Selecting the Correct Control Valve









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Abstract

A maxim that is evident to most valve subject matter experts (SMEs) is that the application dictates the valve. Remarkably the selection of valves in many applications is less than best practice and process suffers when it shouldn't. The consequences of poor control valve sizing and selection can not be understated, affecting both commissioning and start-up as well as established operations, creating safety and output issues.

Through the work initiated by the Manufacturers Standardization Society (MSS) to define Severe Service Valves (SSVs), a clear indication of severe service thresholds for control valves has been identified. Different sources estimate the number of Severe Service Control Valves (SSCVs) between 3% to 10% of plant's valve population, it was also estimated that these valves account for 40% of purchasing cost for all control valves on site, yet once supplied and commissioned in many cases these valves need redesign or replacement as a result of incorrect sizing and selection.

Although control valve sizing is performed in accordance with ISA S75.01 sizing equations and IEC 60534-8-3 Noise Prediction Methods, it may be considered compositely; its parts consist of the following:

- Science
- Personal experience
- Personal preference
- Customer history
- Application history
- Cost of ownership
- Application severity

From a practical standpoint control valve selection is often based on the least expensive alternative which will meet process control requirements. Over the years control valve manufacturers developed practical guidelines to help interpret process data correctly, establish severity of three major severe service conditions - cavitation, flashing and high noise levels; and methods to handle these conditions according to the level of severity in the most cost-effective way. A significant choice remained between a CAPEX and OPEX direction – where does one focus, upfront cost or life-cycle cost? The latter decision is a key differentiator between all users, suppliers and manufacturers.

This holistic approach has proven effective across some of the most challenging industries such as hydrometallurgy, oil sands, hydrocarbon upstream and downstream processing and pulp & paper. Applications such as black liquor flow control, HP boiler feed water, wash water, HP steam, superheated steam and turbine steam supply, inlet separators feed, and HP gas separator to gas flare mostly show not one but a combination of severe service conditions that were addressed cumulatively in devising a solution that would meet acceptable level of performance.

Cavitation

Cavitation is widely accepted is one of the severe service conditions of a control valve's operation. When control valves fail in liquid service, cavitation is often the root cause. Issues commonly caused by cavitation in control valves include:


Figure 1 Cavitation damage on valve plug

- Cavitation Erosion – bubbles collapsing in close proximity to solid surfaces in the valve release energy that will gradually deform, loosen and eventually erode the material. The rough, cinder-like surface created as a result also provides a good surface for subsequent attack by cavitation. Scientists believe that the pressure produced by these cavitation micro-jets can exceed 180,000 psi.
- Cavitation Corrosion - is a combination of cavitation erosion and corrosion, when cavitation jets remove the passive layer on metal surface, it will eventually reform, but indentation in the metal is unavoidable and it intensifies the corrosive attack as the forming top and passivation layers are immediately worn away.
- Cavitation Noise - usually cavitation noise is highly localized to the region immediately downstream of the vena contracta. Reduction or elimination of cavitation is necessary to reduce physical damage to valve parts and the piping system and to reduce the sound pressure level (SPL).
- Vibration - leading to piping fatigue, wandering instrument calibration and eventually valve malfunction
- Flow instabilities - fluid phase is interrupted when cavitation occurs, it affects fluid density and compressibility locally, which limits flow rate in control valves making them choke earlier.

Satisfactory service life of a control valve can be achieved when the effects of cavitation are taken into consideration on sizing and selecting the valve. As outlined in ISA-RP75.23-1995 "Considerations for Evaluating Control Valve Cavitation" successful solutions to cavitation problems still rely heavily on engineering judgements stemming from insight into cavitation basics.

Factors of Cavitation

Major Factors	Challenging Factors	Other Factors
Inlet pressure (P1)	Viscosity	Thermodynamic properties
Outlet pressure (P2)	Mixed fluids	Specific gravity of the fluid
Vapour pressure (Pv)	Fluids with multiple vapour pressures	
Temperature	Corrosion	
Geometry	Particulates in fluids	
Size of valve		

A lot of these factors apply to water, which is a good bench mark but is not an accurate model for all fluids as different fluid properties such as viscosity can dramatically affect cavitation. We use the fluid properties that are available to calculate cavitation. If all the properties are not available, we use the vapour pressure and specific gravity of the fluid.

It is important to understand that we heavily rely on control valve manufacturers to determine when cavitation begins in a control valve and what level of cavitation can be considered tolerable for a specific valve design.

