KLM Technology Group
#03-12 Block Aronia,
Jalan Sri Perkasa 2
Taman Tampoi Utama
81200 Johor Bahru
Malaysia

PROCESS DESIGN OF VALVES AND CONTROL VALVES

(PROJECT STANDARDS AND SPECIFICATIONS)

TABLE OF CONTENT

SCOPE

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

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.

1. **ISA/ANSI (Instrument Society of America/American National Standards Institute)**

   "Flow Equations for Sizing Control Valves, ANSI/ISA-75.01.01-2002"

SYMBOLS AND ABBREVIATIONS

SYMBOL/ABBREVIATION	DESCRIPTION
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/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.
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, Kc = $\frac{\text{change in flow}}{\text{change in lift}}$
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.
N1, N2 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 (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 XT 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.

UNITS

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

GENERAL

Manual Valves

Manual valves serve three major functions in fluid handling systems:

- stopping and starting flow;
- controlling flow rate;
- diverting flow.

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:

   a. Closing-down valves

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

   b. Slide valves

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

   c. Rotary valves

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

   d. Flex-body valves

      The closure member flexes the valve body.

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

   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.

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.

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. Piston valves

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

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

6. Gate valves

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. 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.

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.

9. Ball valves

Applications

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

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

10. Butterfly valves

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

Applications

Duty:

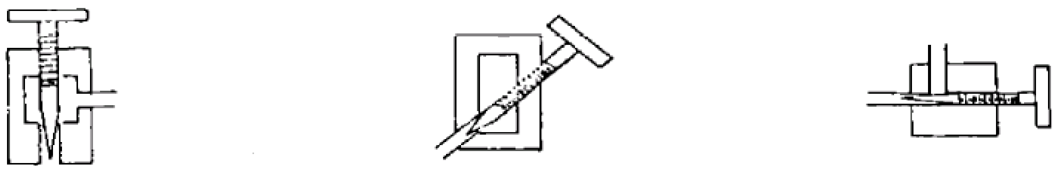
- Stopping and starting flow.
- Controlling flow.

Service:

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

11. Needle valves

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



(a) (b) (c)

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).

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.

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).

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:

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

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.

1. Lift check valves

   Lift check valves may be sub-divided into:
   a. disc check valves;
   b. piston check valves;
   c. ball check valves.

2. Swing check valves

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

3. Tilting-disc check valves

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

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. 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.

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.

7. Ball foot valves

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

8. Membrane foot valves

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

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.

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.

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.

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.

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.

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.

CONTROL VALVE TYPES

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 below.

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:
   - A single-seat construction for minimum leakage in the closed position.
   - 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.

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.

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.

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.

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.

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.

Control Valve Sizing

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.

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.

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

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, Kc, should be employed in place of Cf 2. Values of Kc are listed in Table 1. When reducers are used, the same Kc value may be safely used. To find pressure differential for incipient cavitation use the following formula:

ΔP (invicient cavitation) = $K_c\ (P_1 - P_v)$ Eq. (3)

<u>Where:</u>

Kc is coefficient of incipient cavitation (see Table 1);
ΔP is actual pressure drop, in bars.