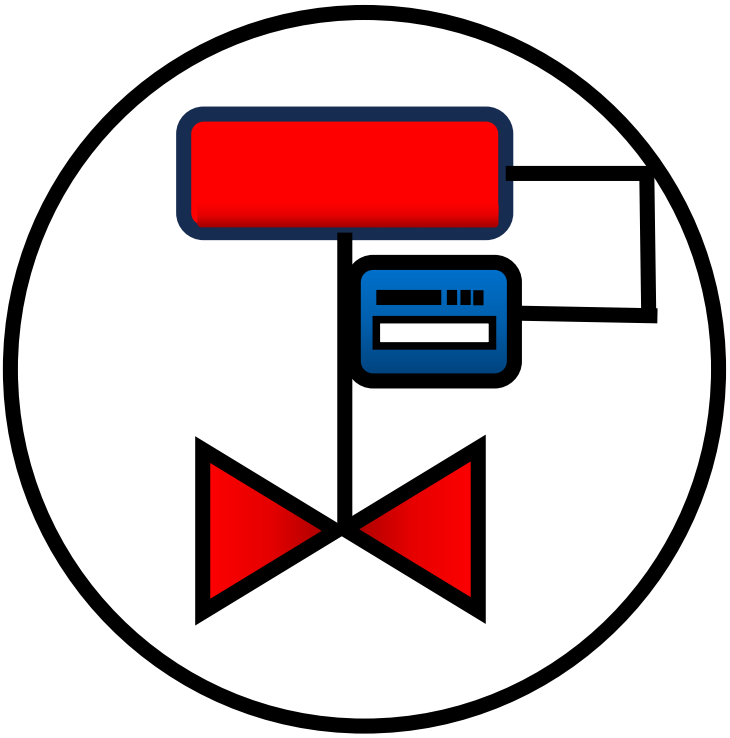
Control Valve Mastery

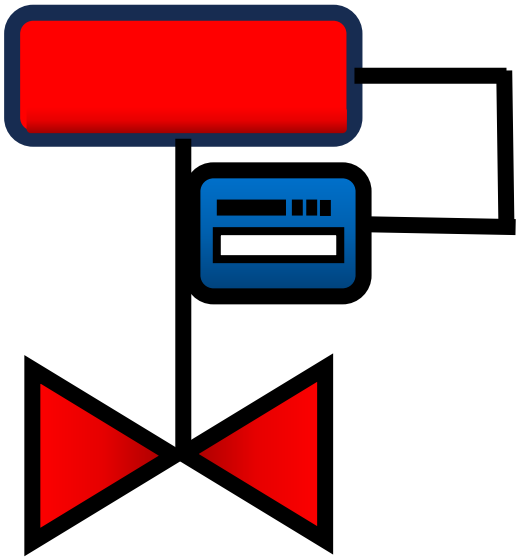


By : Asad Shaikh

1st Edition

www.Asad-Shaikh.com

Immerse Yourself in the World of Valves



Graphics by Asad Shaikh

Valves - they may seem like small components in the grand scheme of industrial processes, but they play a crucial role in ensuring safety, quality, and efficiency.

But don't be fooled by their seemingly simple functions - selecting the wrong control valve can lead to catastrophic incidents that put lives at stake. You will learn about this in coming chapters.

From valve material selection to optimum sizing, leakage classification, NACE requirements, and actuator sizing, we'll cover it all.

So, whether you're a seasoned professional or just starting out in the industry, don't overlook the importance of control valve selection.

Let's explore the world of control valves together and discover the surprising impact they can have on your processes.

$27 Million dollar Control Valve

The explosion in Husky Refinery was so powerful that it caused a fire that burned for several days, and it took over a year for the refinery to fully recover which occurred on April 26, 2018.

The control valve is responsible for regulating the flow of fluid through the FCC unit. It's a critical component that must be carefully selected and maintained to ensure safe and efficient operation.

The control valve in question was located in the FCC unit's regenerator, which is responsible for burning off the coke that accumulates on the catalyst during the cracking process.

The valve was eroded, and air escaped through the opening, mixing with hydrocarbon, and resulting in a massive explosion.

The cause of the valve erosion is still under investigation, but it's believed to be related to the high-temperature and high-pressure conditions in the regenerator.

The erosion may have been caused by a combination of factors, including the type of material used in the valve, the design of the valve, and the operating conditions in the regenerator.

The Husky Refinery explosion is a sobering reminder of just how important it is to pay attention to the details when it comes to valve selection and maintenance.