Historically, F_L (Liquid pressure recovery factor) was used to determine whether the valve operates at or near choked conditions, which meant substantial vapour has been formed within the liquid and cavitation exists. Later on F_i and K_C factors were introduced, with Kc value often referred to as the incipient cavitation index.

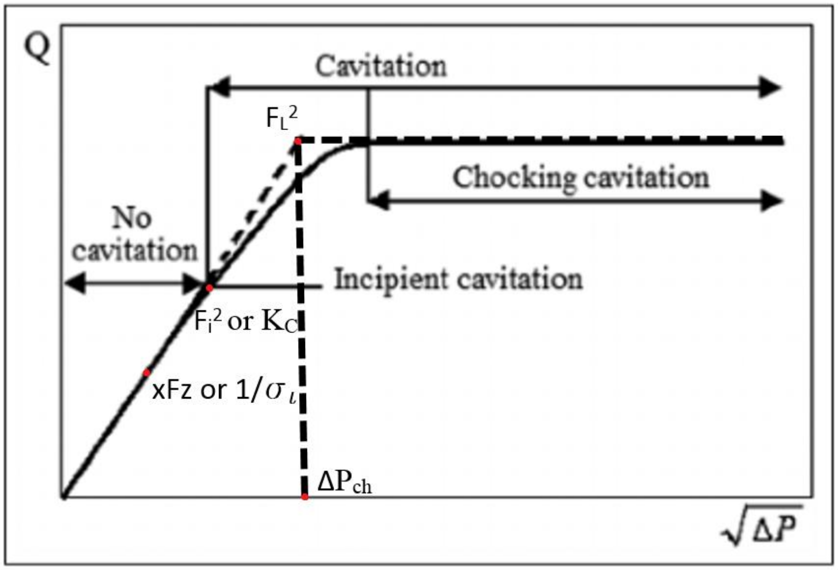


Figure 2. Identification of cavitation by the plot of square root of pressure drop versus flow rate.

However, experiments found that incipient, constant and even damaging cavitation already occurs at the much smaller pressure ratio (marked as xFz on Figure 2). Since the minimum pressure inside the valve, at which cavitation would start, occurs in one of the unsteady vortex cores downstream of the restriction, it cannot be determined by direct measurement.

It is therefore assumed that the minimum pressure p_{min} equals the vapour pressure p_V of the fluid when cavitation noise begins, thus determining the beginning of cavitation and the pressure ratio xFZ by means of noise measurements.

In other words, incipient cavitation in a valve (σ_i or xFz) is experimentally determined by valve manufacturers, and experiments also show that coefficients for incipient, constant, and incipient damage cavitation do not remain constant when different pressures are used or in different sizes of geometrically similar valves. This could explain why similar valves sized for the same set of process conditions by different valve manufacturers sometimes show dissimilar results on whether there will be cavitation present. Although it is evident that the lower σ_i values are (or the closer to 1 xF values are) the worse the damaging effects of cavitation would be, the numerical value of cavitation index at which cavitation begins in each valve is determined by the valve manufacturer.

Depending on the method used to determine the cavitation index IEC-534-8-2 (xFz) or ISA-RP75.23 (σ), once cavitation presence is determined, control valve type selection is dependent on severity of the cavitation.

