ENGINEERING STANDARD

FOR

PROCESS DESIGN OF VALVES

AND

CONTROL VALVES

ORIGINAL EDITION

DEC. 1997

This standard specification is reviewed and updated by the relevant technical committee on Nov. 2005(1) and Feb. 2014(2). The approved modifications are included in the present issue of IPS.

FOREWORD

The Iranian Petroleum Standards (IPS) reflect the views of the Iranian Ministry of Petroleum and are intended for use in the oil and gas production facilities, oil refineries, chemical and petrochemical plants, gas handling and processing installations and other such facilities.

IPS is based on internationally acceptable standards and includes selections from the items stipulated in the referenced standards. They are also supplemented by additional requirements and/or modifications based on the experience acquired by the Iranian Petroleum Industry and the local market availability. The options which are not specified in the text of the standards are itemized in data sheet/s, so that, the user can select his appropriate preferences therein

The IPS standards are therefore expected to be sufficiently flexible so that the users can adapt these standards to their requirements. However, they may not cover every requirement of each project. For such cases, an addendum to IPS Standard shall be prepared by the user which elaborates the particular requirements of the user. This addendum together with the relevant IPS shall form the job specification for the specific project or work.

The IPS is reviewed and up-dated approximately every five years. Each standards are subject to amendment or withdrawal, if required, thus the latest edition of IPS shall be applicable

The users of IPS are therefore requested to send their views and comments, including any addendum prepared for particular cases to the following address. These comments and recommendations will be reviewed by the relevant technical committee and in case of approval will be incorporated in the next revision of the standard.

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GENERAL DEFINITIONS:

Throughout this Standard the following definitions shall apply.

COMPANY:

Refers to one of the related and/or affiliated companies of the Iranian Ministry of Petroleum such as National Iranian Oil Company, National Iranian Gas Company, National Petrochemical Company and National Iranian Oil Refinery And Distribution Company.

PURCHASER:

Means the “Company” where this standard is a part of direct purchaser order by the “Company”, and the “Contractor” where this Standard is a part of contract documents.

VENDOR AND SUPPLIER:

Refers to firm or person who will supply and/or fabricate the equipment or material.

CONTRACTOR:

Refers to the persons, firm or company whose tender has been accepted by the company.

EXECUTOR:

Executor is the party which carries out all or part of construction and/or commissioning for the project.

INSPECTOR:

The Inspector referred to in this Standard is a person/persons or a body appointed in writing by the company for the inspection of fabrication and installation work.

SHALL:

Is used where a provision is mandatory.

SHOULD:

Is used where a provision is advisory only.

WILL:

Is normally used in connection with the action by the “Company” rather than by a contractor, supplier or vendor.

MAY:

Is used where a provision is completely discretionary.

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APPENDICES:

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.

"Process Design of Valves & Control Valves and Piping Systems" 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	"Engineering Standard for Process Design of Valves & Control Valves"
IPS-E-PR-440	"Engineering Standard for Process Design of Piping Systems (Process Piping and Pipeline Sizing)"

This Engineering Standard Specification covers:

"PROCESS DESIGN OF VALVES AND CONTROL VALVES"

1. SCOPE

This Engineering Standard Specification is intended to cover minimum process requirements for manual valves, check valves and control valves as well as field of application, selection of types, design considerations (e.g. cavitations) and control valve sizing calculations.

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).

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.

The application of this Engineering Standard Specification shall be exercised, only in combination with the relevant Piping & Pipelines and Instrument Standards, i.e., IPS-E-PR-440 "Piping Systems", IPS-M-PI-110/I-VI, "Valves", and IPS-E-IN-160, "Control Valves", respectively, some of which are provided base on the following specifications and handbooks:

- "Valve Selection Handbook", 5th Edition, 2003, by R.W. ZAPPE
- Design Practice by EXXON Engineering, 1999
- Process Engineering Design Manual by TOTAL Company.
- Manual control valves- selection, sizing, and specification, April 2003.
- Valve handbook, by: skousen (McGrow hill digital library).

Note 1:

This standard specification is reviewed and updated by the relevant technical committee on Nov. 2005. The approved modifications by T.C. were sent to IPS users as amendment No. 1 by circular No. 273 on Nov. 2005. These modifications are included in the present issue of IPS.

