Practical Control Valve Sizing, Selection and Maintenance

# THIS BOOK WAS DEVELOPED BY IDC TECHNOLOGIES

## WHO ARE WE?

IDC Technologies is internationally acknowledged as the premier provider of practical, technical training for engineers and technicians.

We specialize in the fields of electrical systems, industrial data communications, telecommunications, automation and control, mechanical engineering, chemical and civil engineering, and are continually adding to our portfolio of over 100 different workshops. Our instructors are highly respected in their fields of expertise and in the last ten years have trained over 200,000 engineers, scientists and technicians.

With offices conveniently located worldwide, IDC Technologies has an enthusiastic team of professional engineers, technicians and support staff who are committed to providing the highest level of training and consultancy.

## TECHNICAL WORKSHOPS

### TRAINING THAT WORKS

We deliver engineering and technology training that will maximize your business goals. In today's competitive environment, you require training that will help you and your organization to achieve its goals and produce a large return on investment. With our 'training that works' objective you and your organization will:

- Get job-related skills that you need to achieve your business goals
- Improve the operation and design of your equipment and plant
- Improve your troubleshooting abilities
- Sharpen your competitive edge
- Boost morale and retain valuable staff
- Save time and money

### EXPERT INSTRUCTORS

We search the world for good quality instructors who have three outstanding attributes:

1. Expert knowledge and experience – of the course topic
2. Superb training abilities – to ensure the know-how is transferred effectively and quickly to you in a practical, hands-on way
3. Listening skills – they listen carefully to the needs of the participants and want to ensure that you benefit from the experience.

Each and every instructor is evaluated by the delegates and we assess the presentation after every class to ensure that the instructor stays on track in presenting outstanding courses.

### HANDS-ON APPROACH TO TRAINING

All IDC Technologies workshops include practical, hands-on sessions where the delegates are given the opportunity to apply in practice the theory they have learnt.

### REFERENCE MATERIALS

A fully illustrated workshop book with hundreds of pages of tables, charts, figures and handy hints, plus considerable reference material is provided FREE of charge to each delegate.

### ACCREDITATION AND CONTINUING EDUCATION

Satisfactory completion of all IDC workshops satisfies the requirements of the International Association for Continuing Education and Training for the award of 1.4 Continuing Education Units.

IDC workshops also satisfy criteria for Continuing Professional Development according to the requirements of the Institution of Electrical Engineers and Institution of Measurement and Control in the UK, Institution of Engineers in Australia, Institution of Engineers New Zealand, and others.

**CERTIFICATE OF ATTENDANCE**

Each delegate receives a Certificate of Attendance documenting their experience.

**100% MONEY BACK GUARANTEE**

IDC Technologies' engineers have put considerable time and experience into ensuring that you gain maximum value from each workshop. If by lunchtime on the first day you decide that the workshop is not appropriate for your requirements, please let us know so that we can arrange a 100% refund of your fee.

**ONSITE WORKSHOPS**

All IDC Technologies Training Workshops are available on an on-site basis, presented at the venue of your choice, saving delegates travel time and expenses, thus providing your company with even greater savings.

**OFFICE LOCATIONS**

AUSTRALIA • CANADA • INDIA • IRELAND • MALAYSIA • NEW ZEALAND • POLAND • SINGAPORE • SOUTH AFRICA • UNITED KINGDOM • UNITED STATES

**idc@idc-online.com** **www.idc-online.com**

Technology Training that Works

**Presents**

# Practical Control Valve Sizing, Selection and Maintenance

*Revision 6.1*

*Dave Macdonald BSc(Eng)*

*Website: www.idc-online.com*
*E-mail: idc@idc-online.com*

IDC Technologies Pty Ltd
PO Box 1093, West Perth, Western Australia 6872
Offices in Australia, New Zealand, Singapore, United Kingdom, Ireland, Malaysia, Poland, United States of America, Canada, South Africa and India



First published 2008



ISBN: 978-1-921007-30-9

## Disclaimer

Whilst all reasonable care has been taken to ensure that the descriptions, opinions, programs, listings, software and diagrams are accurate and workable, IDC Technologies do not accept any legal responsibility or liability to any person, organization or other entity for any direct loss, consequential loss or damage, however caused, that may be suffered as a result of the use of this publication or the associated workshop and software.

In case of any uncertainty, we recommend that you contact IDC Technologies for clarification or assistance.

## Trademarks

All terms used in this publication that are believed to be registered trademarks or trademarks are listed below:

## Acknowledgements

IDC Technologies expresses its sincere thanks to all those engineers and technicians on our training workshops who freely made available their expertise in preparing this manual.

# Contents

# 1

# Introduction to Control Valves and Fluid Flow

*Control valves are the essential final elements used to control fluid flow and pressure conditions in a vast range of industrial processes. The control valve industry is itself a vast enterprise whilst the influence of control valves on the performance of high value processes worldwide is very much larger. Hence it is a major responsibility on control and instrumentation engineers to deliver the best possible control valve choices for every application they encounter.*

*The task of specifying and selecting the appropriate control valve for any given application requires an understanding of the principles of:*

- *How fluid flow and pressure conditions determine what happens inside a control valve.*
- *How control valves act to modify pressure and flow conditions in a process.*
- *What types of valves are commonly available*
- *How to determine the size and capacity requirements of a control valve for any given application*
- *How actuators and positioners drive the control valve*
- *How the type of valve influences the costs*

*Selecting the right valve for the job requires that the engineer should be able to:*

- *Ensure that the process requirements are properly defined*
- *Calculate the required flow capacity over the operating range*
- *Determine any limiting or adverse conditions such as cavitation and noise and know how to deal with these*
- *Know how to select the valve that will satisfy the constraints of price and maintainability whilst providing good performance in the control of the process.*

*This manual is intended to provide an understanding of the key issues involved in the selection of control valves for typical process industry applications. The training material should provide a general background in the subject but it assumes that participants have a basic knowledge of process industry equipment and terminologies.*

*To begin the training manual this chapter looks at the fundamental principles involved in the control of fluid flow and it describes how the adjustment of flow capacity is typically used to control pressure, flow, level and temperature in processes. We then outline the main performance requirements that are expected from a control valve as an aid to selection. The following chapters will then provide training guidance in each of the key subjects.*

## Learning objectives

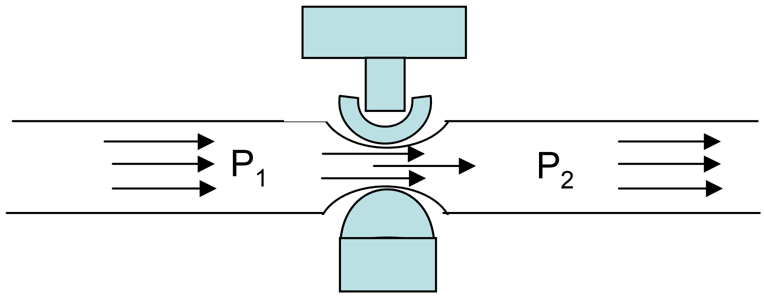
- Purpose of a control valve and how it works to regulate flow or pressure
- What happens inside the control valve
- Examples of process applications of control valves
- General performance requirements of control valves
- Training needs for sizing and selection

## 1.1 Purpose of a control valve

The purpose of a control valve is to provide the means of implementing or actuation of a control strategy for a given process operation. Control valves are normally regarded as valves that provide a continuously variable flow area for the purpose of regulating or adjusting the steady state running conditions of a process. However the subject can be extended to include the specification and selection of on-off control valves such as used for batch control processes or for sequentially operated processes such as mixing or routing of fluids. Many instrument engineers also asked to be responsible for the specification of pressure relief valves. These topics will also be considered briefly in this text but the main emphasis in this training will be on the selection and sizing of valves for continuously variable processes.

