KLM Technology Group **Practical Engineering Guidelines for Processing Plant Solutions**	**KLM Technology Group** **www.klmtechgroup.com**	**Page :** 1 of 64 **Rev: 08** **Rev 7 - Jan 2007** **Rev 8 – November 2010**
KLM Technology Group **#03-12 Block Aronia,** **Jalan Sri Perkasa 2** **Taman Tampoi Utama** **81200 Johor Bahru.**	**CONTROL VALVE SELECTION AND SIZING (ENGINEERING DESIGN GUIDELINE)**	**Author:** **Rev 07 - J H Chan** **Rev 03 – Viska Mulyandasari** **Checked by:** **Karl Kolmetz**

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INTRODUCTION

Scope

Hundreds or even thousands control loops are networked together in a process system plant to maintain some important process condition; such as pressure, fluid flow and level, temperatures, etc. During the process, each of these loops receives and internally creates disturbances that might affect process conditions. Hence sensors and transmitters are installed to collect information about process condition changes and their correlation to the desired set point. Furthermore, a final control element is needed to process the information received; deciding what must be done to get back the normal process condition. The most common type of final control element in industrial process control system is control valve; which can be operated pneumatically, hydraulically, or electrically.

Each type of control valve has a different flow characteristic, and its selection largely based on the type of the application process where it's installed into. Some common cases come along with this control valve sizing; an oversized control valve will spend an extra cost and introduce some difficulties in controlling the low flow rates, while an undersized valve might not be able to handle the maximum capacity of the process flow.

There are many available guidelines developed to aid engineers in selecting and sizing the valves, but mostly these guidelines are developed by certain companies and might only be suitable for the application of the valves provided by their own companies. Hence, it is important to get the general understanding about control valve sizing and selection first. Later, whenever changes are needed in a process system, this basic knowledge is still applicable. This guideline is made to provide that fundamental knowledge and a step by step guideline; which is applicable to properly select and size control valves in a correct manner.

Control valve supports the other devices and work together resulting and ideal process condition. Hence, it is crucial to make some considerations before deciding the correct control valve sizing and selection. The selected valve has to be reasonable in cost, require minimum maintenance, use less energy, and be compatible with the control loop. Malfunction in control valve might cause process system does not work properly.

Two basic steps to determine the control valve to be used are control valve selection and control valve sizing. Selection of control valve includes material selection and control valve type selection. Some commonly used materials are briefly mentioned in the general design consideration section. Different types of control valve actuator together with their advantages and disadvantages are also explained as well in this section.

Sizing the valve should not be done just by entering the numbers into formulas. It requires good understanding of theories behind the numbers. Any limiting or adverse conditions; such as flashing, cavitation, and choked flow need to be considered in design calculation. Their relation for valve sizing is explained in this guideline. Besides, two different types of fluid (liquids and gasses) would result in different calculation which is also included in this guideline. The calculation spreadsheet is also attached in the end of this guideline to make an engineer easy to follow the step by step calculation.

INTRODUCTION

General Design Consideration

A common control valves consist of two parts: the control valve body and control valve actuator. Control valve body is the housing which is contained the flowing medium. It provides inlet and outlet connections; and a movable restrictor which varies the fluid flow as it opens and closes the port. The other term, an actuator, is part of control valve which causes the valve stem to move by providing the force it's needed.

Control Valve Body

The body of a control valve will regulate the fluid flow as the position of the valve is changed by the actuator. Therefore, it is very important for the valve body to be able to permit actuator thrust transmission, resist chemical and physical effects from the process, and easily flange up with the adjacent piping connections. All the criteria mentioned above must be fulfilled without any external leaking. Most control valves are designed as a globe valve, but other configurations such as ball and butterfly styles are available based on the review of the engineering application.

The most common control valve body style is single ported as shown in Figure 1, which has wide range of applications. Single ported valves are available in various forms, such as globe, angle, bar stock, forged and split constructions. These valves are generally specified for applications with stringent shutoff requirements. Metal to metal seating surfaces or "soft seating" with nitrile or other elastomeric materials forming the seal, can handle most service requirements.