Note 2:

This standard specification is reviewed and updated by the relevant technical committee on Feb. 2014. The approved modifications by T.C. were sent to IPS users as amendment No. 2 by circular No. 414 on Feb. 2014. These modifications are included in the present issue of IPS.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

ISA/ANSI (INSTRUMENT SOCIETY OF AUTOMATION/AMERICAN NATIONAL STANDARDS INSTITUTE)

ANSI/ISA-75.01.01-2012 (60534-2-1 MOD)	"Industrial-Process Control Valves - Part 2-1: Flow Capacity – Sizing Equations for Fluid Flow under Installed Conditions"

IPS (IRANIAN PETROLEUM STANDARDS)

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

3. SYMBOLS AND ABBREVIATIONS

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.
E_q	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/s²).
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.
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, $K_c = \frac{\text{change in flow}}{\text{change in lift}}$ **(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 valvefitting 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 (m³/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/m³).
γ_1 (gamma)	Specific mass (weight), upstream conditions, in (kg/m³).
γ_f (gamma)	Specific mass (weight) of liquid, in (kg/m³).
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. DEFINITIONS

4.1 Actuator (Valve Operator)

The Actuator is the device used to move the stem. The most common operator is a spring-loaded diaphragm. It is actuated with compressed air, whether the controller itself is pneumatic or electronic. Other operators are pistons (air or hydraulic), electric motor and air motor.

4.2 Control Valve

A control valve is an engineered variable flow restriction. The input signal to the control valve is the output signal from a controller. The control valve is constructed such that the stem lift (plug position) is proportional to the input signal.

4.3 High Recovery Valve

High Recovery Valve is one that does recover a significant amount of pressure at the outlet compared to the differential pressure across the valve itself. An example is a streamlined angle valve with flow in the side and out the bottom.

4.4 Low Recovery Valve

Low Recovery Valve is one that does not recover very much pressure at the outlet compared to the differential pressure across the valve itself. Examples are cage valves and globe valves with flow upwards against the seat.

4.5 Valve Characteristics

The relationship between the position of a valve plug (or stem lift) and the area open for flow is the valve characteristic. With a constant ΔP across the valve this relationship would also hold for flow rate. The valve area characterized by the coefficient Cv. The Cv coefficient is the number of U.S. gallons of water flowing during one minute through a restriction and pressure drop through this restriction and the pressure drop through this restriction is 1 PSI.

5. UNITS

This Standard is based on International System of Units (SI), as per IPS-E-GN-100 except where otherwise specified.

6. GENERAL CONSIDERATION

Valves are the components in a fluid flow or pressure systems that 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.

These duties are performed by adjusting the position of the closure member in the valve. This may be done either manually or automatically. Manual operation also includes the operation of the valve by means of a manually controlled power operator.

6.1 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) Noise limitation

Affecting choice of valve type.

g) Any special requirements

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.

6.2 Selection of Valves

a) Valves for stopping and starting flow

These valves are normally selected for low flow resistance and a straight-through flow passage. Such valves are Slide, Rotary and Flex-body valves.

b) Valves for control of flow rate

Most common used are Globe, Ball, and Rotary valves.

c) Valves for diverting flow

These valves have three or more ports, depending on the flow diversion duty. 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 that slides across the seat with a wiping motion.

e) Valves for providing pressure drop

Such valves are Globe and Plug.

7. MANUAL VALVES

A manual valve is considered to be a valve that is operated by plant personnel directly, by the use of either a hand wheel/wrench or an on/off actuator in the case of shutdown valves. Certain automated valves with actuators are also supplied with hand wheels to allow manual operation in the event of power failure.

Manual valves serve three major functions in fluid handling systems:

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

7.1 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:

7.1.1 Closing-down valves

A stopper-like closure member is moved to and from the seat in direction of the seat axis, such as globe and piston valves.

7.1.2 Slide valves

A gate-like closure member is moved across the flow passage, such as gate valve.

7.1.3 Rotary valves

A plug or disc-like closure member is rotated within the flow passage, around an axis normal to the flow stream, such as Plug, Ball, and Butterfly valves.

7.1.4 Flex-body valves

The closure member flexes the valve body, such as Pinch and Diaphragm valves.

7.2 Globe Valves

7.2.1 Globe valves are preferred for high pressure drop applications, low flow applications, or where cavitation, flashing, noise are considerations. A globe-style valve that has a cast flanged body that can be serviced while in the line is preferred. Split body valves are not recommended because they are prone to leakage. The sealing of these valves is high.

7.2.2 Three-way and angle body valves may be considered for special applications. Three-way valves can be used for proportioning control of converging or diverging flow. Angle body valves should be considered for outgassing service, coking service (where solids are carried in suspension), severe flashing service, and where the piping design can take advantage of the valve geometry.

7.2.3 Applications

Duty:

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

Service:

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

7.3 Piston Valves

Applications

Duty:

- Controlling flow.
- Stopping and starting flow.

Service:

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

7.4 Gate Valves

7.4.1 Parallel gate valve

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.