### 1.1.1 Definition of a control valve

A control valve is defined as a mechanical device that fits in a pipeline creating an externally adjustable variable restriction.




**Pipe line flow depends on effective area x square root (P1 –P2)**

**Figure 1.1**
*Control valve adjusts the effective area of flow in the pipe*

This throttles the flow for any given pressure drop or it raises the pressure drop for any given flow. Typical process applications can be made based on this ability to change pressure drop or flow capacity as will be seen in the next section. However, we must firstly understand how a typical control valve actually creates a pressure drop by looking at the fundamentals of flow in a pipeline and through a restricted area.

### 1.1.2 Turbulent and laminar flow in pipes

When a fluid is moving slowly through a pipe or if the fluid is very viscous, the individual particles of the fluid effectively travel in layers at different speeds and the particles slide over each other, creating a laminar flow pattern in a pipeline. As can be seen in Figure 1.2 the flow velocity profile is sharply curved and much higher speeds at seen at the centre of a pipeline where there is no drag effect from contact with the wall of the pipe.

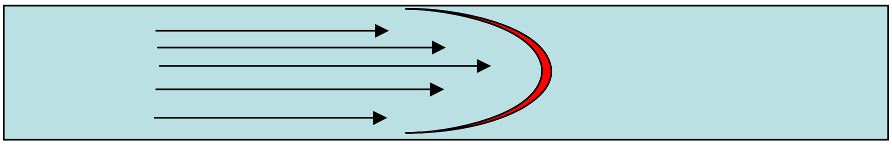


**Figure 1.2**
*Laminar flow in a pipeline has a low energy-loss rate*

At higher velocities high shear forces disturb the fluid flow pattern and the fluid particles start to move in erratic paths, creating turbulent flow. This results in a much flatter flow velocity profile as can be seen in Figure 1.3. The velocity gradient is small across the centre of the pipe but is high at close proximity to the pipe wall.

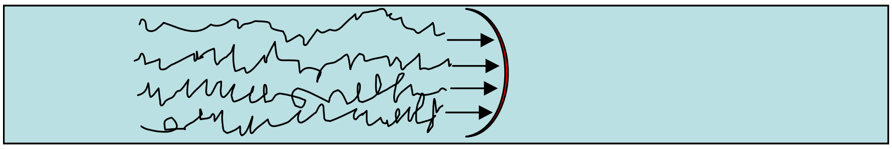


**Figure 1.3**
*Turbulent flow in a pipeline has a high energy-loss rate*

The transition from laminar flow to turbulent flow can be predicted by the parameter known as the Reynolds number (Re), which is given by the equation:

$$Re = V.\ D/\nu$$

Where: V = flow velocity, d= nominal diameter, $\nu$ = *kinematic viscosity*

In a straight pipe the critical values for transition form laminar to turbulent flow is approximately 3000. When the flow is turbulent, part of the flow energy in the moving fluid is used to create eddies which dissipate the energy as frictional heat and noise, leading to pressure losses in the fluid.

### 1.1.3 Formation of vortices

A more drastic change in velocity profile with greater energy losses arises when a fluid passes through a restrictor such as an orifice plate or a control valve opening. Downstream of a restriction there is an abrupt increase in flow area where some of the fluid will be moving relatively slowly. Into this there flows a high velocity jet from the orifice or valve, which will cause strong vortices causing pressure losses and often creating noise if the fluid is a liquid since it is incompressible and cannot absorb the forces.

### 1.1.4 Flow separation

Just after the point where a large increase in flow area occurs the unbalanced forces in the flowing fluid can be sufficiently high to cause the fluid close to the surface of the restricting object to lose all forward motion and even start to flow backwards. This is called the flow separation point and it causes substantial energy losses at the exit of a control valve port. It is these energy losses along with the vortices that contribute much of pressure difference created by a control valve in practice. Figures 1.4 and 1.5 illustrate flow separation and vortices in butterfly and globe valve configurations.

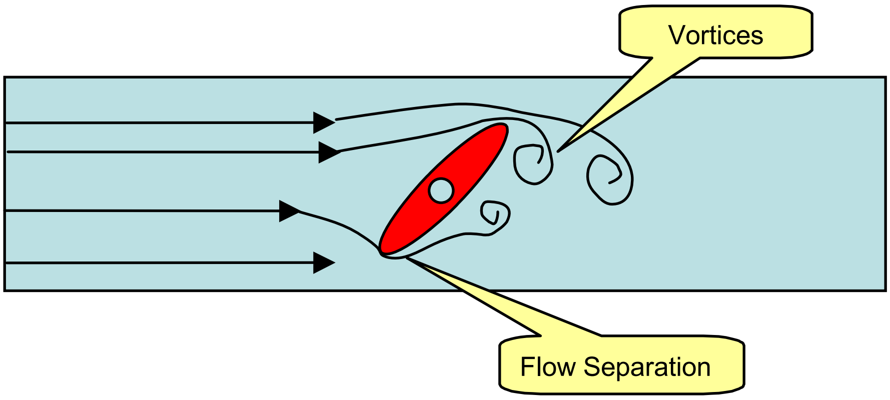



**Figure 1.4**
*Flow separation effects in a butterfly valve.*

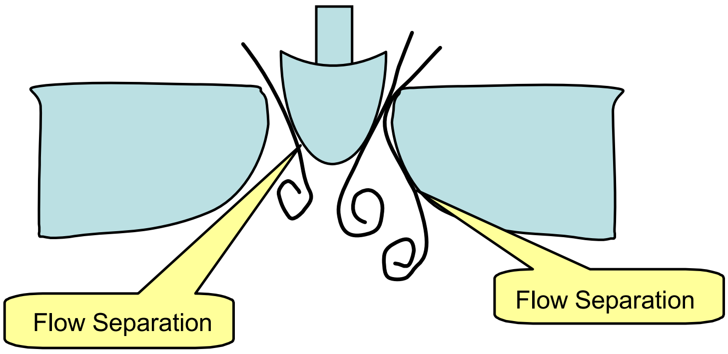



**Figure 1.5**
*Flow separation effects in a single seated globe valve.*

### 1.1.5 Flow pulsation

One of the potential problems caused by vortex formation as described by Neles Jamesbury is that if large vortices are formed they can cause excessive pressure losses and disturb the valve capacity. Hence special measures have to be taken in high performance valves to reduce the size of vortices. These involve flow path modifications to shape the flow paths and create “micro vortices”. Understanding fluid dynamics and separation effects contributes to control valve design in high performance applications particularly in high velocity applications when noise and vibration effects become critical.