Control valves are critical components in industrial processes, and selecting the wrong valve or failing to maintain it properly can lead to catastrophic incidents that put lives at stake.

The total cost of damage in the Husky Refinery explosion was estimated to be around $27 million. This includes the cost of property damage, business interruption, and environmental cleanup.

In addition to the property damage, the explosion also resulted in a significant business interruption for Husky Energy. The refinery was shut down for several months, and the company had to incur additional costs to import fuel to meet its obligations to customers.

Control Valve: Trim Material Selection

The material selection of control valve is divided into 3 major parts.

The first one being material selection of control valve trim.

The second being packing material selection.

And the third but not the least, valve body material selection.

1st Logical selection method

The Basis of Selecting Trim Material is the Trim of Similar manual valve specified in PMS (Piping Material Specification).

Piping Material Specification (PMS) is a document that provides information about the materials used in the construction of piping systems.

It includes details such as the type of material, the grade, the size, and the thickness of the pipes.

The PMS also specifies the standards and codes that the materials must meet, as well as any additional testing or inspection requirements.

When selecting the control valve trim material, the PMS trim information is used as a reference to ensure that the material selected meets the requirements for the intended service conditions.

The Logic behind this engineering selection approach is that if the manual valve in the piping system can handle the process fluid, then the automated valve must also be able to handle the process since the same conditions exist for the manual and automated valve in pipe.

2nd Logical selection method: Special Service Criteria

In general, the basic material specified is Stainless steel 316, however hardened material like 17-4 PH, XM-19, Nitronic etc is also specified based on the fluid and other loop parameters.

This may be updated at a later stage based on recommendation by vendor after control valve sizing, material selected should not be of lower grade than the specified in PMS.

However, the material should be appropriate to the fluid properties for e.g. in Nitric Acid service, the material for trim is SS304 instead of SS316

as the molybdenum content in SS316 is not suitable with concentrated nitric acid.

Hence although the vendor may suggest the material based on their standard catalogue items, it should be properly evaluated.

3rd Logical selection method: Cavitation & Flashing Trim protection

The vendor also provides the recommendation based on severity of cavitation (Called Cavitation Index as per ISA RP 75.23).

The vendor might recommend Stellited Trim or if the cavitation is severe then special anti-cavitation or Lo-db trim (for example multi-stage trim).

In case the process parameter indicates that the pressure at the outlet of the control valve remains below the vapour pressure of fluid, it denotes the flashing service.

The only choice for such service is to have hardened trim and have full stelliting of trim to withstand and delay the erosion.

Full stellited trim is also specified in case of steam service my many engineering companies by default and also if differential pressure across the control valve is more than 10 Kg/cm2 (10 Bar) in general.

Control Valve: Packing Material Selection

It's surprising to learn just how much thought and consideration goes into selecting the right valve packing material.

With the introduction of fugitive emissions norms like the US "Clean air act," valve packing has taken on a new level of importance.

Here are some thumb rules about valve packing material selection:

PTFE Packing : The most commonly used material is Teflon (also called PTFE) but did you know that they have their limitations?

PTFE can only handle temperatures up to about 200°C.

Graphite Packing : The other most commonly used material is Graphite.

As a rule of thumb Graphite can withstand up to 600°C.

Fugitive Emissions : Fugitive emissions refer to the unintended release of gases or vapors from industrial equipment, including control valves.

