of a flexible tube which is pinched either mechanically, or by application of a fluid pressure to the outside of the valve body.

Applications

Duty:

- Stopping and starting flow.
- Controlling flow.

Service:

- Liquids.
- Abrasive slurries.
- Powders.
- Granules.
- Sanitary handling of pharmaceuticals and food stuffs.

5.1.13 Diaphragm valves

Diaphragm valves are flex-body valves in which the body flexibility is provided by a diaphragm. Diaphragm valves fall into two main types:

- Weir-Type Diaphragm valves which are designed for a short stroke between the closed and fully open valve positions.

- Straight-Through Diaphragm valves which have a relatively long stroke which requires more flexible construction materials for the diaphragm.

Applications

Duty:

For weir-type and straight-through diaphragm valves:

- Stopping and starting flow.
- Controlling flow.

Service:
For weir-type diaphragm valves:

- Gases, may carry solids.
- Liquids, may carry solids.
- Viscous fluids.
- Leak-proof handling of hazardous fluids.
- Sanitary handling of pharmaceuticals and food stuffs.
- Vacuum.

Service for straight-through diaphragm valves:

- Gases, may carry solids.
- Liquids, may carry solids.
- Viscous fluid.
- Sludges.
- Slurries may carry abrasives.
- Dry media.
- Vacuum (consult manufacturer).

5.2 Check Valves

Check valves are automatic valves which open with forward flow and close against reverse flow. They are also known as non-return valves. Check valves shall operate in a manner which avoids:

1) The formation of an excessively high surge pressure as result of the valve closing.
2) Rapid fluctuating movements of the valve closure member.

Check valves are commonly used in combination with flow control valves, the type and operating characteristics of which can influence the choice of check valve type. Suitable combinations are:

- Swing check valve-used with ball, plug, gate or diaphragm control valves.
- Tilting disc check valves-similar to swing-type check valve but with a profiled disc.
- Lift check valve-used with globe or angle valves.
- Piston check valve-used with globe or angle valves.
- Butterfly check valve-used with ball, plug, butterfly, diaphragm or pinch valves.
- Spring-loaded check valves-used with globe or angle valves.
- Diaphragm check valves-the closure member consists of a diaphragm which deflects from or against the seat.

5.2.1 Lift check valves

Lift check valves may be sub-divided into:

a) disc check valves;
b) piston check valves;
c) ball check valves.

5.2.2 Swing check valves

- Dirt and viscous fluids cannot easily hinder the rotation of the disc around the hinge.

5.2.3 Tilting-disc check valves

- Potentially fast closing.
- Being more expensive.
- More difficult to repair.

5.2.4 Diaphragm check valves

- Are not as well known as other check valves.
- Is well suited for applications in which the flow varies within wide limits.
- The pressure differential is limited to 1 Megapascal (MPa).
- Operating temperature is limited to 70°C.
- Sizes as small as DN3 (NPS $^1/_8$ inch) and as large as DN 3000 (NPS 120 inch).

5.2.5 Foot valves

- Is basically a check valve
- Often include a strainer.
- Are fitted to the end of a suction pipe.
- Prevent the pump emptying when it stops.

5.2.6 Poppet lift check valves

The travel of the poppet is controlled by a stop on the end of the poppet legs acting as supports for the return spring shouldered on to a washer.

5.2.7 Ball foot valves

- It is particularly suitable for use with contaminated waters or more viscous fluids.

5.2.8 Membrane foot valves

- Consist of a cylindrical rubber membrane fitted inside a steel strainer.

5.2.9 Spring-loaded check valves

- Spring-loaded for more positive shut-off action.
- More rapid response cessation of flow.
- Work in any position, inclined, upward or downward flow.

5.2.10 Dashpots

- The most important application of dashpots is in systems in which flow reverses very fast.
- A dashpot designed to come into play during the last closing movements can considerably reduce the formation of surge pressure.

5.2.11 Selection of check valves

Most check valves are selected qualitatively by comparing the required closing speed with the closing characteristic of the valve. This selection method leads to good results in the majority of applications.

5.2.12 Check valves for incompressible fluids

These are selected primarily for the ability to close without introducing an unacceptably high surge pressure due to the sudden shut-off of reverse flow. Selecting these for a low pressure drop across the valve is normally only secondary consideration.

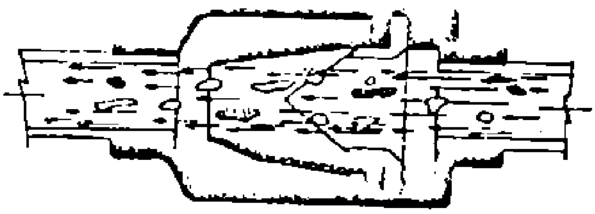
5.2.13 Check valves for compressible fluids

Check valves for compressible fluids may be selected on a basis similar to that described for incompressible fluids. However, valve-flutter can be a problem for high lift check valves in gas service, and the addition of a dashpot may be required.

5.3 Miscellaneous Valves

5.3.1 Membrane checks valves

This features a lipped elastomeric membrane as the working element, offering virtually unrestricted flow in the open position with a capability of passing suspended solids up to the full bore diameter (Fig. 3).



MEMBRANE CHECK VALVE
Fig. 3

Due to the elastic nature of the closure this type of check valve cannot water hammer and is also noiseless in that it has no hinge or spring which can be excited into vibration in either the open or closed position.

5.3.2 Eccentric valves

Throttling characteristics of a valve of this type are generally excellent, and shut-off in the closed position positive with air and gases as well as liquids.

5.3.3 Lenticular valve

The lenticular valve can be described as similar in concept to a ball valve except that the ball is replaced by a lens-shaped cup or lenticule (Fig. 4).