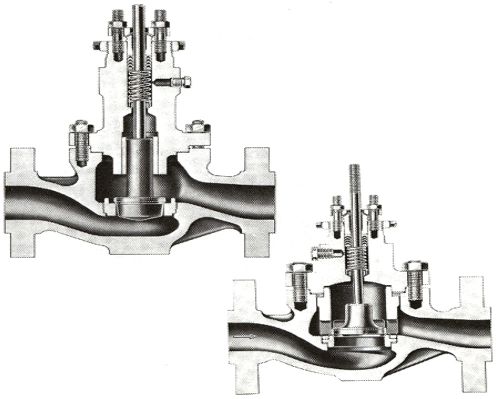

Figure 1: Single port control valve

Since high pressure fluid is normally loading the entire area of the port, the unbalance force created must be considered in selecting actuators for single ported control valve bodies. Single ported valves are know to work well in small sizes but it can often be used in 4 inch to 8 inch sizes with high thrust actuators. Nowadays, many modern single ported valve bodies use cage style construction to retain the seat ring, provide guiding to the valve plug, and means for establishing a particular flow characteristic.

Cage style trim offers advantages in ease of maintenance and flexibility in changing the cages to alter valve flow characteristics. Cage style single seated valve bodies can also be easily modified by change of trim parts to provide reduced capacity flow, noise attenuation, or reduction or elimination of cavitations.

There are other types of valve body design such as double ported valve bodies Figure 2, flanged angle, thee way valve, and many other valves designed for specific service conditions available in the market.

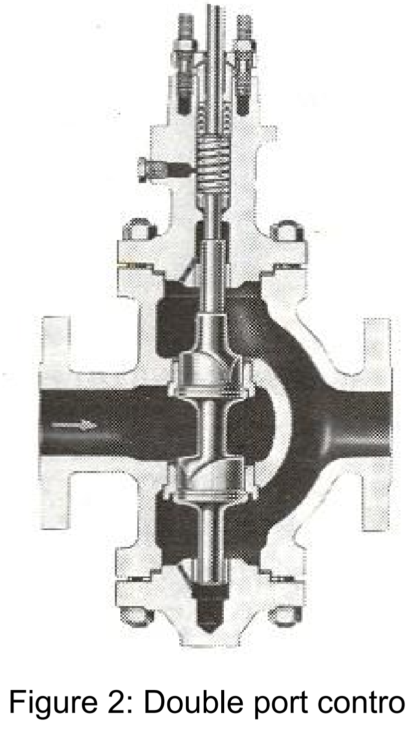

Figure 2: Double port control valve

Control valve bodies may be screwed, flanged, or welded onto the flow line. Screw ends usually are threaded with American Standard female tapered pipe threads. The dimensions, design details, and pressure temperature ratings of flanged ends should be in accordance with American National Standards Institute (ANSI) specifications.

The most common material for control valve body construction is cast iron or carbon steel. Other materials such as chromium-molybdenum, stainless steel, bronze, monel, nickel and many other castable alloys can be used when the control valve is subjected to operate under extreme conditions, e.g. very high or very low temperature, or application under corrosive environment. Valve may also be constructed from solid bar or forged materials when cast valve bodies are not practical, particularly for small valves.

The construction material for control valve trim, i.e. those parts which must retain close machined tolerances for sealing, metering, or moving, must be selected with care. It must generally be more resistant to corrosion, erosion, galling, and distortion than the body material.

Control Valve Actuator

Most common control valve actuators are pneumatically operated but other means of operation such as electric, hydraulic and manual actuators are also available. The operation mechanism of an actuator can be direct acting (Figure 3) or reverse acting (Figure 4). The spring and diaphragm pneumatic actuator is most popular due to its dependability and simplicity of design. Pneumatically operated piston actuators provide integral positioner capability and high stem force output for demanding service conditions. Adaptations of both spring and diaphragm and pneumatic piston actuators are available for direct installation on rotary shaft control valves.(3)