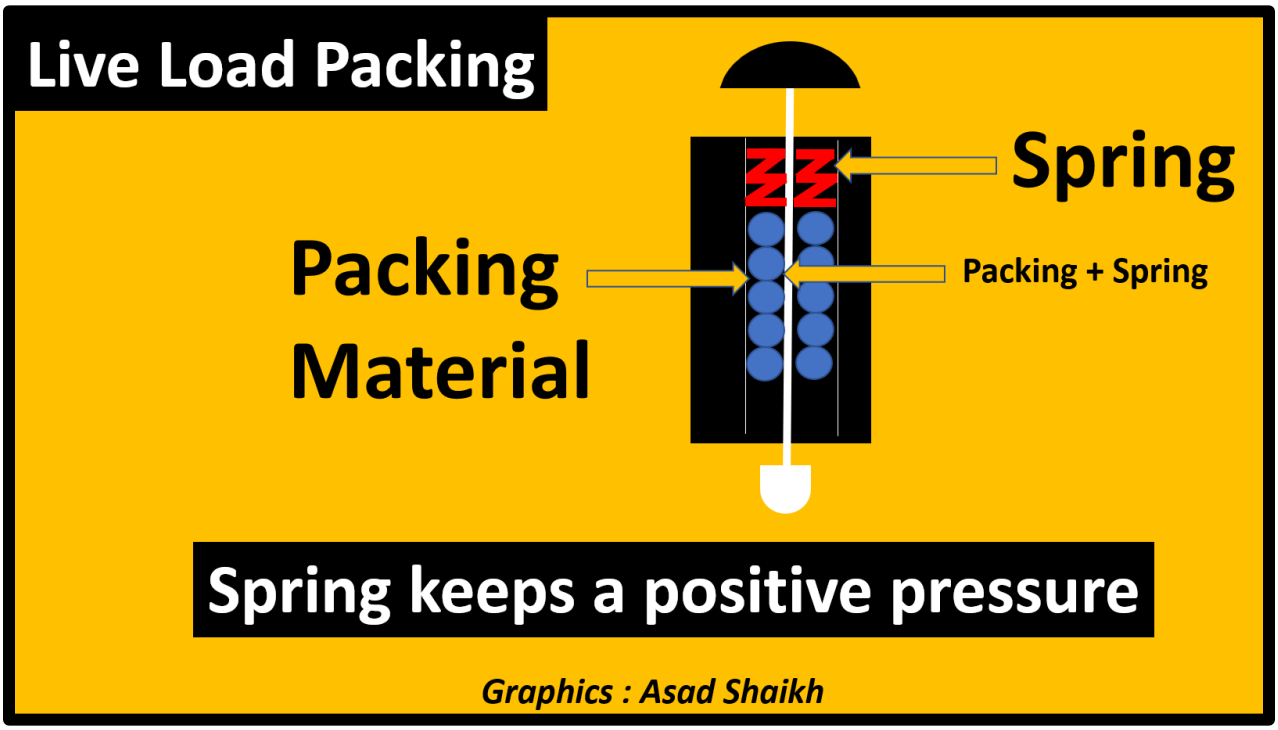
In the case of control valves, fugitive emissions can occur when the valve is not properly sealed, allowing gases or vapors to escape into the environment.

With the introduction of fugitive emissions norms like the US "Clean air act," valve packing has taken on a new level of importance.

Fugitive emission requirements might dictate special packings

Examples are Kalrez Valve Stem Packing (KVSP), Live load packing, Enviro-Seal Packing and Bellows seal (also used in case of toxic or corrosive service)

Below is example of Live Load Packing



Hydrogen Service : For hydrogen service as a thumb rule it is recommended to have fugitive emission packings.The reason is that H2

molecules are very small are there have been quite a few instances of not just release but incidents of fire due to h2 leakage.

Services having H2S (Sour service) : Fugitive emission packings are recommended to be specified.

Bellow seal Packing : Sometimes, you find that design basis specifies Bellow seal packing for Hydrocarbon service or Sour service. However it is important to note that bellow seals are difficult to maintain (one needs to be cautious while maintaining the valve and opening the bonnet) and these are also expensive

You can also explore the alternative to bellow seal packings for Fugitive emission like enviroseal packing as per ISO-15848.

Here are some of the fugitive emission standards that are commonly used in the industry:

1. ISO 15848-1: Type Testing

2. ISO 15848 Part 2: Production acceptance test of valves

3. API 622 - Type Testing of Process Valve Packing for Fugitive Emissions

4. API 624 - Type Testing of Rising Stem Valves Equipped

5. TA-Luft - German Clean Air Act

6. EPA Method 21 - Determination of Volatile Organic Compound Leaks

7. EN 12266-1:2012 - Part 1: Pressure tests, test procedures and acceptance criteria

Control Valve : Valve Body Material Selection

Finally, we get to selection of material of construction of the body of the control valve.

This must be equivalent to or higher than the pipe material where the control valve would be installed.

In general, the body of the control valve is casted or forged.

Generally for valves the casting equivalent of the material required needs to be selected.

Some design basis also specifies forged material for smaller valve body sizes like up to 1”.

However, Forged body is expensive than casting and to be selected only if required as per the contract requirements or if specific service demands for same.

Special Bonnet Selection

One important consideration in body selection is the requirement of special bonnets.

At elevated temperatures, such as in boiler feedwater systems and superheater bypass systems, the standard materials of control valve construction might be inadequate.

Extension bonnets or finned bonnets help protect packing box parts from extremely high temperatures.

For control valve applications in cryogenic services, many of the same issues need consideration as with high temperature control valves.

The length of the extension bonnet depends on the application temperature and insulation requirements. Colder the application, the longer the extension bonnet required.