### 1.1.6 Principles of valve throttling processes

The following notes are applicable to incompressible fluid flow as applicable to liquids but these can be extended to compressible flow of gases if expansion effects are taken into account. These notes are intended to provide a basic understanding of what happens inside a control valve and should serve as a foundation for understanding the valve sizing procedures we are going to study in later chapters.

A control valve modifies the fluid flow rate in a process pipeline by providing a means to change the effective cross sectional area at the valve. This in turn forces the fluid to increase its velocity as passes through the restriction. Even though it slows down again after leaving the valve, some of the energy in the fluid is dissipated through flow separation effects and frictional losses, leaving a reduced pressure in the fluid downstream of the valve.

To display the general behaviour of flow through a control valve the valve is simplified to an orifice in a pipeline as shown in Figure 1.6.

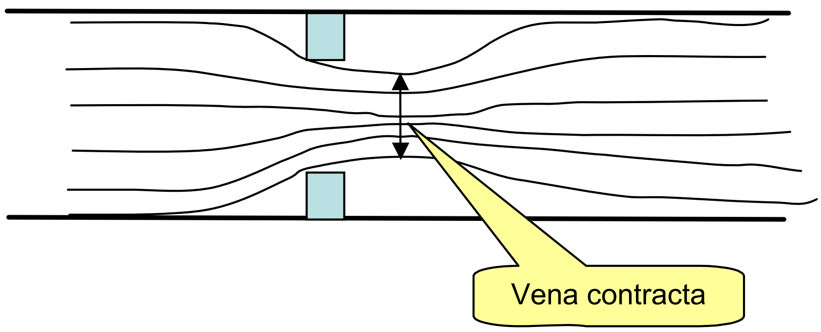



**Figure 1.6**
*Flow through an orifice showing vena contracta point of minimum area*

Figure 1.6 shows the change in the cross-section area of the actual flow when the flow goes through a control valve. In a control valve the flow is forced through the control valve orifice, or a series of orifices, by the pressure difference across the valve. The actual flow area is smallest at a point called vena contracta (Avc), the location of which is typically slightly downstream of the valve orifice, but can be extended even into the downstream piping, depending on pressure conditions across the valve, and on valve type and size.

It is important to understand how the pressure conditions change in the fluid as it passes through the restriction and the vena contracta and then how the pressure partially recovers as the fluid enters the downstream pipe area. The first point to note is that the velocity of the fluid must increase as the flow area decreases. This is given by the continuity of flow equation:

$$\mathbf{V_1 . A_1 . = \ V_2 . A_2}$$

Where: V = mean velocity and A = flow area.
Subscript 1 refers to upstream conditions
Subscript 2 refer to down stream conditions
Hence we would expect to see that maximum velocity occurs at the vena contracta point.

Now to consider the pressure conditions we apply Bernoulli's equation, which demonstrates the balance between dynamic, static and hydrostatic pressure. Energy must be balanced each side of the flow restriction so that:

$$\mathbf{(½ \times \rho_1 \times V_1^2) + (\rho_1 \times g \times H_1) + P_1 = (½ \times \rho_2 \times V_2^2) + (\rho_2 \times g \times H_2) + P_2 + \Delta P}$$

Where:

| | | |
|---|---|---|
| P | = | static pressure |
| ρ | = | density |
| Δ P | = | pressure loss (due to losses through the restrictor) |
| H | = | relative height |
| g | = | acceleration of gravity |

The hydrostatic pressure is due to the relative height of fluid above the pipeline level (i.e. liquid head) and is generally constant for a control valve so we can simplify the equation by making $H_1 = H_2$.

The dynamic pressure component is ($½ \times \rho_1 \times V_1^2$) at the entry velocity, rising to ($½ \times \rho_2 \times V_2^2$) as the fluid speed increases through the restriction. Due to the reduction in flow area a significant increase in flow velocity has to occur to give equal amounts of flow through the valve inlet area (Ain) and vena contracta area (Avc). The energy for this velocity change is taken from the valve inlet pressure, which gives a typical pressure profile inside the valve. The velocity and the dynamic pressure fall again as the velocity decreases after the vena contracta.

The static pressure P experiences the opposite effect and falls as velocity increases and then recovers partially as velocity slows again after the vena contracta. This effect is called pressure recovery but it can be seen that there is only a partial recovery due the pressure loss component, Δ P.

The interchange of static and dynamic pressure can be seen clearly in Figure 1.7 where the pressure profile is shown as the fluid passes through the restriction and the vena contracta. The sum of the two pressures gives the total pressure energy in the system and shows the pressure loss developing as the vena contracta point is reached.

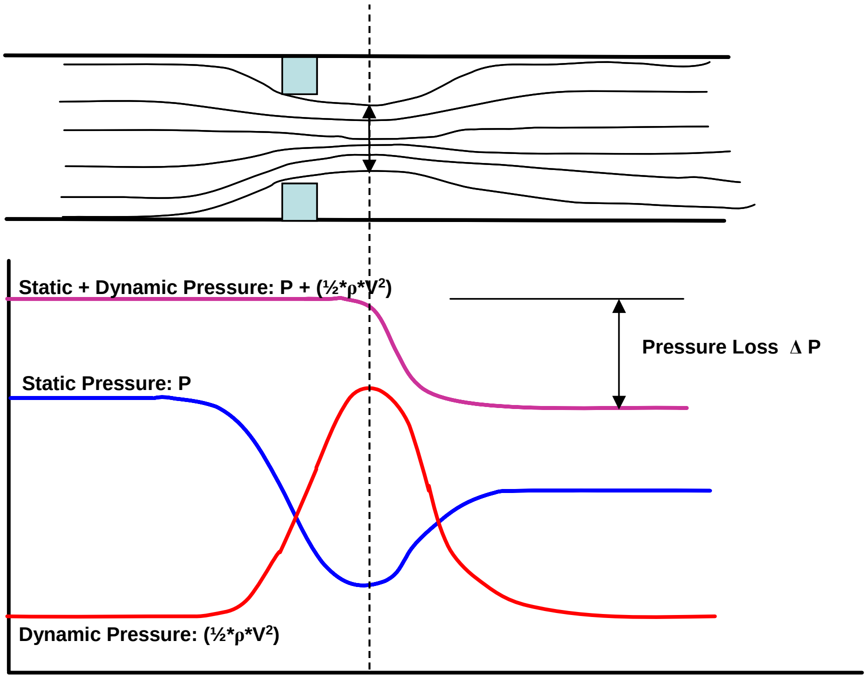



**Figure 1.7**
*Static and dynamic pressure profiles showing pressure loss*

The pressure recovery after the Vena Contracta point depends on the valve style, and is represented by valve pressure recovery factor (F L) as given in equation below. The closer the valve pressure recovery factor (F L) is to 1.0, the lower the pressure recovery.