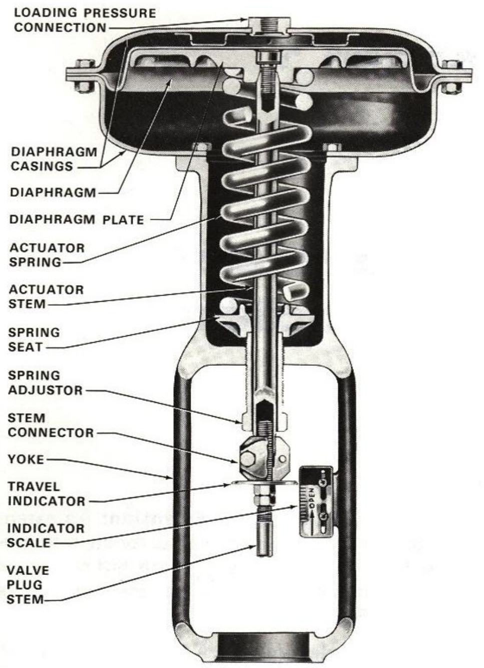

Figure 3: Direct acting diaphragm actuator

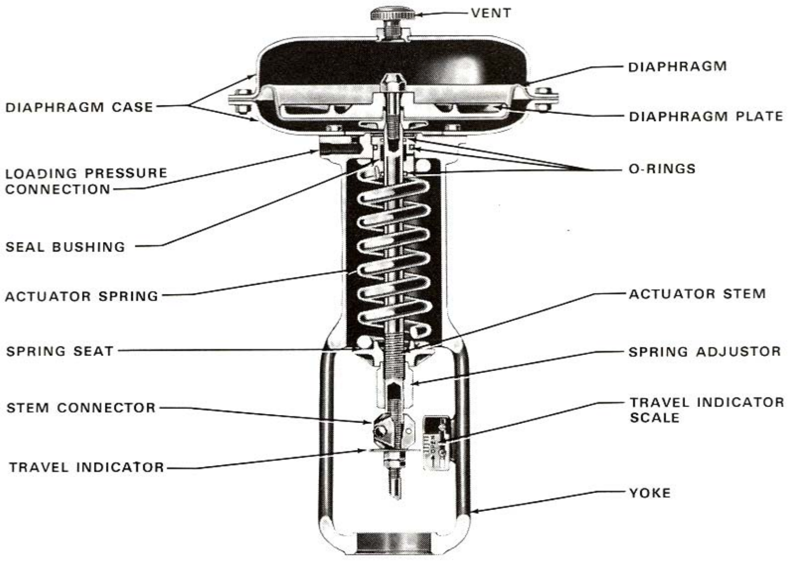

Figure 4: Reverse-acting diaphragm actuator

Electric and electro-hydraulic actuators are more complex and more expensive than pneumatic actuators. This is due to these types of actuators offer advantages where no air supply source is available, where low ambient temperatures could freeze condensed water in pneumatic supply lines, or where unusually large stem forces are needed. A brief summary regarding the design and characteristics of the actuators are give as follows.

I) Diaphragm Actuators

Pneumatically operated, using low-pressure air supply from controller, positioner, or other source.

Various styles include:

- Direct acting - increasing air pressure pushes down diaphragm and extends actuator stem;
- Reverse acing - increasing air pressure pushes up diaphragm and retracts actuator stem;
- Reversible - some small sized actuators can be assembled for either direct or reverse action ;
- Direct acting unit for rotary valves - increasing air pressure pushes down on diaphragm, which may either open or close the valve, depending on orientation of the actuator lever on the valve shaft.

Net output thrust of diaphragm actuators is the difference between diaphragm force and opposing spring force. Molded diaphragms are used to provide linear performance and increased travels. Size is dictated by output thrust required and supply air pressure available. It is simple, dependable, and economical.

II)Piston Actuators

Pneumatically operated using high pressure plant air to 150pisg, often eliminating the need for supply pressure regulator. Furnish maximum thrust output and fast response. It is easily reversible by changing action of the integral valve positioner. Best designs are double acting to give maximum force in both directions. Various accessories can be incorporated to position the actuator piston in the event of supply pressure failure. These include spring return units, pneumatic trip valves and lock up systems.

Also available are hydraulic snubbers, handwheels, and units without yokes, which can be used to operate butterfly valves, louvers, and similar industrial equipment. Other versions for service on rotary shaft control valves include a sliding seal in the lower end of the cylinder. This permits the actuator stem to move laterally as well as up and down without leakage of cylinder pressure. (This feature permits direct connection of the actuator stem to the actuator lever mounted on the rotary valve shaft, thereby eliminating much of the lost motion common to jointed leakage.)