Control Valve : Valve Design Criteria

(Balanced Vs Unbalanced Design)

We will explore the selection between unbalanced and balanced trim.

For Usual applications, an unbalanced design can suffice the requirement.

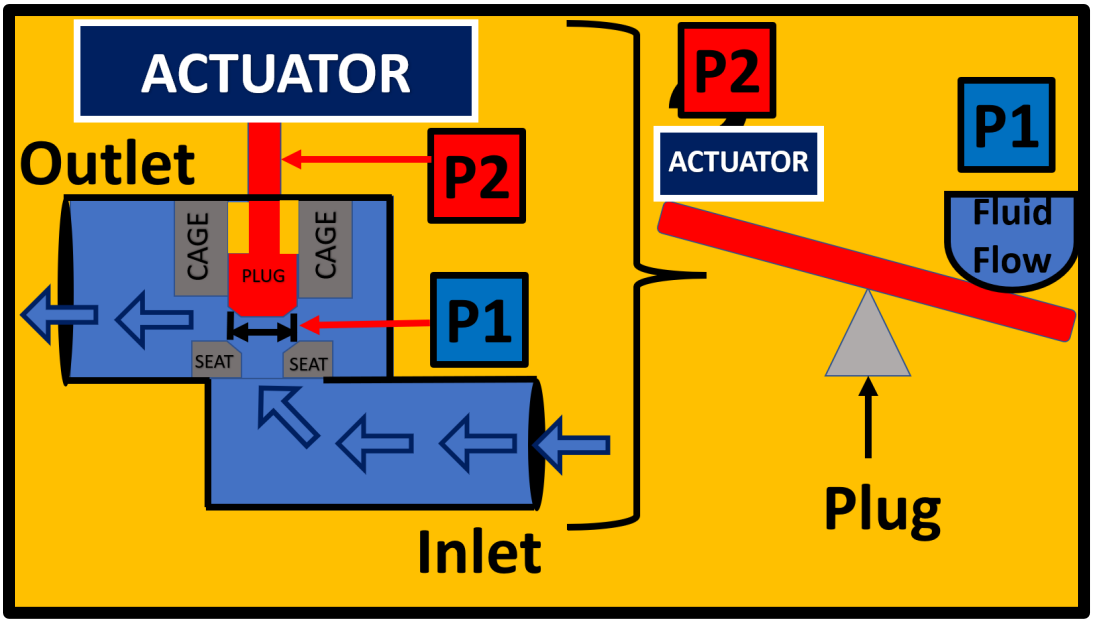
However, for applications with high pressure drop a balanced design is recommended.

When specifying balance design, consideration must be given to verify that it should not hamper with the seat leakage requirements.

This is due to that fact that an unbalanced design has one leakage path while a balanced design is prone to two leakage paths.

Below is example of <u>Unbalanced Trim</u>

Here : The Actuator alone is pushing the Fluid



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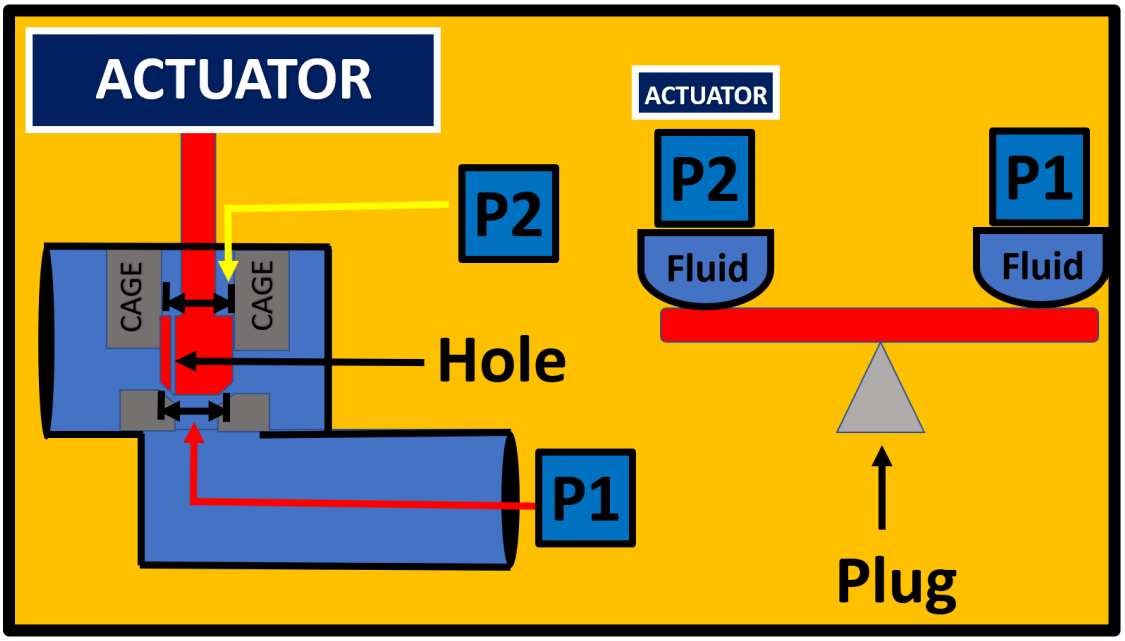
Below is example of <u>balanced Trim</u>