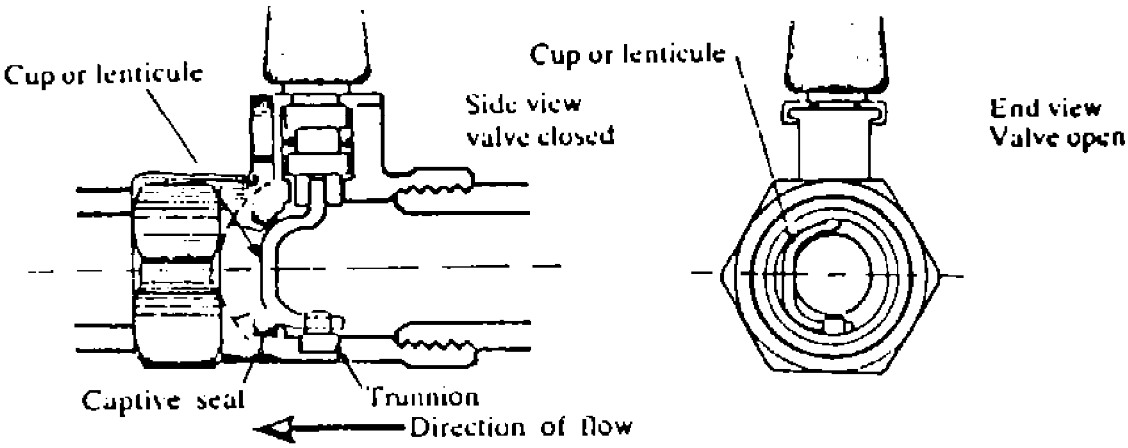


Fig. 4

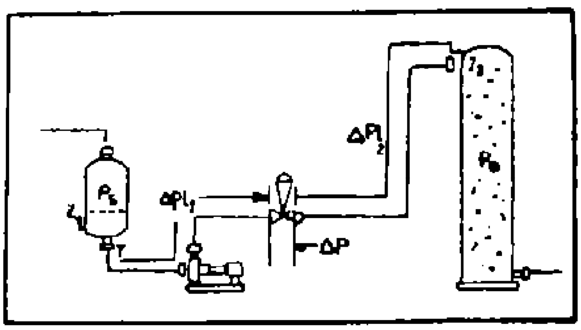
This is a low cost shut-off valve for applications in the light duty, low pressure field, in sizes ranging from 6 mm to 30 mm (¼ in to 1¼ inch). Construction is normally brass body with a stainless steel cup and synthetic rubber seal. Maximum working pressure rating is 16 bar (230 lbf/in²).

6. CONTROL VALVES

A valve selected as optimum for a level control process might not be the best selection for a flow control system. Also, the best valve for one flow control system might not be optimum for a system utilizing a different primary element or flow measurement means. Control valves are used in many applications including liquid flow control, gas pressure reduction, steam flow to heaters, etc.

6.1 Pump and Valve System

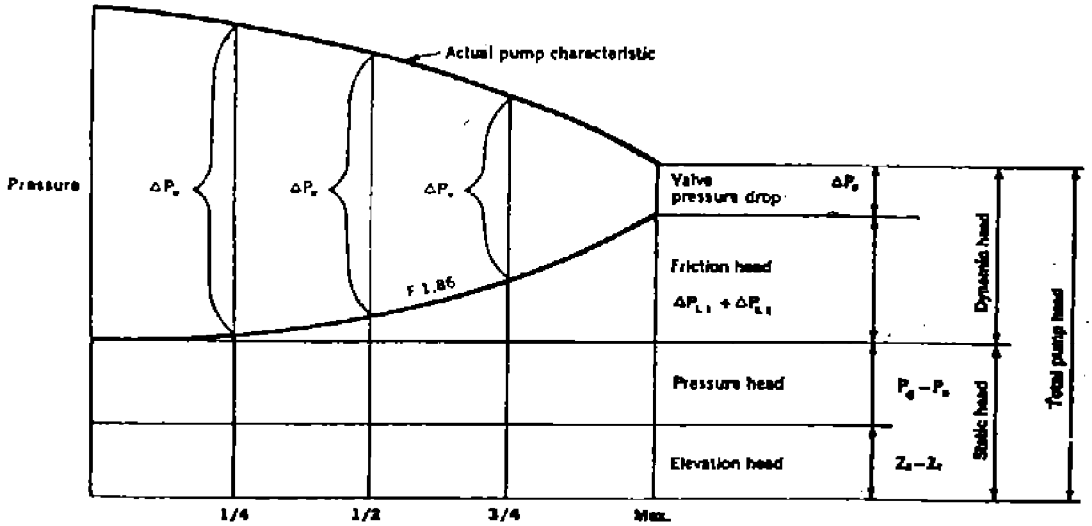
A pumped liquid flow system can have many configurations. A typical arrangement is demonstrated in Fig. 5 below. This system includes a suction tank, pump, control valve, discharge tank and connecting piping. These relationships are seen by a plot of pressure vs. flow in Fig. 6. The elevation head Z_2-Z_1 is constant and for this process we will assume that the pressure head P_D-P_s is also constant.



TYPICAL LIQUID FLOW SYSTEM
Fig. 5

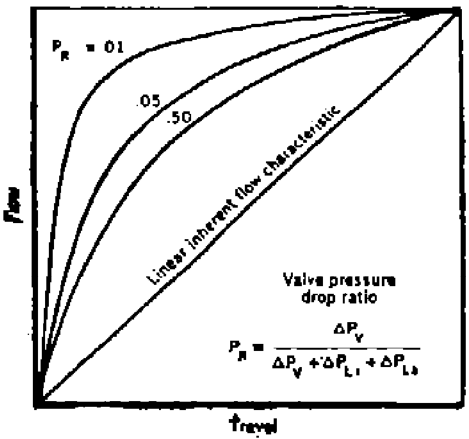
Fig. 6 also shows a relationship which shall be called the valve pressure drop ratio, P_R. It is the ratio of valve pressure drop to total dynamic pressure drop.

$$P_R = \Delta P_v / (\Delta P_v + \Delta P_{L1} + \Delta P_{L2}) \qquad \text{(Eq. 2)}$$

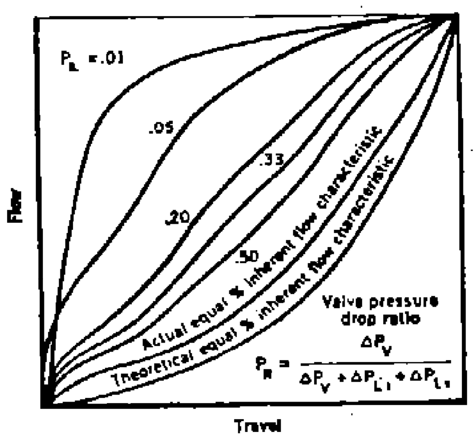


PRESSURE RELATIONSHIPS IN PUMPED LIQUID SYSTEM
Fig. 6

Calculations of the installed flow characteristics for a linear valve are presented in Fig. 7. Actual and theoretical inherent flow characteristic for an equal percentage design are plotted in Fig. 8. In each figure, several values of pressure drop ratio are shown. It is apparent that the higher this value, the less the distortion.



INSTALLED CHARACTERISTICS FOR A LINEAR VALVE
Fig. 7



ACTUAL AND THEORETICAL FLOW CHARACTERISTICS
Fig. 8

7. CONTROL VALVE TYPES

7.1 Selection

Control valves can be classified according to body design. The selection of a valve for a particular application is primarily a function of the process requirements, and no attempt will be made herein to cover this subject. Some of the more common types of control valve bodies are mentioned in 7.1.1 through 7.1.4. For "Typical Valve Selection Guide" see Appendix C hereinafter.

7.1.1 Globe body valve

One of the principle advantages is a balancing feature which reduces required actuator forces. In this design two options are available:

1) A single-seat construction for minimum leakage in the closed position.
2) A more simplified construction where greater leakage in the closed position can be tolerated.

The valve trim may be replaced without removing the valve body from the line. The globe valve design for a double-seated type and has a higher leakage rate in the closed position than a single-seat type.