$$F_L = \sqrt{(P1-P2)/(P1-Pvc)}$$

The dynamic pressure profile corresponds to a flow velocity profile so that we can also see what happens to the fluid speed as it travels through a control valve. Figure 1.8 shows a simplified pressure and velocity profile as a fluid passes through a basic single seat control valve. It can be seen that the fluid reaches a high velocity at the vena contracta.

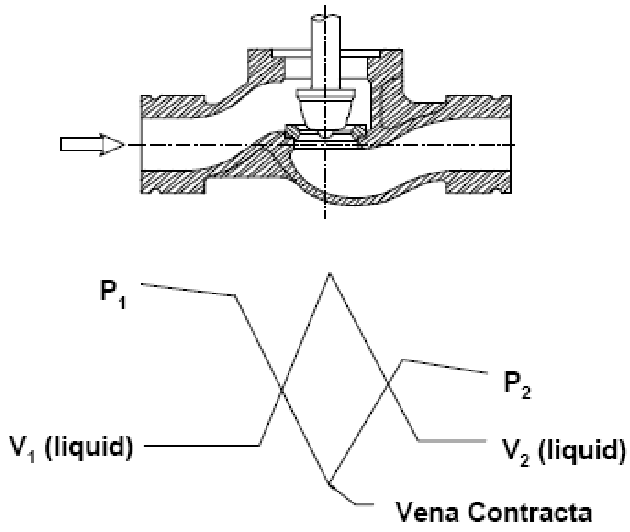



**Figure 1.8**
*Static pressure and velocity profiles across a single seat control valve*

We shall see later how the pressure profile is critical to the performance of the control valve because the static pressure determines the point at which a liquid turns to vapor. Flashing will occur if the pressure falls below the vapor pressure value and cavitation will result if condensing occurs when the pressure rises again.

Figure 1.8 therefore represents the typical velocity and pressure profiles that we can expect through a control valve. Now we need to outline the basic flow versus pressure relationship for the control valve that arises from these characteristics.

### 1.1.7 Pressure to flow relationships

For sizing a control valve we are interested in knowing how much flow we can get through the valve for any given opening of the valve and for any given pressure differential. Under normal low flow conditions and provided no limiting factors are involved, the flow through the control valve as derived from the Bernoulli equation is given by:

$$\mathbf{Q = Valve\ coefficient\ x\ \sqrt{(\Delta P / \rho)}}$$

Where Q = the volumetric flow in the pipeline (= Area of pipe x mean velocity)
$\Delta$ P is the overall pressure drop across the valve and $\rho$ is the fluid density

This relationship is simple if the liquid or gas conditions remain within their normal range without a change of state or if the velocity of the gas does not reach a limiting value. Hence for a simple liquid flow application the effective area for any control valve can be found by modeling and experiments and it is then defined as the flow capacity coefficient Cv.

Hence we can show that the flow versus square root of pressure drop relationship for any valve is given in the form shown in Figure 1.9 as a straight line with slope Cv.

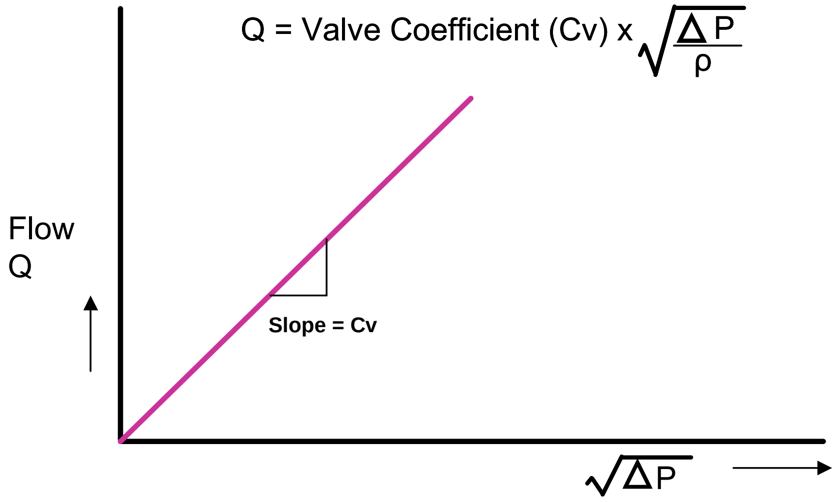



**Figure 1.9**
*Basic flow versus pressure drop relationship for a control valve (sub-critical flow)*

### 1.1.8 Definition of the valve coefficient Cv

The flow coefficient, Cv, or its metric equivalent, Kv, has been adopted universally as a comparative value for measuring the capacity of control valves. Cv is defined as the number of US gallons/minute at 60°F that will flow through a control valve at a specified opening when a pressure differential of 1 pound per square inch is applied.

The metric equivalent of Cv is Kv, which is defined as the amount of water that will flow in $m^3$/hr with a 1 bar pressure drop. Converting between the two coefficients is simply based on the relationship:

$$Cv = 1.16\ Kv$$

In its simplest form for a liquid the flow rate provided by any particular Cv is given by the basic sizing equation:

$$\mathbf{Q = Cv\sqrt{(\Delta P / SG)}}$$

Where SG is the specific gravity of the fluid referenced to water at 60°F and Q is the flow in US Gallons per minute.

Hence a valve with a specified opening giving Cv =1 will pass 1 US gallon of water (at 60°F) per minute if 1 psi pressure difference exists between the upstream and downstream points each side of the valve. For the same pressure conditions if we increase the opening of the valve to create Cv =10 it will pass 10 US gallons/minute provide the pressure difference across the valve remains at 1 psi.
In metric terms:

$$\mathbf{Q = (1/1.16).\ Cv \sqrt{(\Delta P/SG)}}$$

Where Q is in m3/hr and Δ P is in bars and SG =1 for water at 15°C.

Hence the same a valve with a specified opening giving Cv =1 will pass 0.862 $m^3$/hr of water (at 15°C) if 1 bar pressure difference exists between the upstream and downstream points each side of the valve.

These simplified equations allow us to see the principles of valve sizing. It should be clear that if we know the pressure conditions and the SG of the fluid and we have the Cv of the valve at the chosen opening we can predict the amount of flow that will pass.