III) Electro Hydraulic Actuators

Requiring only electrical power to the motor and an electrical input signal from the controller. It is ideal for isolated locations where pneumatic supply pressure is not available but where precise control of valve plug position is needed. Units are normally reversible by making minor adjustments and are usually self-contained, including motor, pump, and double-acting hydraulically operated piston within a weatherproof or explosion proof casing.

IV) Manual Actuators

Manual Actuators is useful where automatic control is not required, but where ease of operation and good throttling control is still necessary. It is often used to actuate the bypass valve in a three valve bypass loop around control valves for manual control of the process during maintenance or shutdown of the automatic system. It is available in various sizes for both globe style valves and rotary shaft valves. It is dial indicating devices available for some models to permit accurate repositioning of the valve plug or disc and much less expensive than automatic actuators.

DEFINITIONS

Capacity – Rate of flow through a valve under stated conditions.

Dead Band (2)- Is the range which an input can be varied without initiating observable response. (By referred to the amount of the diaphragm pressure it can be changed without initiating valve stem movement in a diaphragm actuated control valve. It is usually expressed as a percent of diaphragm pressure span.)

Diaphragm Pressure Span – Difference between the high and low values of the diaphragm pressure range. This may be stated as an inherent or installed characteristic.

Double –Acting Actuator – An actuator capable of operating in either direction, extending or retracting the actuator stem as dictated by the fluid pressure acting upon it.

Dynamic Unbalance - The net force produced on the valve plug in any stated open position by the fluid pressure acting upon it.

Effective Area - Part of the diaphragm area which is effective in producing a stem force in a diaphragm actuator. (The effective area of a diaphragm may change as it is stroked, usually being a maximum at the end of the travel range. Molded diaphragms have less change in effective area than flat sheet diaphragms, and are recommended.)

Equal Percentage Flow Characteristic – An inherent flow characteristic which produces equal percentage of changes in the existing flow for equal increments of rated travel. (Increasing sensitivity)

Fail-Closed - A condition wherein the valve port remains closed should the actuating power fail.

Fail-Open - A condition wherein the valve port remains open should the actuating power fail.

Fail-Safe - An actuator which will fully close, fully open, or remain in the fixed position upon loss of power supply. (May require additional auxiliary controls to be connected to the actuator)

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

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Flow Characteristic - Relationship between the flow of fluid through the valve and the percent of rated travel as the latter is varied from 0 – 100 percent. This term should always be designated as either inherent flow characteristic or installed flow characteristic.

High Recovery Valve - A valve design that dissipates relatively little flow stream energy due to streamlined internal contours and minimal flow turbulence. (Straight-through flow valves, such as rotary-shaft ball valves, are typically high-recovery valves.)

Inherent Diaphragm Pressure Range - The high and low values of pressure applied to the diaphragm to produce rated valve plug travel with atmospheric pressure in the valve body. (This range is often referred to as a “bench set” range since it will be the range over which the valve will stroke when it is set on the work bench.)

Inherent Flow Characteristic - Flow characteristic when constant pressure drop is maintained across the valve.

Inherent Rangeablity - Ratio of maximum to minimum flow within which the deviation from the specified inherent flow characteristic does not exceed some stated limit. (A control valve that still does a good job of controlling when increases to 100 times the minimum controllable flow has a rangeablitiy of 100 to 1. Rangeability might also be expressed as the ratio of the maximum to minimum controllable flow coefficients.)

Installed Diaphragm Pressure Range - The high and low values of pressure applied to the diaphragm to produce rated travel with stated conditions in the valve body. (It is because of the forces acting on the valve plug that the inherent diaphragm pressure range can differ from the installed diaphragm pressure range.)

Installed Flow Characteristic - Flow characteristic when pressure drop across the valve varies as dictated by flow and related conditions in the system in which the valve is installed.

Leakage - Quantity of fluid passing through an assembled valve when the valve is in the closed position under stated closure forces, with pressure differential and pressure as specified.

Linear Flow Characteristic - An inherent flow characteristic which can be represented ideally by a straight line on a rectangular plot of flow versus percent rated travel. (Equal increments of travel yield equal increments of flow at a constant pressure drop.)