Another variation is the split body valve which is available both in globe and angle-type patterns. In this valve, the seat ring is clamped between the two body sections which makes it readily removable for replacement. This design is a single-seat type and does minimize leakage in the closed position.

The split body valve is used extensively in chemical processes due to (a) its availability in alloy materials and (b) the feature of separable flanges which allows the flanges to be manufactured from less expensive materials.

7.1.2 Butterfly valve

The butterfly valve is a rotating-vane, high-pressure recovery type of valve used in applications where high-capacity and low-pressure drop are required. Although not normally used on minimum leakage applications.

7.1.3 Ball valve

The ball control valve is a rotating-stem, high-pressure recovery type of valve, in which the flow of fluid is restricted by using a full-or partial-type ball in the valve body. This valve has a high flow coefficient and may be used to control many types of fluids.

7.1.4 Three-way valve

The three-way valve is a special type of valve primarily used for splitting (diverting) or mixing (combining) service. The most common applications are through or around exchangers to control the heat transferred or in the controlled mixing of two streams.

7.2 Flashing

If the cavitation process could be halted before the completion of the second stage, so that vapor persists downstream of the region where bubble collapse normally occurs, the process would be known as flashing. Flashing, like cavitation, can cause physical damage and decreased valve efficiency. Manufacturers should be consulted for recommendations.

7.3 Rangeability

The rangeability required for the control valve should be considered during valve selection. Although many control valves are available with published ranges of 50 to 1 and even greater, remember that these are at constant pressure drop, a condition which rarely exists in an actual plant. The requirement for rangeability is that the valve must handle the maximum flow at the minimum pressure drop available down to the minimum flow at maximum pressure drop. Sizing calculations should be checked at both extremes to assure controllability over the entire range of flow rates and pressure drops.

7.4 Control Valve Sizing

7.4.1 Having obtained the control valve's pressure drop allocation from pump head available, the further step is to size the valve. The other factors involved are flow rate and liquid relative density (specific gravity). Appendix A herein shows a selected summary of the equations for control valve sizing calculations, respectively.

7.4.2 Valve sizing shall be based on maximum sizing capacity of 1.3 times the normal maximum flow or 1.1 times the absolute maximum flow, whichever is greater.

7.4.3 The valve should be selected such that the opening of the valve at C_v calculated, should not be greater than 75 percent of total travel. For the exceptional cases, the approval of the company shall be obtained.

8. CAVITATION IN CONTROL VALVES

Cavitation, in a control valve handling a pure liquid, may occur if the static pressure of the flowing liquid decreases to a value less than the fluid vapor pressure. At this point continuity of flow is broken by the formation of vapor bubbles. Since all control valves exhibit some pressure recovery, the final downstream pressure is generally higher than the orifice throat static pressure (pressure recovery). When downstream pressure is higher than vapor pressure of the fluid, the vapor bubbles revert back to liquid. This two-stage transformation is defined as cavitation. For applications where no cavitation whatsoever can be tolerated, the coefficient of incipient cavitation, K_c, should be employed in place of C_f^2. Values of K_c are listed in Table 1. When reducers are used, the same K_c value may be safely used. To find pressure differential for incipient cavitation use the following formula:

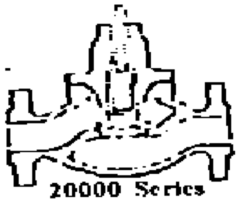
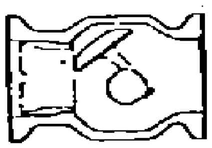
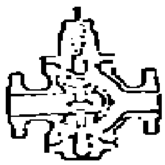
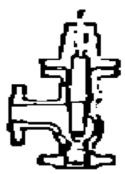
$$\Delta P\ (incipient\ \ cavitatio) = K_c\ (P_1 - P_v) \qquad \textbf{(Eq. 3)}$$

Where:

K_c is coefficient of incipient cavitation (see Table 1);

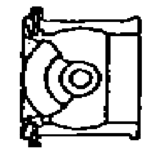
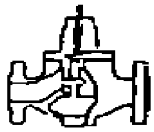
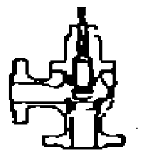
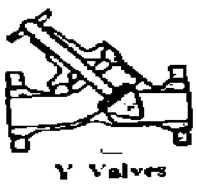
ΔP is actual pressure drop, in bars.

TABLE 1 - TYPICAL CRITICAL FLOW FACTOR AT FULL OPENING

VALVE TYPE	TRIM SIZE	FLOW TO	C_f	K_c*	C_{fr} D/d = 1.5 or greater
 20000 Series	A	Close Open	0.85 0.90	0.58 0.65	0.81 0.86
	B	Close Open	0.80 0.90	0.52 0.65	0.80 0.90
 Camflex Valve	A	Close Open	0.68 0.85	0.35 0.60	0.65 0.80
	B	Close Open	0.70 0.88	0.39 0.62	0.70 0.87
 10000 Series	A	Contoured V-Port	0.90 0.98	0.70 0.80	0.86 0.94
	B	Contoured V-Port	0.80 0.95	0.31 0.73	0.80 0.94
 Split Body Globe Valves	A	Close Open	0.80 0.75	0.51 0.46	0.77 0.72
	B	Close Open	0.80 0.90	0.52 0.65	0.80 0.89
 71000 Series	A	Close Open	0.48 0.90	0.17 0.65	0.45 0.84
	B	Close Open	0.55 0.95	0.23 0.72	0.54 0.93

(to be continued)

TABLE 1 - (continued)

	A	Flow in Either Direction	0.65	0.32	0.60
 Control Ball Valve	A		0.60	0.24	0.55
 20000 Series with Balanced Quick-Change Trim	A	Close	0.90	0.65	0.86
	B	Close	0.90	0.65	0.90
 70000 Series	A	Close Open	0.81 0.89	0.53 0.64	0.78 0.85
	B	Close Open	0.80♣ 0.90	0.52♣ 0.65	0.80 0.90
 Y Valves	A	Close Open	0.75 0.75	0.46 0.46	0.69 0.69

A) Full capacity trim, orifice dia. ~ 0.8 valve size.
B) Reduced capacity trim 50% of (a) and below.
♣ With venture liner $C_f = 0.50$, $K_c = 0.19$.

Mathematically, the critical pressure drop with the aid of C_f factor can be defined as follows:

$$\Delta P_{crit.} = C_f^2 (P_1 - P_v) \qquad \textbf{(Eq. 4)}$$

with reducers,

$$\text{with reducers, } \Delta P_{crit} = \left(\frac{C_{fr}}{R}\right)^2 (P_1 - P_v) \qquad \textbf{(Eq. 5)}$$

Where:

R is sub-critical flow capacity correction factor (see Table 2).