Unfortunately it is not always as simple as this because there are many factors which will modify the Cv values for the valve and there are limits to the flow velocities and pressure drops that the valve can handle before we reach limiting conditions. The most significant limitations that we need to understand at this point in the training are those associated with choked flow or critical flow as it also known. Here is brief outline of the meaning and causes of choked flow.

## 1.2 Choked flow conditions (critical flow)

Choked flow is also known as critical flow and it occurs when an increase in pressure drop across the valve no longer creates an increase in flow. In liquid applications the capacity of the valve is severely limited if the pressure conditions for a liquid are low enough to cause flashing and cavitation For gases and vapors the capacity is limited if the velocity reaches the sonic velocity (Mach 1). To understand how these conditions occur we first need to look at the normal pressure to flow relationship and then see how it changes when choked flow conditions occur.

As pressure differential increases the flow will reach a choked flow condition where no further flow increase can be obtained. Figure 1.10 shows this effect for a liquid where choked flow conditions occur when vapor formation occurs at the vena contracta point within the valve.

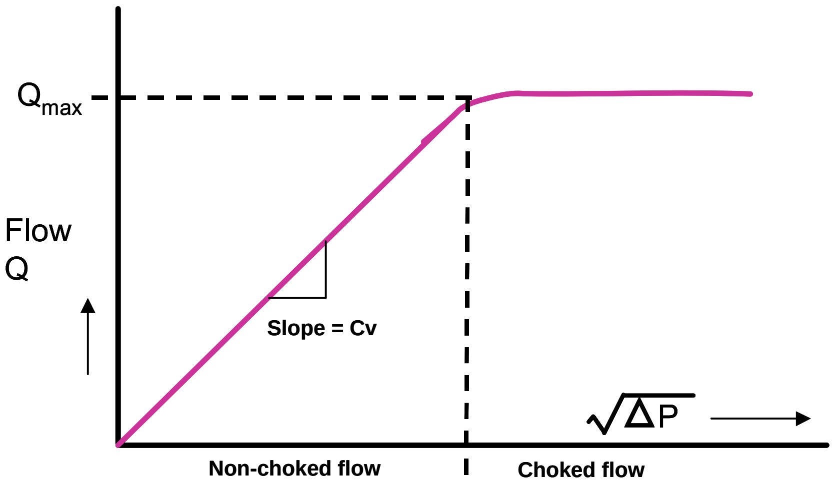



**Figure 1.10**
*Flow versus DP for liquid control valve showing choked flow.*

Vapor formation in liquid flow is generally termed flashing and it results either in a vapor stream or bubbles continuing downstream from the valve, if the bubbles condensed again the transient effect is described as cavitation.

### 1.2.1 Cavitation

The pressure profile diagram in Figure 1.11 best illustrates how flashing and cavitation occur. As static pressure falls on the approach to the vena contracta, it may fall below the vapor pressure of the flowing liquid. As soon as this happens vapor bubbles will form in the liquid stream, with resulting expansion and instability effects.

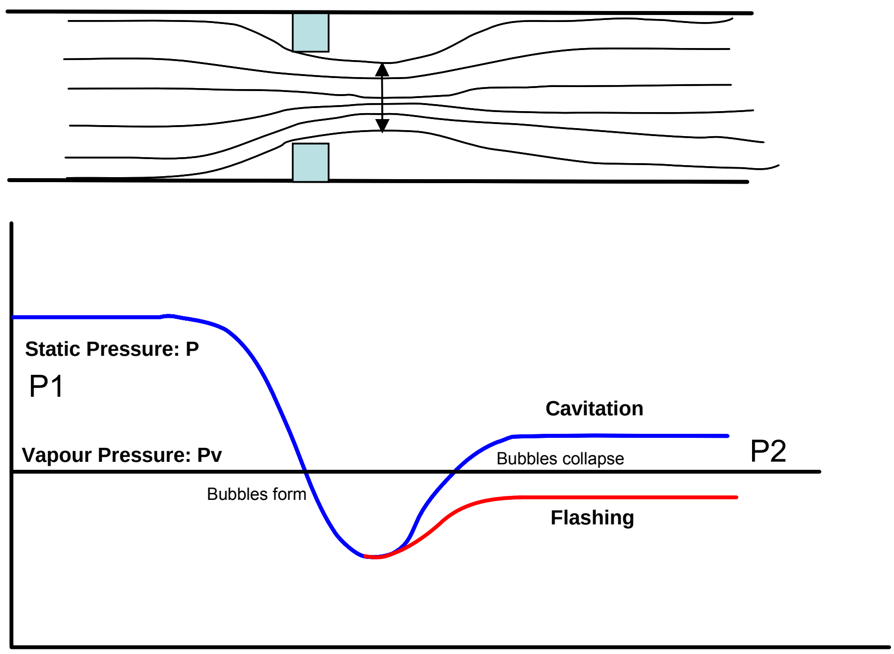



**Figure 1.11**
*Pressure profiles for flashing and cavitation*

In the diagram the bubbles so formed are collapsing again as the pressure rises after the vena contracta and the fluids leave the valve as a liquid. This is cavitation, which can potentially damage the internals of the valve. Figure 1.12 illustrates the same effect in the flow profile through a simple valve.

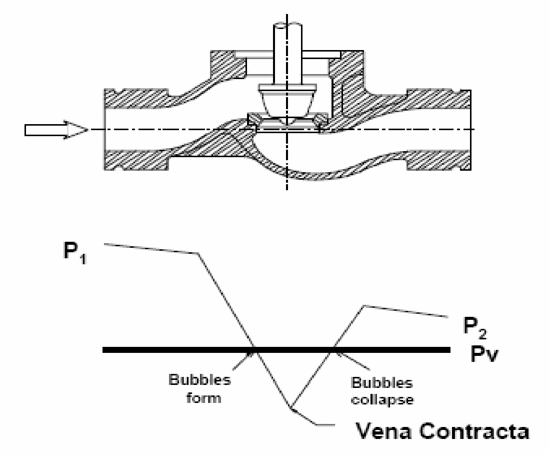



**Figure 1.12**
*Pressure profile for cavitation in a single seated globe valve*

### 1.2.2 Flashing

Flashing in the control valve also describes the formation of vapor bubbles but if the downstream pressure remains below the boiling point of the liquid, the bubbles will not condense and the flow from the valve will be partially or fully in the vapor state. Again this effect severely chokes the flow rate possible through the valve. Figure 1.13 illustrates this effect.