Here : The Actuator is supported by the Fluid and hence requires less force



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Control Valve : Valve Design Criteria

(Single Vs Dual Port)

In valve design there is an option of single or dual port.

A double port valve is used where the pressure drop is significantly high.

However the industry has predominantly moved away from using double ported valve design due to its other drawbacks like higher seat leakage (two probable leakage paths etc).

Thus, usually Single port is the most common valve design specified in datasheet and is simple in construction. For very special cases double port would be considered.

Control Valve : Valve Leakage Class

The most predominant standard for leakage class in Control Valve is ANSI/FCI 70-2.

This standard divides the leakage class in six categories. i.e Class I to VI. Out of these the most common leakage class that is used in process plants is Class IV.

We can achieve Class IV with a metal seat design. However, for Tight Shut off applications Class V or Class VI Soft Seat is required to be specified, though Class V can also be achieved using metal seated design.

For cases where TSO is required, Class VI needs to be specified. Usually TSO (Tight shutoff) valves are used in very hazardous service requiring very precise process control or where any leakage through valve seat may contribute to the loss of the hydrocarbon or product

E.g., Line connecting to flare header for pressure control.

Control Valve : Valve Characteristics Selection (Linear / Equal percentage / Quick Opening)

Understanding the basics as to why are there different valve characteristics such as linear, equal percentage, quick opening is very important.

This is due to concept called inherent and installed valve characteristics.

Inherent valve characteristics

The valve characteristics when evaluated with constant pressure drop is linear and this is called as inherent valve characteristics.

It is important to note that we achieve best controllability when the valve characteristics are linear.

However as soon as we install a valve in actual process condition then it is ideally impossible to maintain constant pressure drop across the valve.

Installed valve characteristics

Thus, we get characteristic that deviate from the pure linear characteristic that we achieved during testing of the valve under constant pressure drop. This is called as installed valve characteristic.

In order to achieve linear curve, we try to counter this by changing the plug or cage characteristics such that the net result gives us a linear curve or near about linear curve. So, for some application a quick opening or equal percentage might be suitable to counter for the installed valve characteristics.

Selection Thumb Rules for valve characteristics

This selection between Linear, Equal, Quick opening depends on the nature of the application where the valve would get installed.

As a rule of thumb this is usually specified as equal percentage.

Vendor may provide recommendation and go for modified linear or modified equal percentage characteristics.

However, for basis we can use the following table (Table 6.1f) from Bela Liptak's Instrument Engineers' Handbook, Vol. 2: - Process Control and Optimization.

TABLE 6.1f

Valve Characteristics Selection Guide

Service	*Valve (Δp_{max} /Δp_{min}) Under 2:1*	*Valve (Δp_{max}/Δp_{min}) Over 2:1 but Under 5:1*
Orifice-type flow	Quick-opening	Linear
Flow	Linear	Equal %
Level	Linear	Equal %
Gas pressure	Linear	Equal %
Liquid pressure	Equal %	Equal %

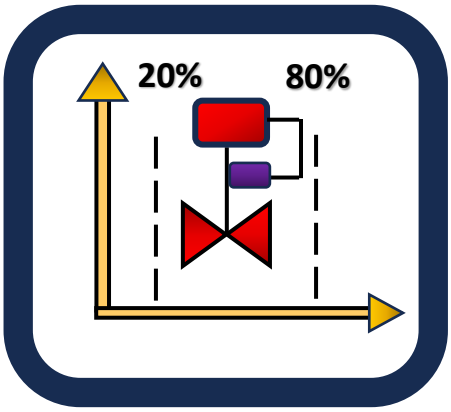
Where delta Pmax stands maximum differential pressure experienced by valve. And delta Pmin stands minimum differential pressure experienced by valve.

Thus, if the ratio of the two is under 2:1 then we use column 1 else we use column 2.