8.1 How to Avoid Cavitation

Referring to the relationship $\Delta P_{crit.} = C_f^2 (P_1 - P_v)$ to avoid cavitation, the following procedures shall be considered:

- Reduce the pressure-drop across the valve below $\Delta P_{crit.}$ This can be done, for example, by increasing P_1 through the selection of a valve location at a lower elevation in the piping system.

- Select a valve type that has a larger C_f or K_c factor. For example choosing a V-port instead of a contoured plug.

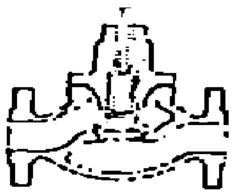
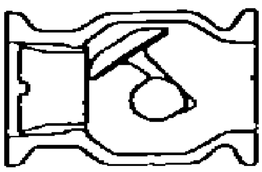
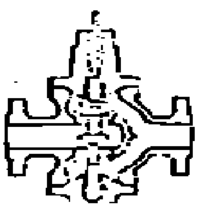
- A change in flow direction can bring a marked improvement. For instance, installing a streamlined angle valve "flow to open" will increase the C_f factor from 0.48 to 0.9, meaning that the allowable ΔP can be more than tripled.

- In extreme cases, two identical control valves in series should be installed. The combined C_f factor of the two valves can be estimated as follows:

C_f ***total*** = $\sqrt{C_f}$ ***of single valve***

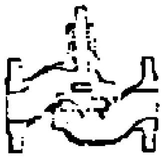
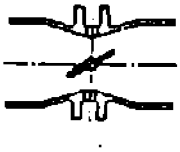
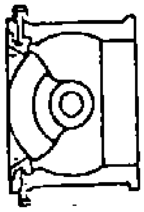
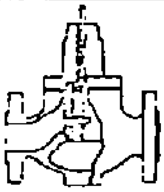
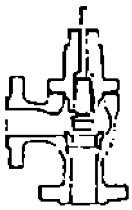
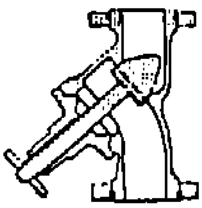
- The C_v of each valve has to be increased by 40% to compensate for the reduced pressure drop. It is important that flow characteristic and valve lift be identical.

TABLE 2 - EFFECT OF INLET AND OUTLET REDUCERS

VALVE TYPE	FLOW TO	D/d = 1.5		D/d = 2.0	
		R	C_{fr}/R	R	C_{fr}/R
 20000 Series	Close	0.96	0.84	0.94	0.86
	Open	0.96	0.89	0.94	0.91
 Camflex Valve	Close	0.95	0.68	0.92	0.71
	Open	0.95	0.84	0.92	0.86
 10000 Series	Contoured	0.96	0.89	0.94	0.91
	V-Port	0.96	0.93	0.94	0.95

(to be continued)

TABLE 2 - (continued)

 Split Body Globe Valves	Close	0.96	0.80	0.94	0.81
	Close	0.96	0.75	0.94	0.77
 71000 Series	Close	0.85	0.53	0.77	0.57
	Open	0.95	0.89	0.91	0.91
 37000 Series	Flow in Either Direction	0.81	0.74	0.72	0.83
 Control Ball Valve		0.87	0.63	0.80	0.68
 20000 Series with Balanced Quick-Change Trim	Close	0.96	0.89	0.94	0.91
 70000 Series	Close	0.96	0.81	0.94	0.82
	Close	0.96	0.88	0.94	0.90
 Y Valves	Close	0.92	0.75	0.86	0.79
	Close	0.92	0.75	0.86	0.79

Values shown are for full area trim. For reduced trim, assume R = 1.0.

8.2 Equations

The following equations make up the procedure for predicting the conditions for incipient and critical cavitation in ball and butterfly valves. The following symbols are defined here for convenience:

U_i	the velocity in the inlet pipe that will create incipient cavitation in the valve, in (m/s).
U_c	the velocity in the inlet pipe that will create critical cavitation in the valve, in (m/s).
d	valve inside diameter. Use i.e. of schedule 40 pipe of same nominal size, in (cm).
ΔP	pressure drop, in bars.
C_d	required 6.45 C_v / d² at a specified flow condition.

$$Cv = 1.158 \frac{m^3/h}{(P_1 - P_2)^{1/2}} \qquad \textbf{(Eq. 6)}$$

P_1	upstream pressure, in bar absolute [bar(abs)].
P_v	vapor pressure, in bar absolute [bar(abs)].

$$U_i = 0.3048 \cdot J_o \cdot J_i \cdot J_n \cdot J_d \qquad \textbf{(Eq. 7)}$$

$$U_c = 0.3048 \cdot J_o \cdot J_c \cdot J_n \cdot J_d \qquad \textbf{(Eq. 8)}$$

Where:

$$J_d = \left(\frac{3.16 \log \frac{12}{d}}{\log^{-1} (0.329 - 0.615 \log J_k)} + 1 \right) \qquad \textbf{(Eq. 9)}$$

$$J_k = \left(\frac{890}{C_d^2} + 1 \right)^{1/2} \qquad \textbf{(Eq. 10)}$$

$$J_n = 2.84 \left[\frac{P_1 - P_v}{71.5} \right]^{0.39} \qquad \textbf{(Eq. 11)}$$

$$J_o = \begin{cases} 1.06 \text{ for } d < 30.48 \\ 1.00 \text{ for } d = 30.48 \\ 0.94 \text{ for } d \,.\, 30.48 \end{cases} \qquad \textbf{(Eq. 12)}$$

$$J_i = \begin{cases} 60.4\, J_k \text{ for } J_k \leq 0.1 \\ 36.2\, J_k + 2.42 \text{ for } J_k \geq 0.1 \end{cases} \qquad \textbf{(Eq. 13)}$$

$$J_c = \begin{cases} 71.0\, J_k \text{ for } J_k \leq 0.1 \\ 43.0\, J_k + 2.80 \text{ for } J_k \geq 0.1 \end{cases} \qquad \textbf{(Eq. 14)}$$

$$\Delta P = 4.44\, G.U^2 / C_d^2 \qquad \textbf{(Eq. 15)}$$

8.3 Maximum Effective ΔP

The limits of the homogeneous equation would be reasonable to assume that where gas is the continuous phase, the maximum effective ΔP in the equation is:

$$lim\ \Delta P = P_1 \cdot F_k \cdot X_{TP} \qquad \textbf{(Eq. 16)}$$

Where liquid is the continuous phase, when vaporization at the vena contracta prevents a further reduction of the pressure at this point. The maximum effective ΔP in the equation is:

$$lim\ \Delta P = F_L^2\,(P_1 - F_F \cdot P_v) \qquad \textbf{(Eq. 17)}$$

Liquid may be considered the continuous phase at the vena contracta when:

$$\frac{W_f}{\rho_f} > \frac{W_g \cdot T_1}{0.0209\ G_g\,(P_1 - \Delta P / F_L^2)} \qquad \textbf{(Eq. 18}$$

Where:

G_g = Relative density (specific gravity) of gas at STP for liquid which may considered as Liquid-vapor is the same as above equation except with less confidence.