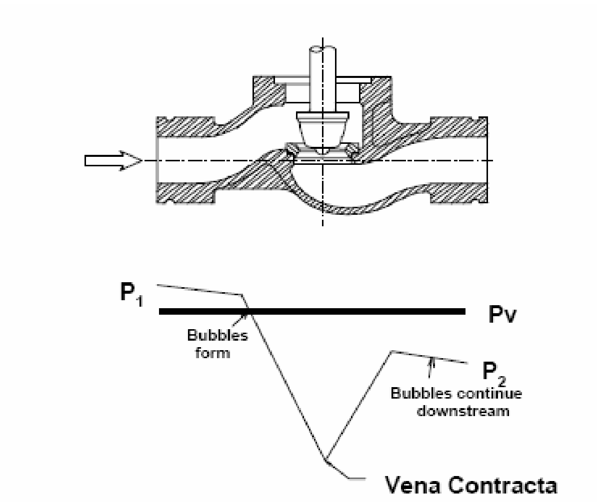



**Figure 1.13**
*Pressure profile for flashing in a single seated globe valve*

The problem in valve sizing work is determining when critical flow conditions apply, as we cannot easily see how much the static pressure will fall within a particular valve; we can only see the downstream pressure after recovery has occurred. In Chapter 3 we shall see how liquid sizing equations are set up to determine flashing conditions and how the sizing equations are modified to deal with this condition.

### 1.2.4 Choked flow in gas valves

Choked or critical flow also occurs in gas and vapor applications when the gas reaches sonic velocity as it squeezes through the valve opening. Under these conditions the velocity of the gas cannot be increased further and increasing the differential pressure will not itself increase the flow. Figure 1.14 shows the capping of gas velocity at Mach 1.

However, in the case of gases and vapors the flow rate is still affected by the density of the gas at the flowing conditions. Raising the inlet pressure P1 will increase flow and raising the flowing temperature will reduce flow. These influences will be seen in the Gas sizing equations and calculations in Chapter 4.

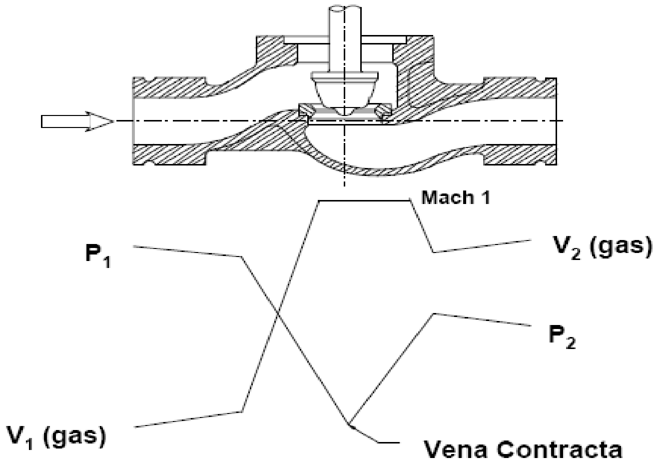



**Figure 1.14**
*Pressure profile for gas at critical flow through a single seat globe valve*

This completes our introduction the key features of flow through the control valve. Now we can turn our attention to understanding how the control valve works within typical process control applications.

## 1.3 Typical control valve applications

Typically the control valve is required to behave as a means of adjusting flow or pressure conditions in a process plant or in an item of plant equipment such as a compressor. It is fundamental to control valve sizing and selection that full consideration must always be given to the overall performance requirements of the combined valve and process.

Some of the most commonly encountered applications are outlined here so that we can see what is typically required for the sizing and selection process.

### 1.3.1 Flow control

A typical flow control loop has the control valve as its final element designed to provide a controlled flow rate in the pipeline. Ideally the flow rate should change in a fixed proportion to the control signal delivered from the flow controller system as depicted in Figure 1.15.

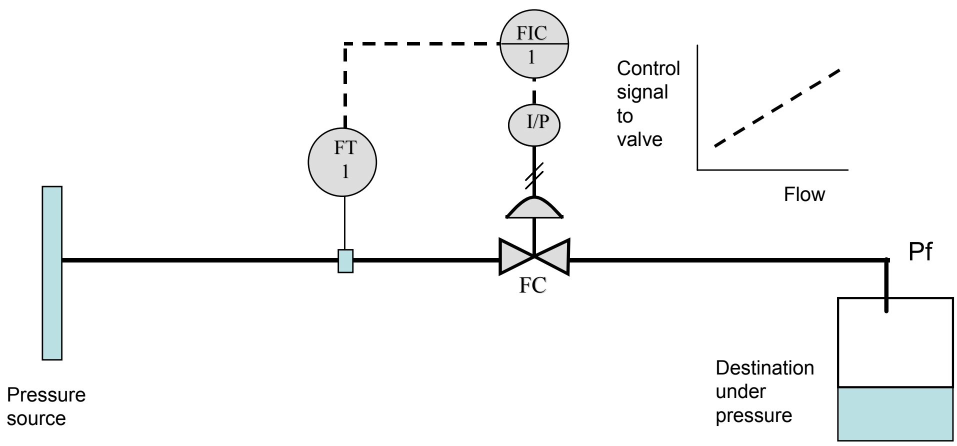



**Figure 1.15**
*Typical flow control arrangement*

In a typical process arrangement a fluid is supplied from a pressure source along a pipeline that has a significant flow resistance upstream and there is also some downstream flow resistance. Flow resistance is seen as the effect that pressure differential across a flow restriction rises with velocity squared as we have seen for the valve.

### 1.3.2 Flow resistance model diagram

The pressure drops and flow resistance for the flow control application are depicted in Figure 1.16. Here we see that the control valve must act as a variable resistance or pressure drop element that modifies the total flow resistance of the line to change the flow to a desired value between zero and maximum.