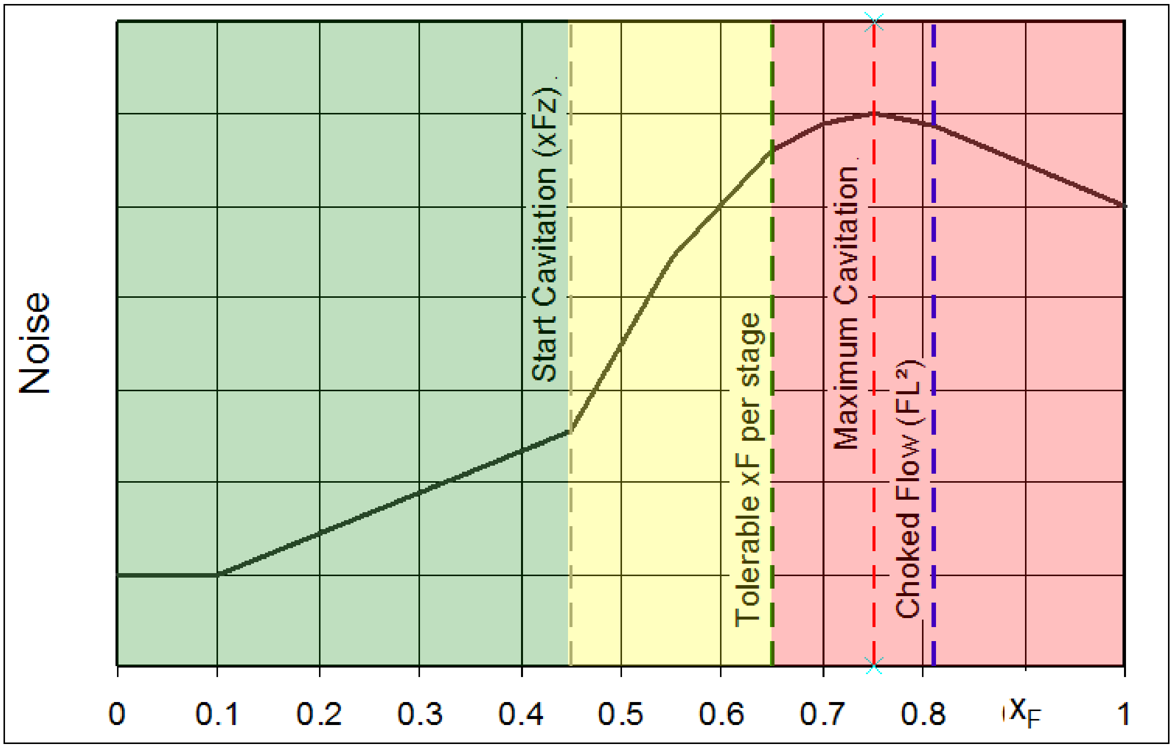


Figure 3. The three regimes (green-yellow-red) are important to identify the severity of the cavitation.

This chart illustrates the noise level as a function of the delta P ratio xF. Up to a point where cavitation starts, we have a linear function between sound and increase of delta p. When the first cavitation bubbles are collapsing and imploding the sound level increases much faster like an inverse parabolic funtion. When we reach the maximum sound level we have reached our maximum cavitation as well. By increasing the delta p we get to the choked flow point where we can't increase the flow rate by simply increasing the delta p. The sound level is decreasing because of a high ratio of gas inside the media. At an xF of 1 we have flashing. This means there is no recovery of the bubbles and the media remains in the gaseous state. Basically we have defined three areas, a green area where no cavitation occurs and therefore no resulting damage. The yellow area designates tolerable cavitation. It begins at the point where cavitation starts up to a point defined by the manufacturer. From that point on we have severe cavitation or damaging cavitation which we need to avoid. This is the red zone.

Pressure ratio xF coefficients are determined through testing by vibration measurement. Curves are generated to predict values for other geometrically similar valves. These values then need to be adjusted for scale, size and process pressure.