7.4.2 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.

7.4.3 Conduit gate valves

Applications

Duty:

- Stopping and starting flow (on & off).
- Zero leakage and High integrity.
- Low and High line pressure.

Service:

- Gases.
- Liquids.
- Through conduit gate valve, a full bore gate valve, with very low pressure drop and allows for the passage of pipeline pigs or scrapers for cleaning, de-watering, batching, etc.

7.5 Plug Valves (Cocks)

Applications

Duty:

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

Service:
- 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.

7.6 Ball Valves

Applications

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

Service:
- Gases.
- Liquids.
- Non-abrasive slurries.
- Vacuum.
- Cryogenic.
- A full bore ball valve has very low pressure drop and allows for the passage of pipeline pigs or scrapers for cleaning.

7.7 Butterfly Valves

Butterfly valves are rotary valves in which a disc-shaped closure member is rotated through 90°, or approximately, to open or close the flow passage.

Applications

Duty:
- Stopping and starting flow.
- Controlling flow.

Service:
- Gases.
- Liquids.
- Slurries.
- Powder.
- Granules.
- Sanitary handling
- Vacuum.

7.8 Needle Valves

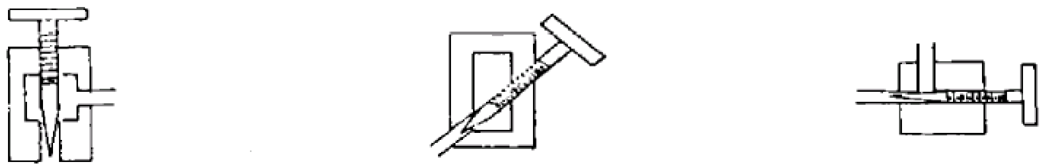
Small sizes of globe valves fitted with a finely tapered plug are known as needle valves.

Duty:

- Secondary system for on and off application.
- Sampling.
- Available in smaller size.

Service:

- Gases.
- Liquids.



a) b) c)

Fig. 1

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).

7.9 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.
- Particle-entrained fluids.
- Abrasive slurries.
- Powders.
- Granules.
- Sanitary handling

7.10 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
- 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).

8. 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.

8.1 Check Valve Type

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.
- The different type of check valve which are most used in oil and gas industries, their importance as follows:

8.1.1 Lift check valves

Lift check valves may be sub-divided into:

a) Disc check valves;

b) Piston check valves;

c) Ball check valves.

8.1.2 Swing check valves

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

8.1.3 Tilting-disc check valves

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

8.1.4 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 74°C. (Refer to Zappe handbook, page no. 167)
- Sizes as small as DN3 (NPS 1/8 inch) and as large as DN 3000 (NPS 120 inch).

8.1.5 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.

8.1.6 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.

8.1.7 Ball foot valves

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

8.1.8 Membrane foot valves

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

8.1.9 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.

8.2 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.

8.2.1 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.

8.2.2 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. 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.

9. CONTROL VALVES

A control valve is an engineered variable flow restriction. The input signal to the control valve is the output signal from a controller. The control valve is constructed such that the stem lift (plug position) is proportional to the input signal. 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.

9.1 Control Valve Characteristics

There are determined principally by the design of the valve trim. The three fundamental characteristics available are quick opening, linear, and equal percentage:

9.1.1 Quick opening

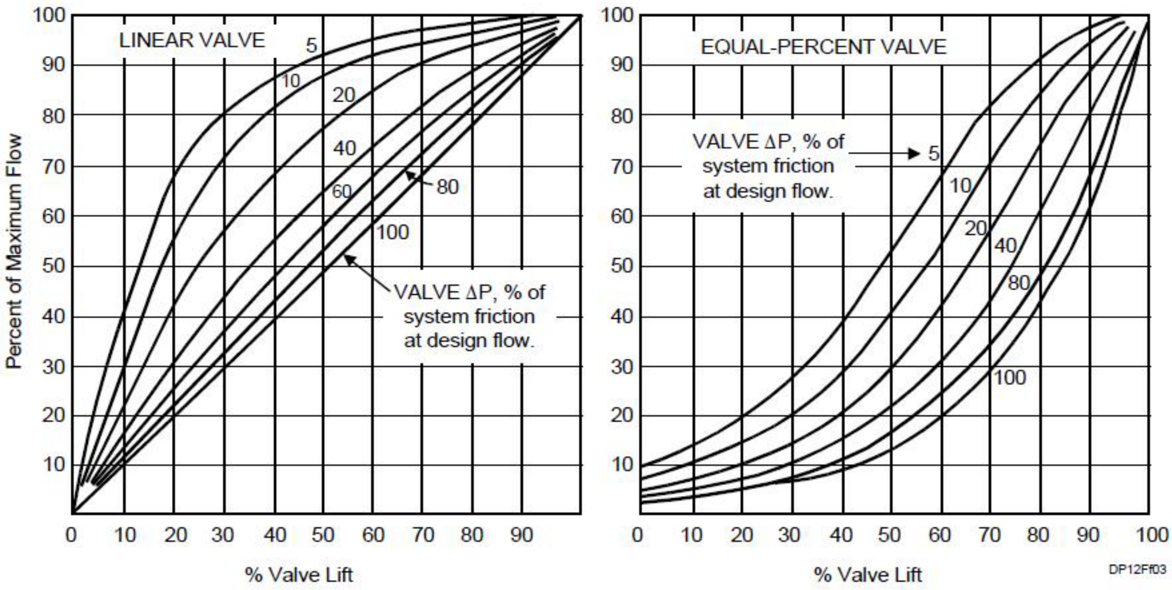
As the name implies, this type provides a large opening as the plug is first lifted from the seat with lesser flow increase as the stem opens further. The most common application if for simple on-off control with no throttling of flow required.