Control Valve : Control Valve Sizing

Valve Travel Percentage

As Control Valve calculation is performed, it is to be ensured in general that the valve travel percentage for min, normal and maximum CV condition must be between 20 to 80 % of the valve's rated capacity to achieve better controllability.



In some cases, the design basis also specifies that the control valve must accommodate 110% of the maximum flow rate, in such case the calculation must also be checked for 110% of rated flow rate and ensure that the percentage travel falls within required limit.

Rangeability

We also need to consider the rangeability which is the ratio of maximum controllable flow to minimum controllable flow which

preliminary depends on valve geometry, Actuator accuracy and leakage rate.

In some cases, we find that the ratio of maximum to minimum flow is very high, in such case one has to take into account the point at which the flow needs to be controlled i.e as per process requirement, whether it is important to control the flow rate on higher limits or on lower limits and decision has to be reached in consultation with process / licensor about sacrificing the controllability (Only inaccuracies will add on) over the range where control is not dominant requirement.

Pressure Drop Across valve

We also need to be seen about the amount of pressure drop required across the valve.

Very high pressure drops warrants for change in type of valve and may require going for Angle type globe control valves.

In some cases, if the pressure drops are too large to handle, then multistage trims are used, or pressure is dropped gradually using two control valves in series.

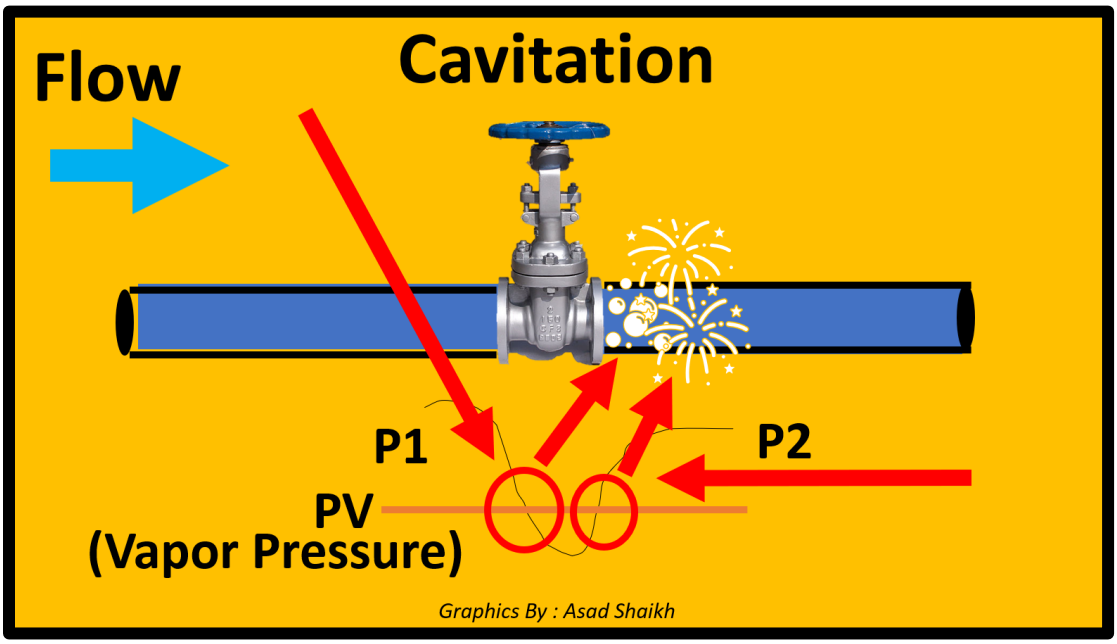
In some cases, it is also seen that the pressure drops are achieved by control valve to certain extent and then further pressure drop is

achieved by multi-hole restriction orifice, such installations are sometime seen in Deaerator applications of steam boilers.

However, the configuration will depend on the process requirements, vendor available offerings and cost optimization.

Special Sizing Conditions

1. Cavitation : If there is Cavitation present, sufficient measures are required to be taken like Stellited Trim or anti-cavitation trim (single/multi-stage trim) etc by the vendor.



This is based on severity of cavitation (Called Cavitation Index as per ISA RP 75.23).

The sizing software might recommend Stellited Trim or if the cavitation is severe then special anti-cavitation or Lo-db trim (for example multi-stage trim).

2. Chocked Flow : When dealing with choked flow, the process becomes more complex. Choked flow occurs when the fluid velocity reaches the speed of sound, and the pressure drop across the valve is so high that the fluid cannot flow any faster.