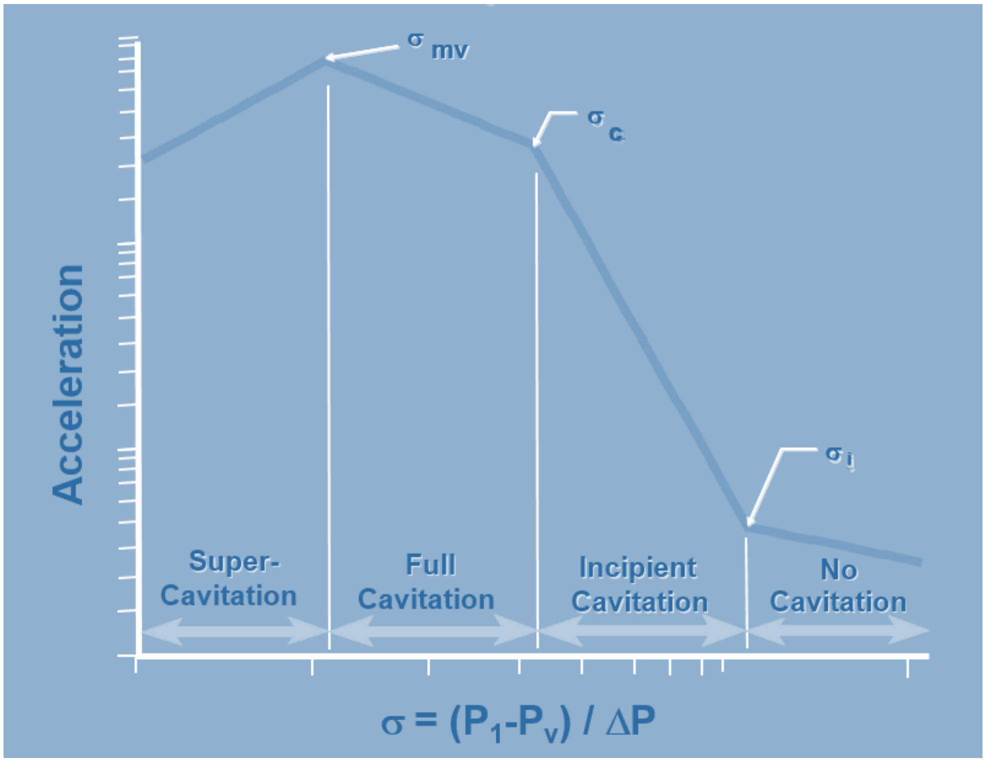


Figure 4. ISA-RP75.23-1995 Cavitation level plot.

This is a representative cavitation vibration level plot showing acceleration vs σ.

Similar correlation is used by most major valve manufacturers. Some manufacturers use velocity or kinetic energy criteria to address cavitation level, which is a part of a comprehensive formulation defining cavitation yet does not necessarily avoid cavitation damage since it depends on topology of the flow field, flow velocity and application pressures.

Once presence and severity of cavitation is established, other factors such as cavitation damage intensity are considered by taking into account PSE (Pressure Scale Effect) and SSE (Size scale effect). For example, Pressure Scale Effect:

Case #1	Case #2
P1 = 500 psia (34 Bar)	P1 = 700 psia (48 Bar)
P2 = 150 psia (10 Bar)	P2 = 196.5 psia (13.4 Bar)
Pv = 45 psia (3 Bar)	Pv = 45 psia (3 Bar)
Sigma = 1.30	Sigma = 1.30

Even though the sigma values are the same the actual cavitation in case #2 is more severe. Severity of cavitation increases with higher pressure (increasing P1-Pv). Also as P1 gets further from P2, the problem gets worse. In most cases, the actual test pressure to determine recommended limiting value for σ above which the valve may be safely operated will be less than 100 PSI, but the severity of cavitation does not remain constant for all pressures or in different sizes of similar valves. To evaluate severity of real cavitation σ needs to be scaled for actual conditions. In other words, even though actual process σ does not change, the recommended σ_{MR} will be higher in Case#2, which means this valve will operate at level of cavitation that is more severe compared to Case#1.

This also demonstrates that σ, by itself does not convey any information about the performance of a particular valve in a particular application.

Simplified explanation for size scale effect is that larger valves can produce larger bubbles, and larger bubbles will have bigger jets and more damage.

Another factor we would consider is frequency and the length of time that a control valve will be operating at a cavitating condition (i.e., continuous, intermittent or infrequent). Sometimes the valve will experience the cavitating condition only during start-up or a rare upset in which case it will not affect overall performance of the valve since the damage effects are time dependent.

There are three ways to address control valve operation with cavitation – containment, prevention and changing the process flow conditions. The latter involves the velocity or pressure drop variation by slightly changing the upstream or downstream pressures, which may lessen the cavitation damage or noise generation. While it can be achieved by relocating the control valve to area with more backpressure or creating backpressure by means of additional downstream equipment such as an orifice plate, it is usually challenging to implement in an established system.

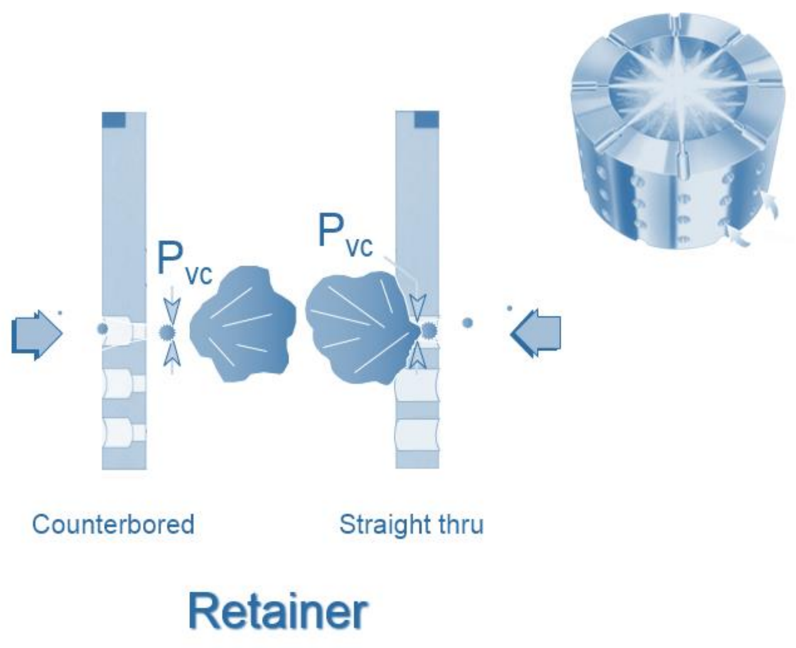


Figure 5. An example of Cavitation containment type control valve retainer.