8.4 Specification Form for Control Valve

For this Clause reference is made to Appendix A, Item No. 1, specification form for control valves of IPS-G-IN-160 as shown as Appendix D of this Standard Specification.

APPENDICES

APPENDIX A
EQUATIONS FOR CONTROL VALVE SIZING CALCULATIONS

A.1 Flow Coefficient:

$$C_v = q \sqrt{\frac{\text{relative density (SP.Gr.)}}{\Delta P}} \qquad \text{(Eq. A.1)}$$

A.2 Equations for Incompressible Flow of Nonvaporizing Liquid

Flow rate
$$q = N. C_v \sqrt{\frac{\Delta P}{G_f}} \qquad \text{(Eq. A.2)}$$

A.2.1 For turbulent flow

In volumetric rate
$$q = N_1 . F_p . C_v \sqrt{\frac{P_1 - P_2}{G_f}} \qquad \text{(Eq. A.3)}$$

In mass flow rate
$$W = N_6 . F_p . C_v (P_1 - P_2) \qquad \text{(Eq. A.4)}$$

A.2.2 Piping geometry factor F_p

$$F = \left(\frac{\Sigma K . C_v^2}{N_2 . d^4} + 1\right)^{½} \qquad \text{(Eq. A.5)}$$

Head loss coefficient $\Sigma K = K_1 + K_2 + K_{B1} - K_{B2}$ (Eq. A.6)

$$K_1 = 0.5 \left(1 - \frac{d^2}{D_1^2}\right)^2 \qquad \text{(Eq. A.7)}$$

$$K_2 = 1.0 \left(1 - \frac{d^2}{D_2^2}\right)^2 \qquad \text{(Eq. A.8)}$$

$$K_1 + K_2 = 1.5 \left[1 - \frac{d^2}{D^2}\right]^2 \qquad \text{(Eq. A.9)}$$

(to be continued)

APPENDIX A (continued)

Bernoulli coefficient K_B

When diameters of the inlet and outlet fitting are identical $K_{B1} = K_{B2}$,

then

$$K_B = 1 - \left(\frac{d}{D}\right)^4 \quad \textbf{(Eq. A.10)}$$

A.3 Equations for Non-Turbulent Flow

Volumetric flow rate

$$q = N_1 \cdot F_R \cdot C_V \sqrt{\frac{P_1 - P_2}{G_f}} \quad \textbf{(Eq. A.11)}$$

Mass flow rate

$$q = N_6 \cdot F_R \cdot C_V \sqrt{(P_1 - P_2)\,\gamma_1} \quad \textbf{(Eq. A.12)}$$

Reynolds number

$$Re_V = \frac{N_4 \cdot F_d \cdot q}{V \cdot F_L^{1/2} \cdot C_V^{1/2}} \left(\frac{F_L^2 \cdot C_V^2}{N_2 \cdot d^4} + 1\right)^{\frac{1}{4}} \quad \textbf{(Eq. A.13)}$$

A.4 Equations for Liquid Choked Flow

Maximum flow in straight pipes

$$q_{max} = N_1 \cdot F_L \cdot C_V \sqrt{\frac{P_1 - P_{vc}}{G_f}} \quad \textbf{(Eq. A.14)}$$

or

$$C_V = \frac{q_{max}}{N_1 \cdot F_L} \sqrt{\frac{G_r}{P_1 - P_{vc}}} \quad \textbf{(Eq. A.15)}$$

Liquid pressure recovery factor

$$F_L = \sqrt{(P_1 - P_2)/(P_1 - P_{vc})} \quad \textbf{(Eq. A.16)}$$

Absolute pressure at vena contracta

$$P_{vc} = F_F \cdot P_v \quad \textbf{(Eq. A.17)}$$

$$F_F = 0.96 - 0.28\left(\frac{P_v}{P_c}\right)^{1/2} \quad \textbf{(Eq. A.18)}$$

Maximum flow with attached fittings

$$q_{max} = N_1 \cdot F_{LP} \cdot C_V \sqrt{\frac{P_1 - P_{vc}}{G_f}} \quad \textbf{(Eq. A.19)}$$

(to be continued)

APPENDIX A (continued)

or $$C_V = \frac{q_{max}}{N_1 \,.\, F_{LP}} \sqrt{\frac{G_r}{P_1 - P_{vc}}}$$ (Eq. A.20)

A.5 Combined Liquid Pressure Recovery Factor F_{LP}

$$F_{LP} = F_L \left[\frac{K_i \,.\, F_L^2 \,.\, C_V^2}{N_2 \,.\, d^4} + 1 \right]^{½}$$ (Eq. A.21)

Velocity head factor for inlet fitting $K_i = K_1 + K_{B1}$ (Eq. A.22)

Values for N are listed in Table A.1:

TABLE A.1 - NUMERICAL CONSTANTS FOR LIQUID FLOW EQUATIONS

CONSTANT		UNITS USED IN EQUATIONS					
N		w	q	p, ΔP	d, D	γ_1	ν
N_1	0.0865	—	m³/h	kPa	—	—	—
	0.865	—	m³/h	bar	—	—	—
	1.00	—	gpm	psia	—	—	—
N_2	0.00214	—	—	—	mm	—	—
	890	—	—	—	in	—	—
N_4	76000	—	m³/h	—	mm		centistockes*
	17300	—	gpm	—	in		centistockes*
N_6	2.73	kg/h	—	kPa	—	kg/m³	—
	27.3	kg/h	—	bar	—	kg/m³	—
	63.3	lb/h	—	psia	—	lb/ft³	—

To convert m²/s to centistokes, multiply m²/s by 10^6. To convert centipoises to centistocks, divide centipoises by G_f.

A.6 Compressible Fluid-Flow of Gas and Vapor

A.6.1 Equation for turbulent flow

Mass flow $$W = N_6 \,.\, F_P \,.\, C_V \,.\, Y \sqrt{X \,.\, P_1 \,.\, \gamma_1}$$ (Eq. A.23)

$$W = N_8 \,.\, F_P \,.\, C_V \,.\, P_1 \,.\, Y \sqrt{\frac{X \cdot M}{T_1 \cdot Z}}$$ (Eq. A.24)

Volumetric flow $$q = N_7 \,.\, F_P \,.\, C_V \,.\, P_1 \,.\, Y \sqrt{\frac{X}{G_g \cdot T_1 \cdot Z}}$$ (Eq. A.25)

(to be continued)

APPENDIX A (continued)

$$q = N_9 \,.\, F_P \,.\, C_V \,.\, P_1 \,.\, Y \sqrt{\frac{X}{M \,.\, T_1 \,.\, Z}} \qquad \textbf{(Eq. A.26)}$$