This can cause a significant drop in flow rate and can lead to unstable control.

To size a control valve for choked flow, you need to determine the critical pressure ratio (CPR) for the fluid. This is the ratio of the downstream pressure to the upstream pressure at which choked flow occurs.

Once you know the CPR, you can calculate the maximum flow rate through the valve.

Then compare that flow rate to the required process flow rate.

3. Noise Consideration

As a rule of thumb the Noise must be below 85 dBA, else low db. trim may be warranted in some cases.

In special cases, to reduce the noise, silencers are also used at the downstream of valve.

And thus, Select a valve with a Cv value that can handle the maximum flow rate calculated in step 3, while also ensuring that the valve has a low enough pressure drop to avoid cavitation.

4. Extremely high pressure drops : This warrants for change in type of valve and may require going for Angle type globe control valves.

In some cases, if the pressure drops are too large to handle, then multistage trims are used, or pressure is dropped gradually using two control valves in series.

In some cases, it is also seen that the pressure drops are achieved by control valve to certain extent and then further pressure drop is achieved by multi-hole restriction orifice, such installations are sometime seen in Deaerator applications of steam boilers.

However, the configuration will depend on the process requirements, vendor available offerings and cost optimization.

Control Valve : Special Considerations

1. Handwheels : There are some special requirements for control valves like Handwheels.

Handwheel requirement is usually specified on P&ID.

Example : A control valve is actuated by a pneumatic piston actuator but is also equipped with a manual operated handwheel.

Such Handwheel requirements is to ensure that valve can be opened or closed in emergency in case of the power failures or Air failure.

Example: Advertently opening the valve which is Air fail closed for draining the residue / inventory in case of power or Air failure or for release of pressure under emergency.

2. SIS Application (Solenoid with Control Valve) : There also few cases where a solenoid valve is required and is shown on P&ID.

A typical arrangement is where the solenoid is operated via ESD and the solenoid is placed on pneumatic line connected to control valve.

In case of emergency, the ESD can cut the supply to the valve and thus the valve enters it fail safe position.

This can be done in 1oo2 or 2oo2 configuration refer API RP 553 for in depth information.

There are other requirements like position transmitter, limit switches which are required to be specified as per process requirement.

NACE Requirements : Finally, due care must be given towards other requirements like NACE for Sour Service.

NACE MR 0175 is required for Offshore applications and NACE MR 0103 is required for Refinery applications.

Inspection and Testing : Inspection requirements like NDT (DPI, X-ray), PWHT, etc must be catered to as per contractual requirements and service requirements (e.g., for hydrogen service).

I hope you have enjoyed the Free E-book on Control valves and I was able to provide some value to your professional experience.

Incase of feedback you can reach out at :

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Asad.shaikh.channel@gmail.com

Control Valves : In-Depth Learning ?

This is for professionals wanting an advance level of Learning.

Control Valve Standards in Depth

API RP 553 - In depth analysis

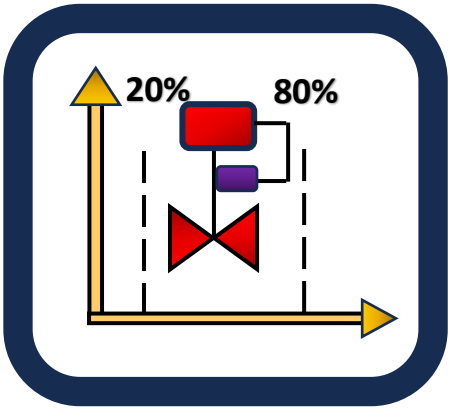
ASME 16.34 – How to calculate Flange Ratings

ASME 16.10 – How to use the standard etc

Fugitive Emission standards (Type testing / Production Test) etc

And the list can go on ….

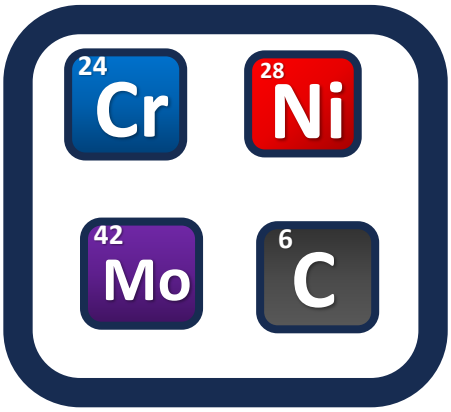
Control Valve Sizing Concepts & Software :



Right from how to download the software, to how to size a control valve and how to read sizing Reports.

Plus Cavitation, Flashing, Chocked flow and High Noise cases will be evaluated in Software.