Containment does not eliminate the cavitation but rather minimizes or isolates the damage through controlling mild cavitation by isolating the cavitation bubbles away from metal surfaces. The most common method of doing this is to use cages with opposing drilled holes. This method can only control low levels of cavitation and does not eliminate it. The resulting collision of the streams causes the cavitation bubbles to implode in the middle of the flow away from the cage and control surfaces. The surrounding liquid absorbs much of the bubbles collapse energy.

As the flow passes through the holes in the retainers shown here, notice what happens to the flow path. Using straight through holes, the vena contracta occurs inside the wall of the retainer. However, counter bored holes push the vena contracta to a point inside the retainer rather than within the wall of the retainer.

Example of containment method in practice helping to handle cavitation and cavitation caused control valve erosion:

Fluid: HP Boiler Feed Water
Service: BFW Inlet from Heater
Unit Name: Hydrogen Manufacturing Unit
Plant: Secondary Upgrader
Shutoff Pressure: 9060 kPag
Operating Temp: 121C
Size/ANSI Class/Material: 1”600 WCC
Solution: Drilled hole seat retainer with stepped holes to move the vena contracta away from metal surfaces.

However, in a similar type of application for a larger valve cavitation has become fully developed and containment method will no longer sufficiently protect the valve, in this case a Multi-stage anti-cavitation valve is required to eliminate cavitation within the control valve. Example:

Fluid: HP Boiler Feed Water
Service: BFW to Gas Oil – BFW Exchanger
Plant: Secondary Upgrader
Shutoff Pressure: 6270 kPag
Operating Temp: 128C
Size/ANSI Class/Material: 2”600 WCC
Solution: 3-stage Anti-Cavitation trim

Ideally, we would prefer to prevent cavitation completely, however in many cases an ability to do so is restricted to lower pressure drop applications. There might be other limitations such as physical space available, process variables, susceptibility of multi-stage trims to plugging and cost. Figure 6 below shows debris produced by corrosion of adjacent piping plugging anti-cavitation trim, gradually reducing its flow capacity and making it inefficient in handling process cavitation:

Figure 6. Plugged Anti-Cavitation trim

A solution that could address both cavitation and contamination would be an axial flow anti-cavitation trim as seen in Figure 7.