Low-Recovery Valve - A valve design that dissipates a considerable amount of flow stream energy due to turbulence created by the contours of the flow path. This results into a lower pressure recovery across the vena contracta and hence the valve will have a larger pressure drop. (Conventional globe-style valves generally have low pressure recovery capability.)

Normally Closed Control Valve - A control valve which closes when the diaphragm pressure is reduced to atmospheric.

Normally Open Control Valve - A control valve which opens when the diaphragm pressure is reduced to atmospheric.

Push-Down-to-Close Construction (2)- A globe-style valve construction in which the valve plug is located between the actuator and the seat ring. The valve closes when the extension of the actuator stem moves the valve plug toward the seat ring, finally closing the valve. This mechanism is also called Direct Acting. (For rotary-shaft, linear extension of the actuator stem moves the ball or disc toward the closed position.)

Push-Down-to-Open - A globe type valve construction in which the seat ring is located between the actuator and the valve plug. The valve opens when the extension of the actuator stem moves the valve plug away from the seat ring. This mechanism is also called Reverse Acting. (For rotary-shaft valve, linear extension of the actuator stem moves the ball or disc toward the open position.

Quick Opening Flow Characteristic - An inherent flow characteristic in which there is maximum flow with minimum travel. (Decreasing sensitivity)

Rated C_v - The value of C_v at the rated full-open position.

Rated Travel - Linear movement of the valve plug from the closed position to the rated full-open position. (The rated full-open position refers to the maximum opening recommended by the manufacturer.)

Seat Load - The contact force between the seat and the valve plug. (In practice, the selection of an actuator for a given control valve will be based on how much force is required to overcome static, stem , and dynamic unbalance with an allowance made for seat load.)

Spring Rate - Force change per unit change in length. (In diaphragm control valves, the spring rate is usually stated in pounds force per inch compression.)

Static Unbalance - The net force produced on the valve plug in its closed position by the fluid pressure action upon it.

Stem Unbalance - The net force produced on the valve plug stem in any position by the fluid pressure action upon it.

Valve Flow Coefficient (C_v) - The amount of 60°F water in US gallons per minute that will flow through a valve with a one pound per square inch pressure drop.

Vena Contracta - The point where the pressure and the cross-sectional area of the flow stream is at its minimum, whereas the fluid velocity is at its highest level. (Normally occurs just down stream of the actual physical restriction in a control valve.)

NOMENCLATURE

α	Ratio of valve head differential at max flow to zero flow
C_v	Valve sizing coefficient
d	Nominal valve size
D	Pipe internal diameter
F_d	Valve style modifier, dimensionless
F_k	Ratio of specific heats factor
F_L	Liquid pressure recovery factor
F_{LP}	Combined liquid pressure recovery and piping geometry factor of valve attached to fittings, dimensionless
F_R	Reynolds number factor
S	Liquid specific gravity, dimensionless
S_g	Gas specific gravity, dimensionless
k	Ratio of specific heats, adiabatic index or isentropic exponent, dimensionless
M	Molecular weight, dimensionless
N	Numerical constant from Table 1
N_{Re}	Reynolds number, dimensionless
P1	Upstream pressure (Absolute)
P2	Downstream pressure (Absolute)
P_c	Critical pressure (Absolute)

P_v	Vapor pressure (Absolute) of liquid at inlet temperature
ΔP	Pressure drop across the valve (P_1-P_2)
$\Delta P_{critical}$	Maximum allowable pressure drop across the valve for design purpose
ΔP_s	Pressure drop across the valve for sizing
Q	Volumetric flow rate
Q_{max}	Maximum flow rate (choked flow conditions) at given upstream condition
r_c	Liquid critical pressure ratio factor, dimensionless
T_1	Upstream temperature (Absolute, T or R)
W	Mass flow rate
x	Ratio between pressure drop across the valve and inlet pressure, dimensionless
x_T	Rated pressure drop ratio factor, dimensionless
x_{TP}	Rated pressure drop ratio factor for valves attached to fittings, dimensionless
Y	Expansion factor, dimensionless
ρ	Density
z	Compressibility factor, dimensionless
γ_1	Density at inlet conditions
υ	Kinematic viscosity, centistokes

THEORY

A) Control Valve Flow Characteristic

The flow characteristic of a control valve can be described as the relationship between the flow rate through the valve and valve travel as the valve travel is varied from 0 to 100%. Flow characteristic can be stated as “inherent” flow characteristic or “installed” flow characteristic.