Control Valve Material Selection in depth :



What do these common material like A105, CF8M, SS304, SS304L, Duplex 2205 actually mean.

Plus What happens when Carbon, Nickel and other elements are added, and what are the temperature limitation of each material.

Analysis on material selection and recommendations based on API RP 553 and other standards will be covered.

Control Valve Datasheet & G.A review :

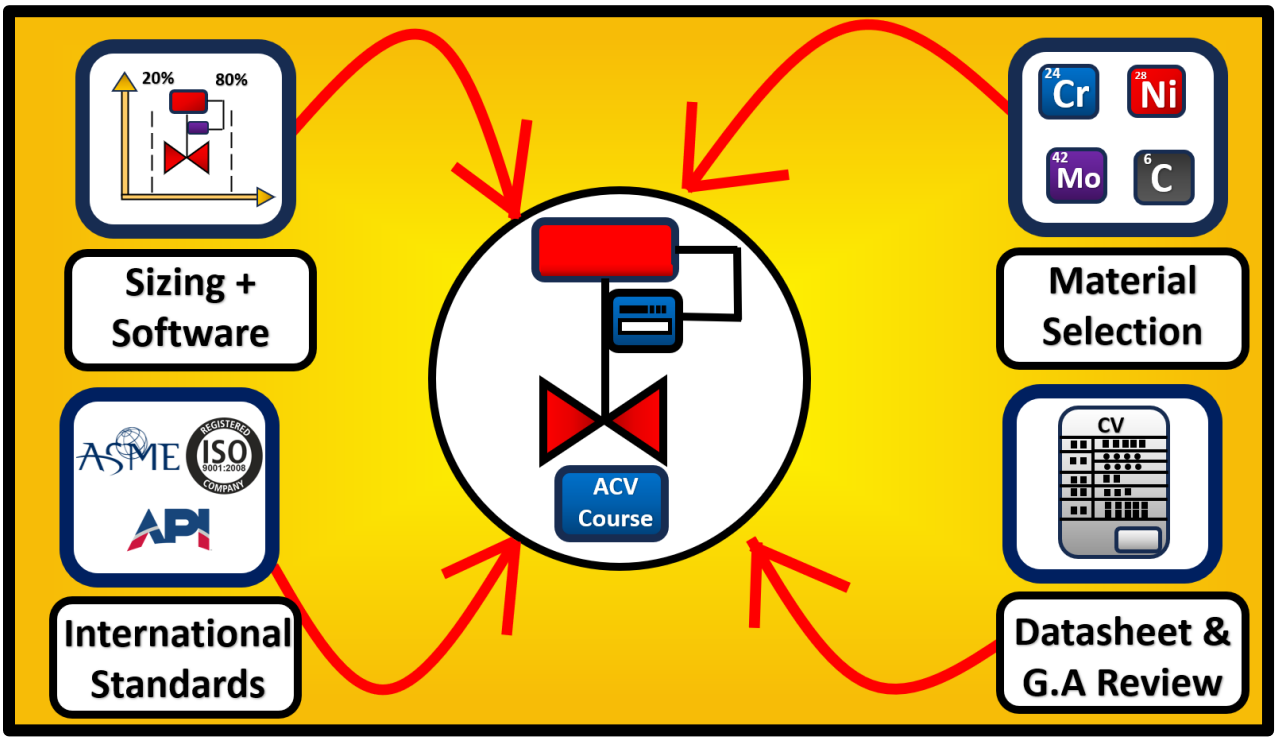
Here we will explore ISA Format datasheet and look into everything that is entered in datasheet.

And Row by Row understand each and every requirement of datasheet.

Plus we will look into sample G.A Drawings of Control Valves and what minimum details must be included in them.

Advanced Control Valves Course (ACV)

(Coming Soon)



This will be a Premium Course with minimum price range of 100 Dollars.

It is not for college students since such in depth knowledge on sizing , material selection is not expected at that level of experience.

Its been a whole year reading international standards, sizing valves, design basis etc and building the course alongside.

However, still it will take some more months since I would want the course to be game changer for professionals.

If you would be interested to know about the course when it gets launched then ping me “Share when course is launched” at a special whatsapp number dedicated for the course: +91 9326145849

Or Ping me at instrumentation@asad-shaikh.com

And If you think the course is not a good fit for you ?

No Problem. 😊

Every Saturday a new Learning video is published on my YouTube channel : https://www.youtube.com/c/AsadShaikhICEngineer

Let us together reach the top !!

Happy learning,

Asad Shaikh