TABLE A.2 - NUMERICAL CONSTANTS FOR GAS AND VAPOR FLOW EQUATIONS

CONSTANT		UNITS USED IN EQUATIONS					
N		w	q*	p, ΔP	γ_1	T_1	d, D
N_5	0.00241 1000	— —	— —	— —	— —	— —	mm in
N_6	2.73 27.3 63.3	kg/h kg/h lb/h	— — —	kPa bar psia	kg/m³ kg/m³ lb/ft³	— — —	— — —
N_7	4.17 417 1360	— — —	m³/h m³/h scfh	kPa bar psia	— — —	K K °R	— — —
N_8	0.948 94.8 19.3	kg/h kg/h lb/h	— — —	kPa bar psia	— — —	K K °R	— — —
N_9	22.5 2250 7320	— — —	m³/h m³/h scfh	kPa bar psia	— — —	K K °R	— — —

*** q is in cubic feet per hour measured at 14.73 psia and 60°F, or cubic meters per hour measured at 101.3 kPa and 15.6°C.**

A.6.2 Expansion factor Y for a valve

Without attached fittings $Y = 1 - \dfrac{X}{3F_K \cdot X_T}$ *(Limits 1.0 ≥ Y ≥ 0.67)* **(Eq. A.27)**

With attached fittings♣ $Y = 1 - \dfrac{X}{3F_K \cdot X_{TP}}$ **(Eq. A.28)**

$$F_K = \frac{K}{1.40} \qquad \textbf{(Eq. A.29)}$$

*** Chocked flow $P_1/P_{vc} > 2.0$.**

A.6.3 Pressure drop ratio factor with reducers or other fittings X_{TP}.

$$X_{TP} = \frac{X_T}{F_P^2} \left(\frac{X_T \,.\, K_i \,.\, C_V^2}{N_5 \,.\, d^4} + 1 \right)^{-1} \qquad \textbf{(Eq. A.30)}$$

Table A.3 for X_T, F_L, F_s, F_d, C_v / d^2.

*** If all inlet conditions are held constant and the differential pressure ratio (X) is increased by lowering the downstream pressure (P_2), the mass flow rate will increase to a maximum limit. Flow conditions where the value of X exceeds this limit are known as chocked flow.**

♣ Expansion factor Y at choked flow ($X \geq F_k . X_{TP}$) is then at minimum value of $^2/_3$°.

(to be continued)

APPENDIX A (continued)

A.6.4 Representative values of valve capacity factors

TABLE A.3 - REPRESENTATIVE VALUES OF VALVE CAPACITY FACTORS

VALVE TYPE	TRIME TYPE	FLOW DIRECTION*	X_T	F_L	F_s	F_d**	C_V/d^2♣
GLOBE							
Single port	Ported plug	Either	0.75	0.90	1.0	1.0	9.5
	Contoured plug	Open	0.72	0.90	1.1	1.0	11
		Close	0.55	0.80	1.1	1.0	11
	Characterized cage	Open	0.75	0.90	1.1	1.0	14
		Close	0.70	0.85	1.1	1.0	16
	Wing guided	Either	0.75	0.90	1.1	1.0	11
Double port	Ported plug	Either	0.75	0.90	0.84	0.7	12.5
	Contoured plug	Either	0.70	0.85	0.85	0.7	13
	Wing guided	Either	0.75	0.90	0.84	0.7	14
Rotary	Eccentric spherical plug	Open	0.61	0.85	1.1	1.0	12
		Close	0.40	0.68	1.2	1.0	13.5
ANGLE	Contoured plug	Open	0.72	0.90	1.1	1.0	17
		Close	0.65	0.80	1.1	1.0	20
	Characterized cage	Open	0.65	0.85	1.1	1.0	12
		Close	0.60	0.80	1.1	1.0	12
	Venture	Close	0.20	0.50	1.3	1.0	22
BALL	Segmented	Open	0.25	0.60	1.2	1.0	25
	Standard port (diameter ≡ 0.8d)	Either	0.15	0.55	1.3	1.0	30
BUTTERFLY	60-Degree aligned	Either	0.38	0.68	0.95	0.7	17.5
	Fluted vane	Either	0.41	0.70	0.93	0.7	25
	90-Degree offset seat	Either	0.35	0.60	0.98	0.7	29

*** Flow direction tends to open or close the valve, i.e., push the closure member away from or towards the seat.**

**** In general, an F_d value of 1.0 can be used for valves with a single flow passage. An F_d value of 0.7 can be used for valves with two flow passages, such as double-ported globe valves and butterfly valves.**

♣ In this Table, d may be taken as the nominal valve size, in inches.

APPENDIX B
VALVE TYPES TABLES

TABLE B.1 - APPLICATIONS OF VALVE TYPES

Valve category	General application(s)	Actuation	Remarks
Screw-down stop valve	Shut-off or regulation of flow of liquids and gases (e.g. steam)	(i) Handwheel. (ii) Electric motor. (iii) Pneumatic actuator. (iv) Hydraulic actuator. (v) Air motor.	(a) Limited applications for low pressure/low volume systems because of relatively high cost. (b) Limited suitability for handling viscous or contaminated fluids.
Cock	Low pressure service on clean, cold fluids (e.g. water, oils, etc.).	Usually manual.	Limited application for steam services.
Check valve	Providing flow in one direction.	Automatic.	(a) Swing check valves used in larger pipelines. (b) Lift check valves used in smaller pipelines and in high pressure systems.
Gate valve	Normally used either fully open or fully closed for on-off regulation on water, oil, gas, steam and other fluid services.	(i) Handwheel. (ii) Electric motor. (iii) Pneumatic actuator. (iv) Hydraulic actuator. (v) Air motor.	(a) Not recommended for use as throttling valves. (b) Solid wedge gate is free from chatter and jamming.
Parallel slide valve	Regulation of flow, particularly in main services in process industries and steam power plant.		(a) Offers unrestricted bore at full opening. (b) Can incorporate venture bore to reduce operating torque.
Butterfly valve	Shut-off and regulation in large pipelines in waterworks, process industries, petrochemical industries, hydroelectric power stations and thermal power stations.	(i) Handwheel. (ii) Electric motor. (iii) Pneumatic actuator. (iv) Hydraulic actuator. (v) Air motor.	(a) Relatively simple construction. (b) Readily produced in very large sizes [e.g. up to 5.5 m (18 ft) or more.]
Diaphragm valve	Wide range of applications in all services for flow regulation.	(i) Handwheel. (ii) Electric motor. (iii) Pneumatic actuator. (iv) Hydraulic actuator. (v) Air motor.	(a) Can handle all types of fluids, including slurries, sludges, etc., and contaminated fluids. (b) Limited for steam services by temperature and pressure rating of diaphragm.
Ball valve	Wide range of applications in all sizes, including very large sizes in oil pipelines, etc.	(i) Handwheel. (ii) Electric motor. (iii) Pneumatic actuator. (iv) Hydraulic actuator.	(a) Unrestricted bore at full opening. (b) Can handle all types of fluids. (c) Low operating torque. (d) Not normally used as a throttling valve.
Pinch valve	Particularly suitable for handling corrosive media, solids in suspensions, slurries, etc.	(i) Mechanical. (ii) Electric motor. (iii) Pneumatic actuator. (iv) Hydraulic actuator. (v) Fluid pressure (modified design).	(a) Unrestricted bore at full opening. (b) Can handle all types of fluids. (c) Simple servicing. (d) Limited maximum pressure rating.