9.1.2 Linear

Linear trim provides equal increases in stem travel. Thus the flow rate is linear with plug position throughout its travel (Fig.2).

9.1.3 Equal percentage

Provides equal percentage increases in rate of flow for equal increments of stem travel. The characteristics provide a very small opening for plug travel near the seat and very large increase toward the fully open position. As a result, a wide rangeability of flow rate is achieved (Fig.2).



CHARACTERISTICS OF LINEAR AND EQUAL PERCENTAGE VALVES

Fig. 2

9.2 Control Valve Types

If the application allows, valves with a rotating spindle are preferred to linear motion valves for reasons of capacity and turndown. Control valves and pressure regulators shall be selected in accordance with the requirements of the piping class.

9.2.1 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.

9.2.1.1 Globe valve

a) Two-way globe valves

If rotary valves cannot be used, globe valves should be considered as the first choice.

b) Three-way globe valves

Each flow path shall be sized separately for three way globe valves. Except for instrument air dryers, the application of three-way globe valves requires the approval of the Principal.

Control valve used in most of cases except at very high pressure drop as defined by instrument group, or on water networks, and compressor suction lines for throttling purposes.

9.2.1.2 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 doubleseated type 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.

9.2.1.3 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.

Butterfly valves shall be considered for the following circumstances:

- If the required size would make it economically attractive (usually due to a high flow rate with a low pressure drop);

- If eccentric plug / segmented ball or globe valves are not suitable;

- For corrosive services, where body lining of globe valves becomes economically unattractive.

- Suction lines to centrifugal gas compressors and air blowers.

- Outlet lines from water disengaging drums.

- As a substitute for a large (or unavailable) 3-way (two butterfly valves are needed) in gas lines through and by-passing heat exchangers. Special needs of this service are covered under 3-way valves.

9.2.1.4 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.

Ball valves may be considered for on-off service.

Ball valves for use in erosive (e.g. slurry) service etc. should be equipped with a scraper type of seat construction.

Unless equipped with a special trim, i.e. anti-cavitation or low-noise design, certain ball valves may be unsuitable for high differential pressures.

9.2.1.5 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.

9.2.1.6 Angle valve

Angle valves should be considered for:

- Hydrocarbon services where coke may form;

- Erosive services, e.g. slurries;

- Flashing service;

- Applications where solid contaminants might settle in the body of a globe valve;

- Liquid service where high differential pressure prevails.

9.2.2 Rangeability

The rangeability required for the control valve should be considered during valve selection. 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.

Each control valve type (and size) has a minimum area open to flow, below which operation is not sufficiently consistent or precise for satisfactory control. The rangeability of the valve is defined as this minimum divided into the area open to flow at full stem lift.

However, actual control valve rangeability is limited by the following factors:

- Control valves are specified with opening percentage at maximum flow, to insure it is in a controlling position.
- The specified valve capacity will rarely match a commercially available size, since the next larger valve is frequently supplied.
- Erosion and corrosion in service will cause a deterioration of the valve's rangeability.

9.2.3 Choice of failure position

When selecting the positions to which the valves go on air or power failure the goal is to require minimum operator attention to put the unit in the safest possible standby condition; to minimize upsets to associated units; and to ease the problem of returning to service when the failure is corrected. So-called general rules are seldom “generally” applicable; there usually will be some valves that are contrary to the rule. However, the following rules can be useful as a point of departure:

1. Close valves feeding heat and material to the unit.

2. Close valves on streams leaving the unit.

These two actions “bottle-up” the unit and may cause actuation of safety valves.