I) Inherent Flow Characteristic

Physical properties of fluid are important for any flow problem and the accuracy of the values it affect the flow of fluids. If was the input of the engineering design of the piping and it will determine the pipe material selection and sizing.

The inherent flow characteristics are determined by the valve orifice and the plug geometry. It refers to the flow characteristic when there is a constant pressure drop across the control valve (The ∆P is normally 6.9 kPa or 1 psi).

Typically there are three types of inherent flow characteristic, namely, linear, quick opening and equal percentage. These flow characteristic can be represented graphically as illustrated in Figure 5(3). The characteristics can be classified based on the sensitivity of the rate of change of flow through the valve to the valve stem position.

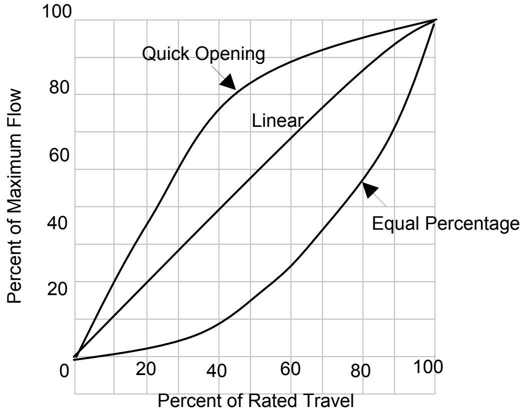

Figure 5: Flow Characteristic Curves

Decreasing sensitivity

$$\left.\frac{dQ}{dL}\right|_{Q=0} > C_v > \left.\frac{dQ}{dL}\right|_{Q=\max}$$

Linear (constant) sensitivity

$$\frac{dQ}{dL} = C_v$$

Increasing sensitivity

$$\left.\frac{dQ}{dL}\right|_{Q=0} < C_v < \left.\frac{dQ}{dL}\right|_{Q=\max}$$

Where L is the percentage of maximum valve stem travel, Q is a percentage of maximum flow, and C_v is the valve flow coefficient.

II) Linear Flow Characteristic

Linear flow characteristic shows that the flow rate is directly proportional to the valve travel. For instance, at 50% of rated travel, flow rate is 50% of maximum flow; at 80% of rated travel, the flow rate is 80% of maximum flow and so on. The sensitivity of a control valve with linear flow characteristic is always constant. This proportional relationship produces a characteristic with a constant slope so that with constant pressure drop, the valve gain will be the same at all flows.

Valve gain is the ratio of an incremental change in flow rate to an incremental change in valve plug position. Gain is a function of valve size and configuration, system operating conditions, and valve plug characteristic.

Control valves with linear flow characteristic are commonly specified for liquid level control and for certain flow control applications requiring constant gain.

III) Equal Percentage Flow Characteristic

In equal percentage flow characteristic, equal increments of valve travel produce equal percentage changes in the existing flow. The change in flow rate is always proportional to the flow rate just before the change in valve plug, disc, or ball position is made. The change in flow rate observed with respect to travel will be relatively small when the valve plug is near its seat and relatively high when the valve plug is nearly wide open. (Increasing sensitivity)

Therefore, a valve with an inherent equal percentage flow characteristic provides precise throtting control through the lower portion of the travel range and rapidly increasing capacity as the valve plug nears the wide open position. Valves with equal percentage flow characteristics are used on pressure control applications, on applications where a large percentage of the pressure drop is normally absorbed by the system itself with only a relatively small percentage available at the control valve, and on applications where highly varying pressure drop conditions can be expected.

IV) Quick Opening Flow Characteristic

A valve with quick opening flow characteristic provides a maximum change in flow rate at low travels and small changes when the valve plug is near maximum. (Decreasing sensitivity) The curve is basically linear through the first 40 percent of valve plug travel, and then flattens out noticeably to indicate little increase in flow rate as travel approaches the wide open position. Control valves with quick opening flow characteristics are often used for on/off applications where significant flow rate must be established quickly as the valve begins to open. Consequently they are often used in relief valve applications.