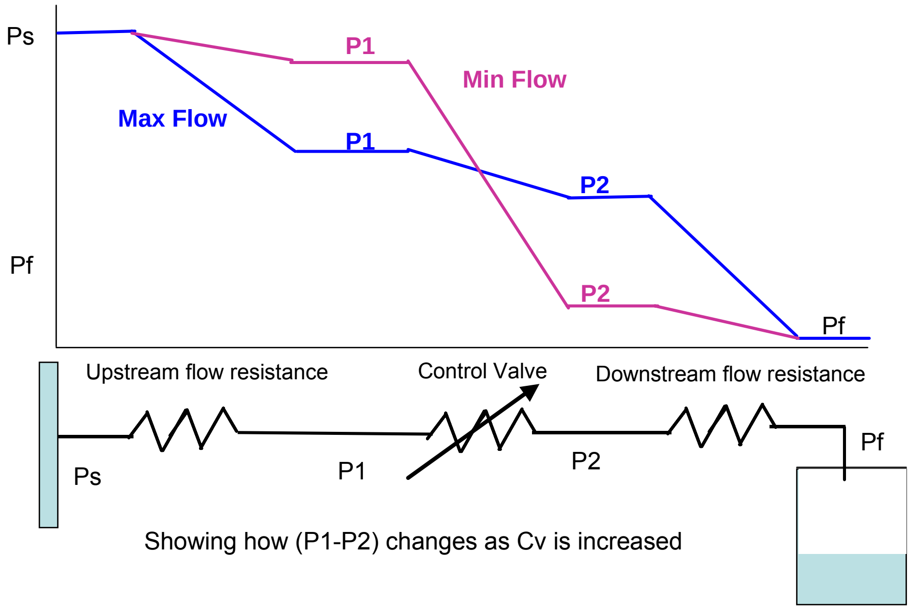



**Figure 1.16**
*Pressure profile for gas at critical flow through a single seat globe valve*

The upstream pressure of the valve, P1, is determined by the pressure at the source (Ps) minus the pressure drop over the upstream pipeline. Similarly P2 is determined by the flow through the pipeline downstream of the valve added to the pressure at the destination (Pf) which might be a tank under pressure or an open ended pipe. As Figure 1.14 shows, when flow increases from minimum (when the valve has a small opening) to the maximum (when the valve would be typically 70% open) the value of P1 will fall as flow rises whilst P2 will rise. Hence the value of DP available for driving flow through the valve falls substantially as the valve is opened.

It should be clear from this model that the specification of the flow and Cv requirements for the valve must take into account the extremes encountered between minimum flow at high DP and maximum flow at low DP. The valve is also required to tolerate the maximum shut off pressure that can be delivered from the source and it may also be required to ensure a low level leakage when it is shut.

It is also very important that the sensitivity or gain of the valve should be more or less constant over the range of the controlled operation so that the feedback control loop may have a near constant overall gain under all conditions. Failure to meet this requirement means that the control loop may be sluggish at high flows and oversensitive at low flows leading to instability.

The overall sensitivity of the control valve opening versus the flow that is delivered in response to a control signal is called *the installed characteristic*. We shall study this further in chapter 4 but it should noted here that *the valve characteristic* provided by the manufacturer is always based on a fixed pressure drop across the valve whilst the finally installed characteristic depends on the combination of the process pressure characteristics and the valve characteristic.

### 1.3.3 Level control

In level control applications the control valve may operate in a similar mode to the flow control situation and it provides flow in proportion to the level control deviation. In some level applications the valve may simply be draining liquid from a tank. In this case the upstream pressure may be variable due to the changing level in the tank. The downstream pressure may be constant or in some cases the pipeline to a drain may create a siphon effect leading to a very low downstream pressure with risk of flashing.

#### Temperature control by adjusting steam flow rate to a load

In a typical temperature control application, steam flow to a heat exchanger is modulated by a steam control valve to maintain a consistent secondary fluid outlet temperature. This can be achieved by using a control valve on the inlet to the primary side of the heat exchanger, as shown in Figure 1.17.

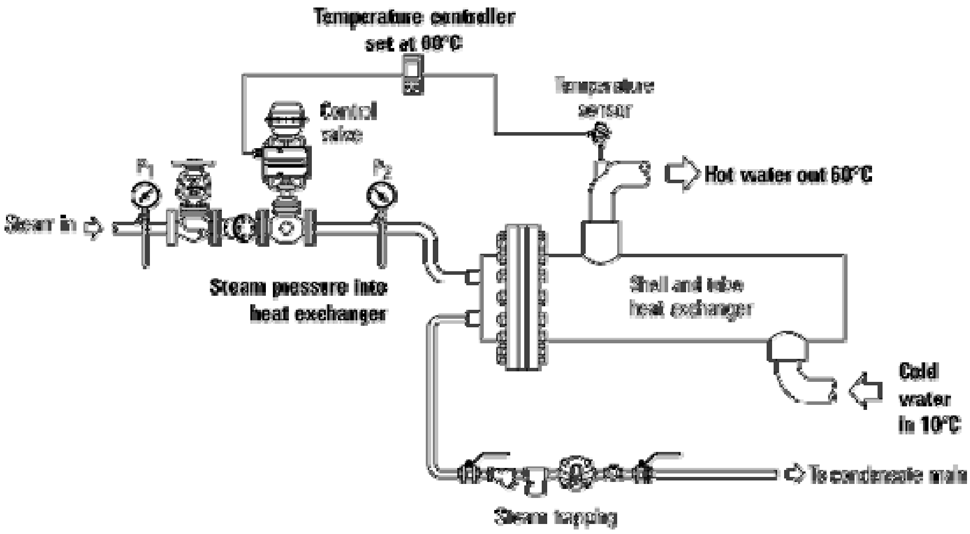



**Figure 1.17**
*Typical temperature control of a steam/water shell and tube heat exchanger*
*(Source: International site from Spirax Sarco)*

In the typical installation example shown in Figure 1.17 the outlet hot water from a heat exchanger is required to be controlled at 60˚C. The cold-water inlet at 10˚C may vary in temperature and quantity, which presents a variable load to the system. Modulating the position of the steam valve then controls the outlet temperature of the secondary fluid. A sensor on the secondary fluid outlet monitors its temperature, and provides a signal for the controller. The controller compares the actual temperature with the set temperature and, as a result, signals the actuator to adjust the position of the control valve.

Level control by adjusting in flow or out flow from a tank

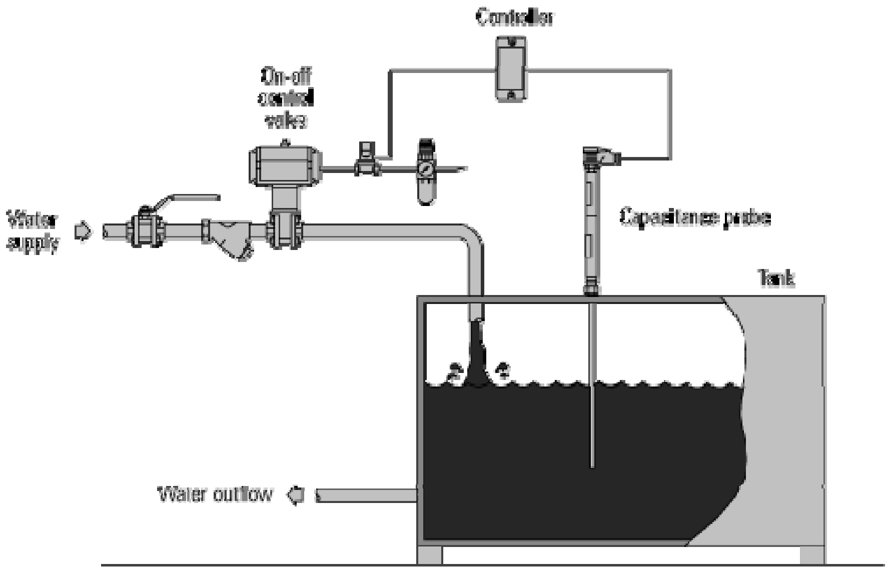



**Figure 1.18**
*An adjustable on/off level control system (Source: International site from Spirax Sarco)*

It consists of a controller and a capacitance probe, an on/off control valve and electric solenoid valve shown in Figure 1.18. The system provides control valve open/closed control plus one alarm point. Additional alarm points for high and low level indication are also available in the controller. The on and off levels at which the valve operates can be adjusted through the controller functions. A pneumatic electric solenoid operated valve gets the signal from the controller as per the level in the reservoir.