3. Open valves in heat absorbing circuits such as furnace coils, heat exchangers, the exchanger port of 3-way valves, reflux streams, pumparounds, etc. Note that on process units such as crude pipe stills and steam crackers this rule will supersede rule No. 1.

9.3 Control Valve Sizing

9.3.1 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.

9.3.2 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.

9.3.3 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.

9.4 Common Control Valve Problems

Common valve problems can be categorized as Cavitations, Flashing, Choked flow and Noise.

9.4.1 Cavitation problem

Cavitation occurs in liquid service when the pressure in the valve body falls below the vapour pressure of the liquid. The bubbles formed will implode immediately after leaving the valve, due to the downstream pressure of the control valve recovering to rise above the liquid vapour pressure. Cavitation should be avoided because it limits the valve capacity, generates vibration and noise and might physically damage the control valve. For preventing of cavitation, following remedial actions can be considered :

- Select a valve with a higher liquid pressure recovery factor;
- Modify the piping of control valve upstream to reach a higher inlet pressure and/or a lower inlet temperature;
- Install a restriction orifice directly downstream of the control valve, provided that flow rate variations are small and providing that the restriction orifice is not damaged by cavitation;
- Use hardened or special anti-cavitation trim to prevent damage;
- Install two (or more) control valves in series.

For more details refer to Appendix D.

9.4.2 Flashing problem

Flashing problem occurs, for liquids only, when the pressure in the valve body falls below the liquid vapour pressure and when the bubbles thus formed remain as vapour in the fluid, owing to the fact that the downstream pressure of the control valve is at or below the liquid vapour pressure. The first stage of flashing is identical to that for cavitation. In the second stage, a portion of the vapour formed at the vena contracta remains in vapour phase as the downstream pressure is equal or less than the vapour pressure of the liquid. In situations where flashing in the control valve cannot be prevented by relocating the valve measures shall be taken to prevent damage as a result of high fluid velocities. Consult the control valve Manufacturer for guidance, as the required measures depend on valve and trim geometry.

9.4.3 Choked flow problem

Choked flow occurs for an incompressible or compressible fluids when the fluid velocity at the vena contracta reaches sonic velocity; For incompressible fluids, choked flow is associated with cavitation or flashing. For remedial actions, see recommendations of Flashing and cavitation problems. For compressible fluids, choked flow shall be avoided, as the associated high fluid velocities result in high noise levels and physical damage to valves and downstream piping.

9.4.4 Noise problem

Noise is generated when vibration produces wide variations in atmospheric pressure, which are then transferred to the eardrums as noise. Noise spreads at the speed of sound [which is 335 m/s]. Noise in valves can be created in a number of different ways; however, the most common cause is turbulence generated by the geometry of the valve, which is radiated by the downstream piping . Noise can also be generated by hydrodynamic and aerodynamic fluid sound. With liquid applications, hydrodynamic noise is caused by the turbulence of the flow, cavitation, flashing, or the high velocities that occur as the flow moves through the vena contracta.

10. SELF-ACTING REGULATORS

10.1 Self-Acting Pressure-Reducing Regulators

Self-acting pressure regulators shall only be used in clean fluid services and only in applications that need no operator intervention, such as reducing instrument supply pressure or gas blanketing of vessels or storage tanks. Pressure-reducing regulators in gas blanketing service shall not be provided with an internal self-relieving function.

10.2 Self-Acting Back-Pressure Regulators

Self-acting back-pressure regulators shall only be considered for clean fluids in applications which need no operator intervention, such as for maintaining a uniform back pressure in utility (e.g. nitrogen) distribution systems or for lubrication, sealing or control oil applications in rotating equipment.

The use of self-acting back-pressure regulators requires the approval of the Principal.

10.3 Self-Acting Differential-Pressure Regulators

Self-acting differential-pressure regulators shall only be considered for clean fluids in applications that need no operator intervention, such as for secured instrument air systems or for lubrication, sealing or control oil applications of rotating equipment. Except in secured instrument air supply systems, the use of self-acting differential-pressure regulators requires the approval of the Principal.

10.4 Self-Acting Temperature Regulators

Self-acting temperature regulators shall only be considered for simple, non-safety related heating applications where utilities (e.g. instrument air or gas) are not available. The use of self-acting temperature regulators requires the approval of the Principal.

11. SPECIFICATION FORM FOR CONTROL VALVE

For specification form for valves, reference shall be made to IPS-E-IN-160.