Quick opening valves can also be selected for many of the same applications for which linear flow characteristics are recommended, since the quick opening characteristic is linear up to about 70 percent of maximum flow rate. Linearly decreases sharply after flow area generated by valve plug travel equals the flow area of the port.

Besides sensitivity, Rangeability (R) and Turndown (T) are two important control valve properties. They are defined as:

$$\boldsymbol{R} = \frac{\text{max controllable flow}}{\text{min controllable flow}}$$

$$\boldsymbol{T} = \frac{\text{normal max flow}}{\text{min controllable flow}}$$

Generally, control valves are sized so that T ≈ 0.7R, where the value of R is ranged from 20 to 50 depending on the type of control valve.

The use of rangeability and turndown may be indicated by a specific control valve application. For example, if the design of a tank level control system calls for a 25:1 change in inlet flow rate to maintain the level because of a changing outlet flow rate, then the indicated control valve turndown ratio is at least 25 and the rangeablitiy ratio at least 35. Typically, increasing sensitivity type valves have higher rangeability ratios.

V) Installed Flow Characteristic

Installed flow characteristic refers to the flow characteristic of the control valve when the valve is installed and subjected to variable pressure drop, flow and other changes of the system. When the control valves are combined with other fluid handling equipment in processing systems, the composite flow rate characteristics differ from the characteristics of any single component in the system. Flow rates through the valve are no longer determined solely by the geometry of the valve body and plug.
The effect of resistances resulting from pipelines, orifices, or other equipment in series with the control valve and the variation of available head with flow rate affect the flow versus stem position relationship. This effect may be described for a liner valve by the equation:

$$\boldsymbol{Q} = \frac{\boldsymbol{L}}{\left[\alpha + (1-\alpha)\boldsymbol{L}^2\right]^{1/2}}$$

and for increasing sensitivity type (parabolic or equal percentage):

$$\boldsymbol{Q} = \frac{\boldsymbol{L}^2}{\left[\alpha + (1+\alpha)\boldsymbol{L}^4\right]^{1/2}}$$

where Q and L are the fractions of maximum flow and stem travel respectively; and α is defined as:

$$\alpha = \frac{\text{valve head differential at maxflow}}{\text{valve head differential at zero flow}}$$

Installed flow characteristic for linear control valve installed in flow systems having different values of α are shown in Figure 6 (4). Decreasing values for α indicates increasing restrictions external to the valve. For α equal to 1, the installed flow characteristic is identical to the inherent flow characteristic.

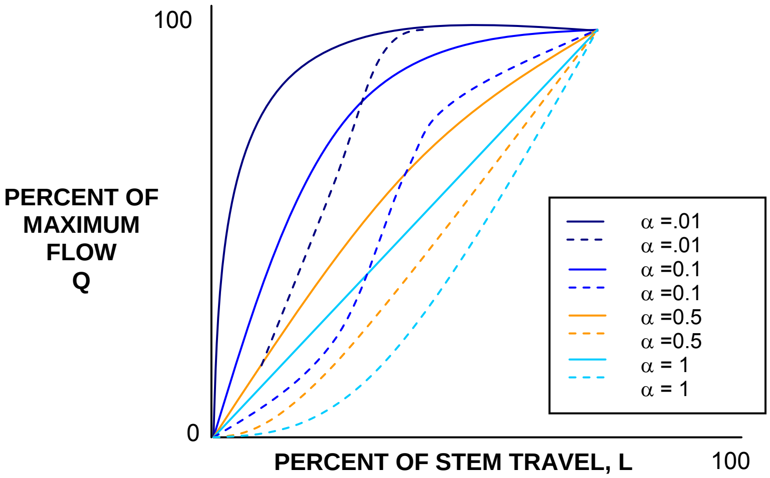

Figure 6: Installed flow characteristic for linear control valve installed in flow systems having different values of α

B) Control Valve Sizing

Being the most popular final control element which determines the value of manipulated variable, the knowledge to be able to size a control valve correctly is crucial. A control valve cannot be simply sized without knowing the theory behind the selection.

Simply sizing a control valve may create an impractical situation in terms of initial investment and adequacy of control. A valve too small will not be able to provide the required flow and an oversized valve will be unnecessarily expensive and may create instability problems as it attempts to control the flow at very low increments of valve travel.