Adjustable on/off level control allows the level settings to be altered without shutting down the water outflow to process. This control can be used for most liquids, including those with low conductivities.

This system can also be used in situations where the liquid surface is turbulent, and the in-built electronics can be adjusted to prevent rapid on/off cycling of the pump (or valve).

## 1.4 Requirements of control valves

### 1.4.1 Wide range of types and sizes

A wide variety of types and sizes of control valves is needed to cater for a very wide range of industries. Major valve families and types can be based on type of fluids used, for example:

- Liquids
- Gases
- Steam
- Slurries

Another major category of valve is produced for “hygienic designs” needed for food and drug processing.
The control valve must have adequate capacity to meet process design requirements like pressure, flow, temperature etc. with good control over the operating range. Consequently suppliers must have available a reasonably wide range of sizes in each type to meet the demands.

### 1.4.2 Cost effective solutions

During the application and selection of control valve one of the important aspects is cost effectiveness. At the same time it should not be in any case at the cost of performance. Hence the cost of the valve versus line size or capacity needs to be well defined. For example, a butterfly valve is cheaper than a globe valve for the same capacity when applied to larger sizes if it can perform the pressure duty. Globe valves often produce the best control for higher pressures but are very expensive as size increases. However it is important to note that very often a control valve will have the required capacity in a size somewhat smaller than the pipeline size, hence costs will be reduced if a smaller valve body is adapted to a larger line size by using pipeline reducers.

### 1.4.3 Flow in proportion to travel

To achieve control over the process the control valve is expected to have control over one or more important process variables at any point of time. This need calls for an ability to allow fluid through valve accurately in proportion to valve opening, repeatedly. In the operation of the valve the valve stem movement is either linear or rotary. In other words we say the valve should have ability to adjust flow in proportion to valve travel.  This is always needed for stable feedback control. To get the best performance the valve characteristics need to be matched to the process characteristics.

### 1.4.4 Ability to close fully and provide good shut off

In operation where the control valve is used for on-off functions the effective closing during shut off condition is very essential. In applications with corrosive, hazardous or expensive fluids the ability of the valve to close fully and provide good shut off is very much needed.

### 1.4.5 Ability to withstand static pressure in the pipe without leakage

The control valves are subjected to pressure changes during the operation of full opening to minimum opening. The control valve should have ability to withstand the static pressure in the pipe without external /internal leakages.

### 1.4.6 Material of construction resistant to corrosion

The control valves are subjected to fluids, which are corrosive in nature. These fluids can have chemical reactions on seals, valve body, glands and gaskets. In such applications the material used for construction of the control valve must be resistant to the corrosion caused by the particular fluid.

### 1.4.7 Internal resistance to erosion and corrosion

The internal parts of the valve, which are responsible for proper operation, are also vunerable to corrosion due to the corrosive effect of the fluid. The material of the internal parts must be selected so it is resistant to the action of the fluid. This is very important for consistent and desired service from a control valve. In addition to the corrosive resistance as a selection criteria we have to consider pressure abusive on the internal parts of the control valve. If the valve is subjected to high pressure, operates with large pressure drops and frequent variations of pressures, then the material of the internal parts of the control valve should be such that they can be treated to offer resistance to erosion.

### 1.4.8 Dimensions standardized to fit mechanical standards of pipes and flanges

For an installation in the pipe line the valve body is either threaded or flanged at the inlet and outlet connection points. To have installation and maintenance conformity there has to be a fixed relation in pipe sizes with the mounting threads or flanges. The American Petroleum Institute (API) has set down standards for pipes and flanges and these have been widely adopted. Schedule numbers define the pressure rating of the piping and there are eleven Schedules ranging from the lowest at 5 through 10, 20, 30, 40, 60, 80, 100, 120, 140 to schedule No. 160. All pipes of particular size have the same outside diameter but as the wall thickness increases with pressure rating, the inside diameter is reduced.

The control valve pipe connection dimensions are specified to conform to the API standards for pipes and flanges. In European standards the pipeline dimensions are expressed in metric sizes according to the relevant DIN standards for pipes.

### 1.4.9 Designed to avoid excessive reaction forces on the moving parts such as stems or shafts

As the size and duty of a control valve increases, the forces generated by the fluids passing through it become large and in an unbalanced design these can place high stress on the valve stem or shaft. Similarly the forces needed to close of the flow and withstand static pressure will also determine the size and thrust requirements of the control valve actuator. Control valve designers seek to minimize these forces by the internal design of the valve trim and the configuration of the valve seats. Lower forces permit smoother operation and smaller cheaper actuators, which can be offset against the cost of the valve.

### 1.4.10 Provided with actuators to deliver adequate forces to unstick, open smoothly and reach full opening

In smaller sizes the operation of control valves can be manual. When the pipe size increases (2 inches and above) the energy required to over come sticking, opening and closing is very high. Different types of actuators like pneumatic, electrical, hydraulic are used to provide this force. Smooth and controlled operation of the valve is necessary to avoid jerks and water hammer effect. With a positioner and controller combination, very smooth and continuous control between closed position of the valve and full open position is achieved.

## 1.5 Training needs for sizing and selection

The training requirements for an instrument technician or engineer involved in sizing and selection of control valves should concentrate on developing several important skills including the following:

1) Having a basic understanding of valve capacity and how it can be calculated
2) Understanding how the control valve changes the process flow and pressure conditions in any particular installation. This implies understanding the interaction between flow through the valve and pressure drops in the piping system.
3) Knowing how to manipulate the basic valve sizing equations to arrive at the capacity versus flow values for any given situation.
4) Knowing how to make use of valve sizing software to quickly explore sizing options and then arrive at a sufficiently accurate solution to make the sizing decision.
5) Understand the causes and conditions of choked flow, cavitation and noise in outline sufficiently to discuss and understand solutions offered by vendors. I.e it is not necessary to be an expert in the field when specialist companies have the knowledge and experience in house.
6) Be aware of the principal types of control valve and the factors influencing the choice for an application.
7) Be able to understand the meaning of the catalog data available from major suppliers of control valves and be able to discuss selection choice with the vendor.
8) Be aware of the important roles of actuators and positioners in providing an integrated package for final control of the process.

9) Be able to recognize the role of the installed control valve as part of the complete process control loop.
10) Be aware of the critically important role of materials of construction and trim materials in the long-term reliability of the control valve you select.

The training chapters in this manual together with the glossary, the appendix of frequently asked questions and the application examples are all intended to promote the above skills.