APPENDICES

APPENDIX A
EQUATIONS FOR CONTROL VALVE SIZING CALCULATIONS

A.1 Flow Coefficient:

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

A.2 Equations for Incompressible Flow of Nonvaporizing Liquid

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

A.2.1 For turbulent flow

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

In mass flow rate $W = N_6 \,.\, F_p \,.\, C_v\,(P_1 - P_2)$ **(Eq. A.4)**

A.2.2 Piping geometry factor Fp

$$F = \left(\frac{\sum K\,.\,C_v}{N_2.\,d^4} + 1\right)$$ **(Eq. A.5)**

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

$$K_1 = 0.5\left(1 - \frac{d^2}{P_1^2}\right)^2$$ **(Eq. A.7)**

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

$$K_1 + K_2 = 1.5\left(1 - \frac{d^2}{D^2}\right)^2$$ **(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
$$q = N_1 . F_R . C_v \sqrt{\frac{P_1 - P_2}{G_f}} \quad \textbf{(Eq. A.11)}$$

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

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

A.4 Equations for Liquid Choked Flow

Maximum flow in straight pipes
$$q_{max} = N_1 . F_L . C_v \sqrt{\frac{P_1 - P_{vc}}{G_f}} \quad \textbf{(Eq.A.14)}$$

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

Liquid pressure recovery factor
$$F_L = \sqrt{(P_1 - P_2)/(P_1 - P_{vx})} \quad \textbf{(Eq. A.16)}$$

Absolute pressure at vena contracta $\boldsymbol{P_{vc} = F_F . P_v}$ **(Eq. A.17)**

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

Maximum flow with attached fittings
$$q_{max} = N_1 . F_{LP} . C_v \sqrt{\frac{P_1 - P_{vc}}{G_f}} \quad \textbf{(Eq. A.19)}$$

(to be continued)

APPENDIX A (continued)

or $$C_v = N_1 . F_{LP} . C_v \sqrt{\frac{P_1 - P_{vc}}{G_f}}$$ **(Eq. A.20)**

A.5 Combined Liquid Pressure Recovery Factor FLP

$$F_{LP} = F_L \left(\frac{K_i . F_L^2 . C_v^2}{N_2 . d^4} + 1 \right)^{-\frac{1}{2}}$$ **(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	G1	γ1	ν
N_1	0.0865 0.865 1.00	--- --- ---	m³/h m³/h gpm	kPa bar psia	--- --- ---	--- --- ---	--- --- ---
N_2	0.00214 890	--- --- ---	--- ---	--- ---	mm in	--- ---	--- ---
N_4	76000 17300	--- --- ---	m³/h gpm	--- ---	mm in		centistockes* centistockes*
N_6	2.73 27.3 63.3	kg/h kg/h lb/h	--- --- ---	kPa bar psia	--- --- ---	kg/m³ kg/m³ lb/ft³	--- --- ---

To convert m²/s to centistokes, multiply m²/s by 106. 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 $$W = N_6 . F_p . C_v . Y \sqrt{X . P_1 . y_1}$$ **(Eq. A.23)**

$$W = N_8 . F_p . C_v . P_1 . Y \sqrt{\frac{X . M}{T_1 . Z}}$$ **(Eq. A.24)**

Volumetric flow $$q = N_7 . F_p . C_v . P_1 . Y \sqrt{\frac{X}{G_g . T_1 . Z}}$$ **(Eq. A.25)**

(to be continued)

APPENDIX A (continued)

$$q = N_9 . F_p . C_v . P_1 . Y \sqrt{\frac{X}{M . T_1 . Z}} \quad \textbf{(Eq. A.26)}$$

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	---	---	---	---	---	mm
	1000	---	---	---	---	---	in
N_6	2.73	kg/h	---	kPa	kg/m³	---	---
	27.3	kg/h	---	bar	kg/m³	---	---
	63.3	lb/h	---	psia	lb/ft³	---	---
N_7	4.17	---	m³/h	kPa	---	K	---
	417	---	m³/h	bar	---	K	---
	1360	---	scfh	psia	---	°R	---
N_8	0.948	kg/h	---	kPa	---	K	---
	94.8	kg/h	---	bar	---	K	---
	19.3	lb/h	---	psia	---	°R	---
N_9	22.5	---	m³/h	kPa	---	K	---
	2250	---	m³/h	bar	---	K	---
	7320	---	scfh	psia	---	°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 $$Y = 1 - \frac{X}{3F_K . X_T} \quad \textit{(Limits } 1.0 \geq Y \geq 0.67\textit{)} \quad \textbf{(Eq.A.27)}$$

With attached fittings ♣ $$Y = 1 - \frac{X}{3F_K . X_{TP}} \quad \textbf{(Eq. A.28)}$$

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

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

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

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

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 º 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.
arallel 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:

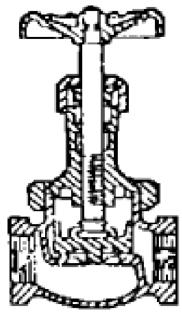
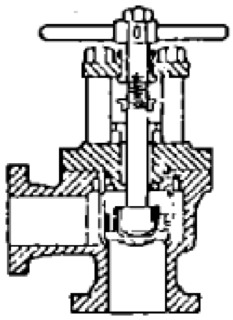
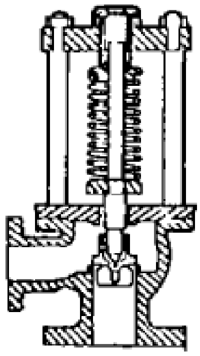
S = Suitable choice

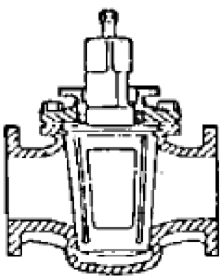
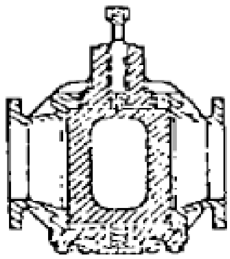
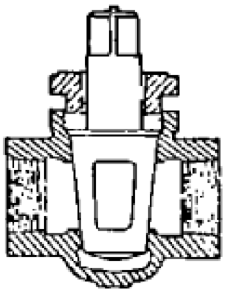
M = May be suitable in modified form

LS = Limited suitability

APPENDIX C

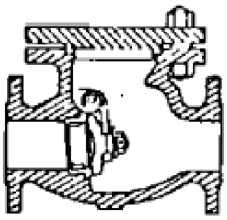
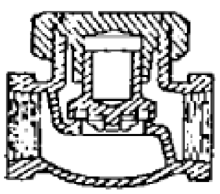
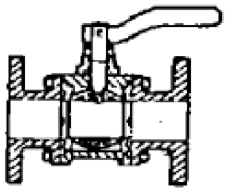
TYPICAL VALVE SELECTION GUIDE

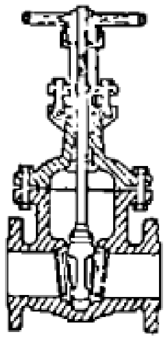
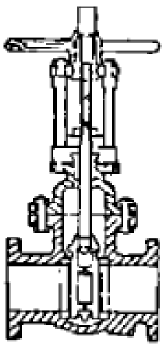
Valve Selection Guide	 Globe Valve	 Combined Stop and Check Valve	 Safety Valve
Size range, mm (in)	DN3 to 80 (1/8 to 3)	DN15 to 600 (1/2 to 24)	DN15 to DN16 (1/2 to 16)
Pressure range, kPa (psi)	to 2,070 (to 300)	to 2,070 (to 300)	to 10,340 (to 1,500)
Temperature range, °C (F)	-40 to 149 (-40 to 300)	-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)	DN3 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)

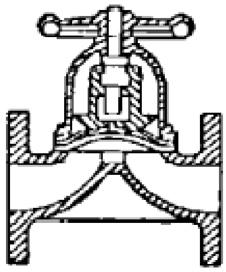
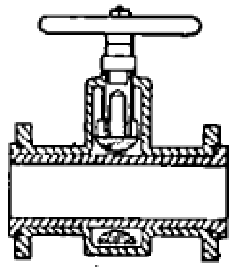
APPENDIX C (continued)

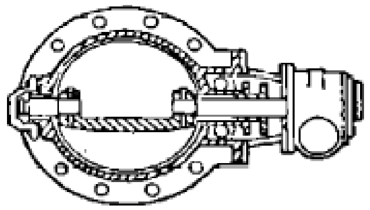
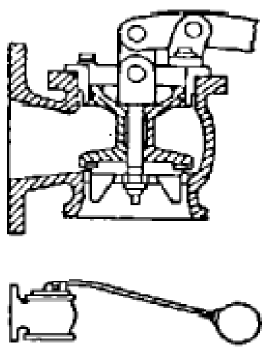
	 Check Valve, Swing Type	 Check Valve, Piston Lift Type	 Ball Plug Valve
Size range, mm (in)	DN6 to DN600 (1/4 to 24)	DN6 to DN 600 (1/4 to 24)	DN15 to DN 600 (1/2 to 24)
Pressure range, kPa (psi)	to 2,070 (to 300)	to 2070 (to 300)	to 2,760 (to 400)
Temperature range °C (F)	-40 to 176 (-40 to 350)	-40 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 2760 (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, mm (in)	DN15 to DN500 (1/2 to 24)	DN6 to DN300 (1/4 to 12)
Pressure range, kPa (psi)	to 5170 (to 750)	to 3450 (to 500)
Temperature range, °C (F)	-45 to 760 (-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, mm (in)	DN25 to DN600 (1 to 24)	DN15 to DN300 (1/2 to 12)
Pressure range kPa (psi)	to 1725 (to 250)	to 3450 (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