A control valve may be used to regulate the flow of liquid stream, vapor stream or a stream with liquid and vapor mixture. The following section will discuss the proper method of sizing a control valve on different applications.

I)Sizing For Liquid Services

Using the principal of conservation of energy, Daniel Bernoulli discovered that as a liquid flows through an orifice, the square of the fluid velocity is directly proportional to the pressure differential across the orifice and inversely proportional to the specific gravity of the fluid.

Based on the Bernoulli Equation, we can conclude that with greater pressure differential across two points, the velocity of fluid which flow across these two points will be greater, and with greater density, the flow will have lower velocity.

By taking into account units of measurement, the proportionality relationship previously mentioned, energy losses due to friction and turbulence, and varying discharge coefficients for various types of orifices (or valve bodies), a basic liquid sizing equation can be created as follows:

$$Q = C_v \sqrt{\frac{\Delta P}{S}} \qquad \text{Eq (1)}$$

Where,

Q = Flow of fluid in gallons per minute
C_v = Valve sizing coefficient determined experimentally for each style and size of valve, using water at standard conditions as test fluid
ΔP = Pressure differential across the valve in psi
S = Specific gravity of fluid. (Water at 15.56^{o}C = 1.00)

Thus, the C_v can be described as the amount of 60°F (15.56°C) water in U.S. gallon that will flow through the valve in one minute with a pressure drop of 1 psi across the valve. The value of C_v varies with both size and style of valve, but provides an index for comparing liquid capacities of different valves under a standard set of conditions.

The Fluid Control Institute (FCI) has developed a standard test piping arrangement as shown in Figure 7 to establish uniform and standardized measurement of liquid flow capacity coefficient C_v among valve manufacturers. By utilizing such piping arrangements, most valve manufacturers develop and publish C_v information for their respective products, making it relatively easy to compare capacities of competitive products.

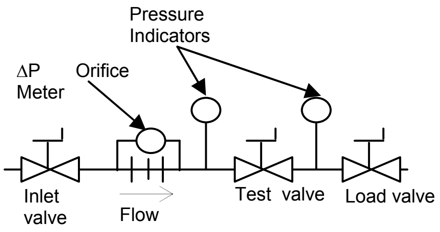

Figure 7: Standard FCI Test Piping for C_v Measurement

In order to calculate the expected C_v for a valve controlling water or liquids that behave like water, the basic liquid sizing equation can be rewritten as:

$$C_v = \frac{Q}{N_1}\sqrt{\frac{S}{\Delta P}}$$ for volumetric flow or, Eq(2a)

$$C_v = \frac{W}{N_6\sqrt{\Delta P \rho}}$$ for mass flow rate Eq (2b)

The N_1 and N_6 shown in the equation above are numerical constants for applications under different unit of measures. All the values of Ns are shown in Table 1. As mentioned, this general form of equation is only good in providing sizing coefficient for water or liquid which behaves similar to water. For other liquids, or valves which is attached to fittings, additional correction factors needs to be introduced. The basic equation 2a and 2b can provide a rough number of C_v that will be used in further calculations of a more specific C_v.

A more specific form of control valve sizing equation which can be applied to all liquids is given as:

$$C_v = \frac{Q}{N_1 F_P F_R}\sqrt{\frac{S}{\Delta P}} \qquad \text{for volumetric flow} \qquad \text{Eq (3a)}$$

$$C_v = \frac{W}{N_6 F_P F_R \sqrt{\Delta P \rho}} \qquad \text{for mass flow} \qquad \text{Eq (3b)}$$

Where,
F_P = Valve/Fitting Geometry correction factor, dimensionless
F_R = Reynolds Number Factor, dimensionless

The Valve/Fitting Geometry correction factor, F_P is a dimensionless factor accounting for difference in piping due to fittings for piping changes at inlet and outlet; values range from 0.80 to 0.98 and are typically about 0.95. F_p value will be 1.0 and drop out of the valve sizing equation if the control valve is not attached to any fittings such as reducers or elbows.

The Reynolds Number Factor, F_R is another dimensionless factor accounting for viscosity effects for liquids. F_R will have a value of 1.0 for fluids with Reynolds numbers greater than $4\text{x}10^4$. The methods of calculating these factors are shown in the step by step guidelines in the following section.