(to be continued)

APPENDIX B (continued)

TABLE B.2 - VALVE TYPES FOR SPECIFIC SERVICES

Service	Main	Secondary
Gases	Butterfly valves Check valves Diaphragm valves Lubricated plug valves Screw-down stop valves	Pressure control valves Pressure-relief valves Pressure-reducing valves Safety valves Relief valves
Liquids, clear up to sludges and sewage	Butterfly valves Screw-down stop valves Gate valves Lubricated plug valves Diaphragm valves Pinch valves	
Slurries and liquids heavily contaminated with solids	Butterfly valves Pinch valves Gate valves Screw-down stop valves Lubricated plug valves	
Steam	Butterfly valves Gate valves Screw-down stop valves Turbine valves	Check valves Pressure control valves Presuperheated valves Safety and relief valves

(to be continued)

APPENDIX B (continued)

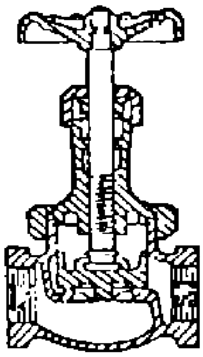
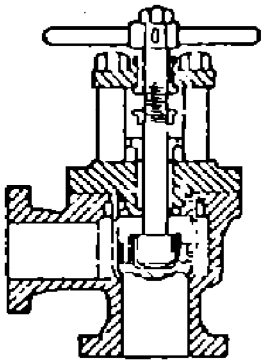
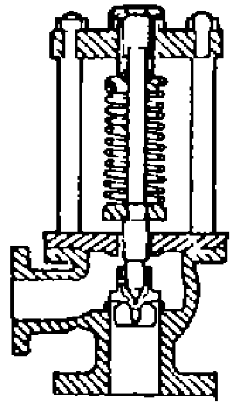
TABLE B.3 - VALVE TYPE SUITABILITY

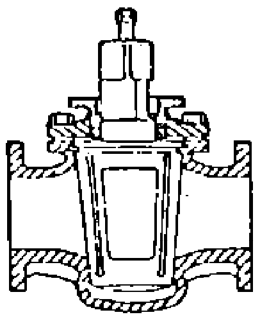
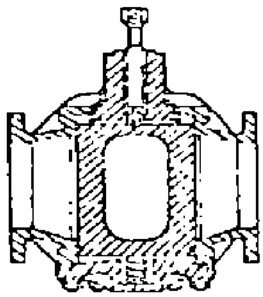
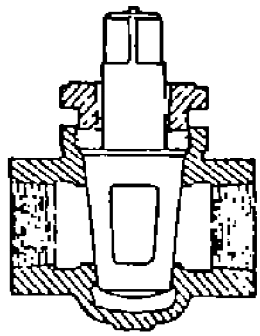
SERVICE OR FUNCTION											
Valve type	On-off	Throttling	Diverting	No reverse flow	Pressure control	Flow Control	Pressure relief	Quick opening	Free draining	Low pressure drop	Handling solids suspension
Ball	S	M	S	—	—	—	—	S	—	S	LS
Butterfly	S	S	—	—	—	S	—	S	S	S	S
Diaphragm	S	M	—	—	—	—	—	M	M	—	S
Gate	S	—	—	—	—	—	—	S	S	S	—
Globe	S	M	—	—	—	M	—	—	—	—	—
Plug	S	M	S	—	—	M	—	S	S	S	LS
Oblique (Y)	S	M	—	—	—	M	—	—	—	—	—
Pinch	S	S	—	—	—	S	—	—	S	S	S
Slide	—	M	—	—	—	M	—	M	S	S	S
Swing check	—	—	—	S	—	—	—	—	—	S	—
Tilting disc	—	—	—	S	—	—	—	—	—	S	—
Lift check	—	—	—	S	—	—	—	—	—	—	—
Piston check	—	—	—	S	—	—	—	—	—	—	—
Butterfly check	—	—	—	S	—	—	—	—	—	—	—
Pressure relief	S	—	—	—	—	—	S	—	—	—	—
Pressure reducing	—	—	—	—	S	—	—	—	—	—	—
Sampling	S	—	—	—	—	—	—	—	—	—	—
Needle	—	S	—	—	—	—	—	—	—	—	—

Key:

S = Suitable choice
M = May be suitable in modified form
LS = Limited suitability

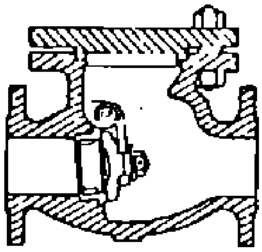
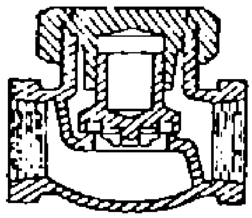
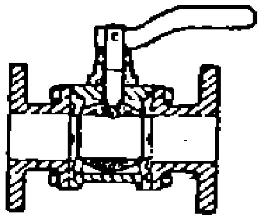
APPENDIX C
TYPICAL VALVE SELECTION GUIDE

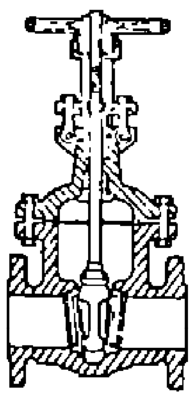
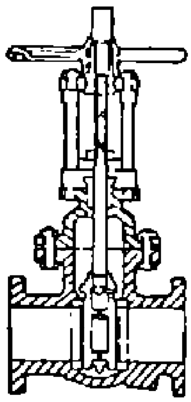
Valve Selection Guide	 **Globe Valve**	 **Combined Stop and Check Valve**	 **Safety Valve**
Size range, mm (in)	DN3 to 80 (1/8 to 3)	DN15 to 600 (1/2 to 24)	DN15 to DN16 (1/2 to 16)
Pressure range, kPa (psi)	to 2,070 (to 300)	to 2,070 (to 300)	to 10,340 (to 1,500)
Temperature range, °C (F)	-40 to 149 -40 to 300	-40 to 176 (-40 to 350)	-40 to 260 (-40 to 500)
Materials of construction	Bronze, iron, steel, stainless steel	Bronze, brass, iron, steel, stainless steel	Brass, bronze, steel, iron, stainless steel
Primary function	On-off service and coarse metering	On-off and metering service along with flow reversal prevention	Pressure control