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 D1. When reducers are used, the same K_c value may be safely used. To find pressure differential for incipient cavitation use the following formula:

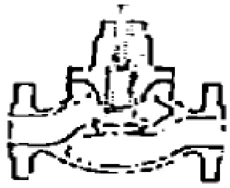
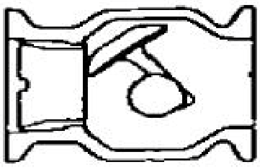
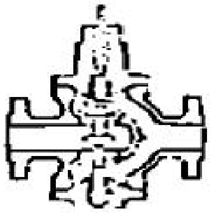
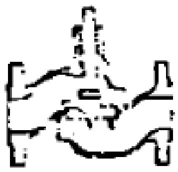
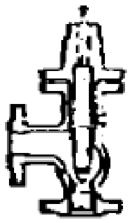
$$\Delta P \text{ (incipient cavitatio)} = K_c \, (P_1 - P_v) \qquad \text{(Eq. 3)}$$

Where:

K_c is coefficient of incipient cavitation (see Table D1);

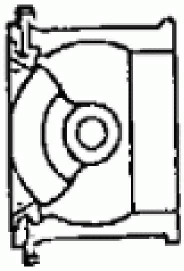
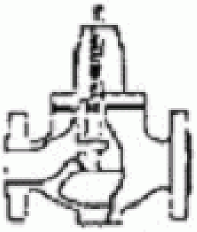
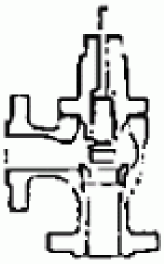
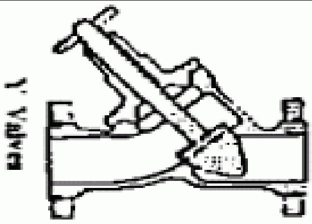
ΔP is actual pressure drop, in bars.

TABLE D.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 D.1 - (continued)

	A	Flow in Either Direction	0.65	0.32	0.60
 Control Ball Valve	A		0.60	0.24	0.55
	A	Close	0.90	0.65	0.86
 20000 Series with Balanced Quick Change Trim	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
	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:

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

with reducers,

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

Where:

R is sub-critical flow capacity correction factor (see Table D2).

D.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.

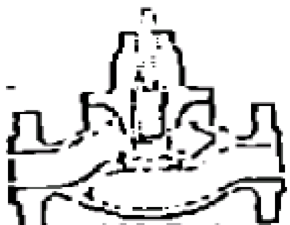
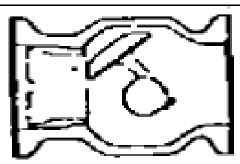
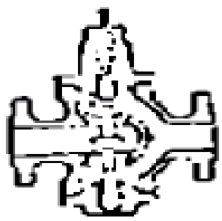
- A change in flow direction can bring a marked improvement. For instance, installing a streamlined angle valve "flow to open" will increase the C_f factor from 0.48 to 0.9, meaning that the allowable ΔP can be more than tripled.

- 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

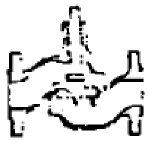
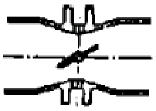
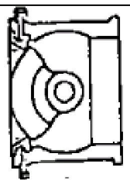
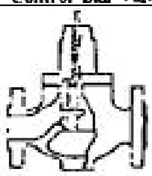
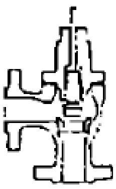
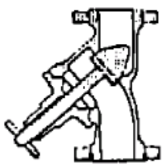
- The C_v of each valve has to be increased by 40% to compensate for the reduced pressure drop. It is important that flow characteristic and valve lift be identical.

TABLE D.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 D.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.

D.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 / d^2 at a specified flow condition.

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

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

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

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

Where:

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

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

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

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

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

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

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

D.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:

$$lim\; \Delta P = P_1 \,.\, F_k \,.\, X_{TP} \quad \textbf{(Eq. 16)}$$

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:

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

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

$$\frac{W_f}{\gamma_f} > \frac{W_g . T_1}{0.0209\, G_g\, (P_1 - \Delta P = F_L^{\,2})} \quad \textbf{(Eq. 18)}$$

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.