	 Lubricated Plug Valve, Taper Plug	 Lubricated Plug Valve, Parallel Plug	 Gland Cock
Size range, mm (in)	DN9 to DN600 (3/8 to 24)	DN9 to DN600 (3/8 to 24)	DN 3 to DN6 (1/8 to 6)
Pressure range, kPa (psi)	to 2,760 (to 400)	to 2,750 (to 400)	to 3,450 (to 500)
Temperature, range (°F) °C	-40 to 121 (-40 to 250)	-40 to 121 (-40 to 250)	-51 to 260 (-60 to 500)
Materials of construction	Brass, bronze, aluminum, ductile iron, semi steel, stainless steel	Brass, bronze, aluminum, ductile iron, semi steel, stainless steel	Brass, bronze, iron, ductile iron, semi steel, stainless steel
Primary function	On off service	On-off service	Shut off

(to be continued)

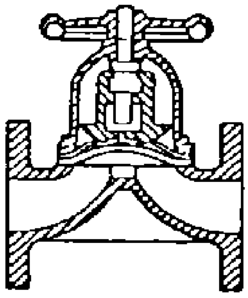
APPENDIX C (continued)

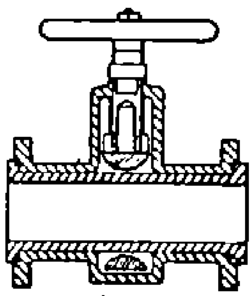
	 Check Valve, Swing Type	 Check Valve, Piston Lift Type	 Ball Plug Valve
Size range, mm (in)	DN6 to DN600 (1/4 to 24)	DN6 to DN 600 (1/4 to 24)	DN15 to DN 600 (1/2 to 24)
Pressure range, kPa (psi)	to 2070 (to 300)	to 2070 (to 300)	to 2,760 (to 400)
Temperature range °C (F)	-40 to 176 (-40 to 350)	-40 to 176 (-40 to 350)	-40 to 121 (-40 to 250)
Materials of construction	Bronze, brass, iron, semi-steel, steel, aluminum, stainless steel	Bronze, brass, iron, semi-steel, steel, stainless steel	Brass, bronze, iron, aluminum, steel, stainless steel
Primary function	Prevent flow reversal	Prevent flow reversal	On-off service and direction control

	 Gate Valve, Rising Stem	 Gate Valve, Traveling Stem
Size range, mm (in)	DN6 to DN 600 (1/4 to 24)	DN6 to DN 600 (1/4 to 24)
Pressure range, kPa (psi)	to 2,760 (to 400)	to 2,760 (to 400)
Temperature range °C (F)	-45 to 260 (-50 to 500)	-45 to 260 (-50 to 500)
Materials of construction	Bronze, brass, iron, semi steel, stainless steel	Bronze, brass, iron semi-steel, stainless steel
Primary function	Metering or throttling	On-off service and throttling

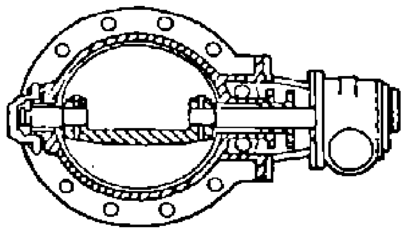
(to be continued)

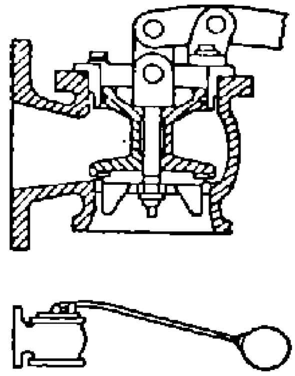
APPENDIX C (continued)





	Diaphragm Valve	Pinch Valve
Size range, m m (in)	DN15 to DN600 (1/2 to 24)	DN6 to DN300 (1/4 to 12)
Pressure range, kPa (psi)	to 5170 (to 750)	to 3,450 (to 500)
Temperature range, °C (F)	-45 to 260 (-50 to 500)	-35 to 176 (-30 to 350)
Materials of construction	Brass, bronze, iron, steel, stainless steel	Brass, bronze, steel, stainless steel
Primary function	On-off service	Metering





	Butterfly Valve, Offset Disc	Ball Float Valve
Size range, m m (in)	DN25 to DN600 (1 to 24)	DN15 to DN300 (1/2 to 12)
Pressure range kPa (psi)	to 1,725 (to 250)	to 3,450 (to 500)
Temperature range °C (F)	-450 to 538 (-50 to 1,000)	-45 to 260 (-50 to 500)
Materials of construction	Brass, bronze, aluminum, iron, steel, stainless steel	Brass, bronze, aluminum, iron, steel stainless steel
Primary function	On-off service	Metering and level control

APPENDIX D
SPECIFICATION FORM FOR CONTROL VALVE

PROJECT ______	DATA SHEET __ of __
UNIT ______	SPEC ______
PO ______	TAG ______
ITEM ______	DWG ______
CONTRACT ______	SERVICE ______
MFR SERIAL* ______	

1 Fluid ______ Crit Pres PC ______

SERVICE CONDITIONS

No.		Units	Max Flow	Norm Flow	Min Flow	Shut-Off	
2	Flow Rate					–	
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							

LINE

13 Pipe Line Size & Schedule | In ______
14 | Out ______
15 Pipe Line Insulation ______

VALVE BODY/BONNET

16 *Type ______
17 *Size ______ ANSI Class ______
18 Max Press/Temp ______
19 *Mfr & Model ______
20 *Body/Bonnet Matl ______
21 *Liner Material/ID ______
22 End Connection | In ______
23 | 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 ______

TRIM

32 *Type ______
33 *Size ______ Rated Travel ______
34 *Characteristic ______
35 *Balanced/Unbalanced ______
36 *Rated C_V ______ F_L ______ X_T ______
37 *Plug/Ball/Disk Material ______
38 *Seat Material ______
39 *Cage/Guide Material ______
40 *Stem Material ______
41 ______
42 ______

SPECIALS/ACCESSORIES

43 Class ______ Group ______ Div ______
44 ______
45 ______
46 ______
47 ______
48 ______
49 ______
50 ______
51 ______
52 ______

ACTUATOR

53 *Type ______
54 *Mfr & Model ______
55 *Size ______ Eff 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 ______

POSITIONER

68 *Type ______
69 *Mfr & Model ______
70 *On Incr Signal Output Incr/Decr ______
71 Gauges ______ By-pass ______
72 *Cam Characteristic ______
73 ______

SWITCHES

74 Type ______ Quantity ______
75 *Mfr & Model ______
76 Contacts/Rating ______
77 Actuation Points ______
78 ______

AIR SET

79 *Mfr & Model ______
80 *Set Pressure ______
81 Filter ______ Gauge ______
82 ______

TESTS

83 *Hydro Pressure ______
84 ANSI/FCI Leakage Class ______
85 ______
86 ______

Rev	Date	Revision	Orig	App

*Information supplied by manufacturer unless already specified.