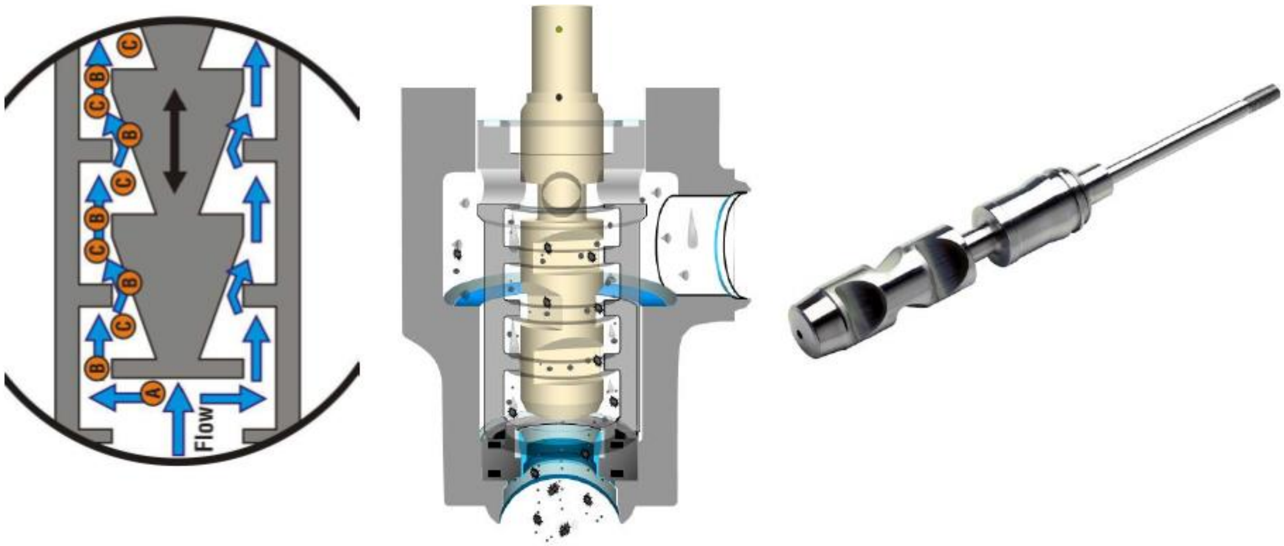


Figure 7. An example of Multi-Stage Axial Trim

Pictures below show trim components of an eccentric rotary plug valve in high temperature cavitating service. The trim material is ceramic - the hardest material available. In ceramic material, microfractures start to appear right from the beginning of the strain without undergoing any noticeable plastic deformation beforehand. As the strain continues, the density of fractures continuously grows. After the incubation time has elapsed, the fractures have spread and joined each other, and breakages occur.

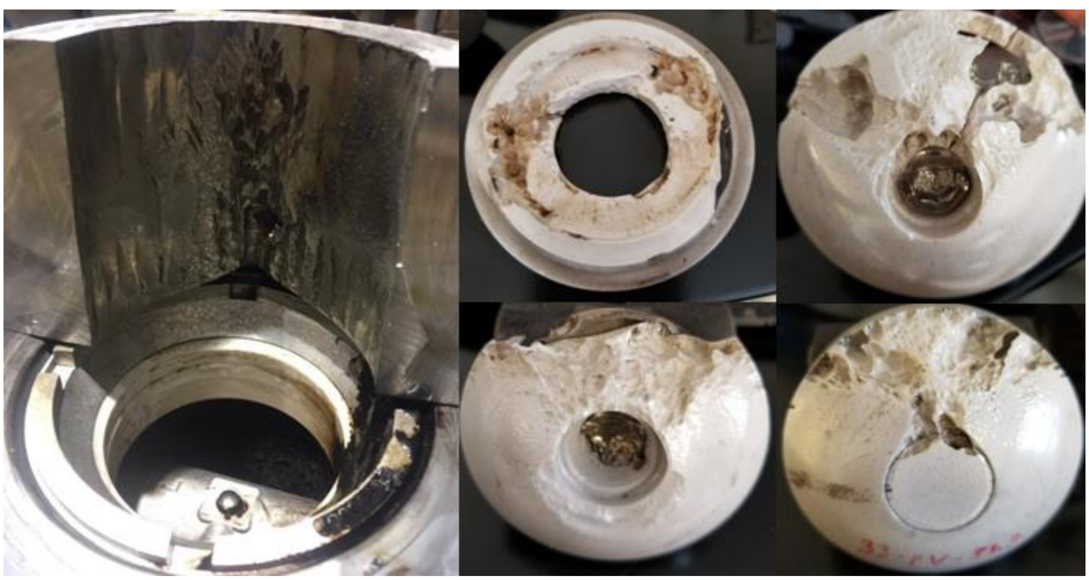


Figure 8. Cavitation damage on ceramic trim.

The nature of this application (furnace feed) makes multi-stage radial or multi-stage axial flow anti-cavitation trims impractical as high viscosity, high solids content media forbids any tortuous flow path solution.

Different valves can tolerate different levels of cavitation and different applications are concerned about different aspects of cavitation. At this point customer history and application history would also be useful for more accurate process data interpretation.

The following “cavitation zone type” approach to control valve selection comprises experience and experience-based preferences and builds on the physical science behind evaluating control valve cavitation.

If cavitation is in incipient zone and progresses to constant cavitation (yellow region) hardened trim materials exposed to this level of cavitation may not be damaged under certain conditions of low Cv or ΔP or intermittent or infrequent service. The service σ is in a potentially damaging regime, but the application may avoid damage with hardened trim due to low Cv or low ΔP considerations. Eccentric rotary type valves can be selected with shaft upstream and a hardened seat ring, alternatively linear globe valves with hardened trim materials should be used. The preferred flow direction would be “flow-up” to take advantage of lower F_L factor. The choice between rotary and linear valve is usually determined by size and required flow capacity. The body may require an erosion resistant alloy or angle configuration to avoid erosion by the cavitating flow stream if the flow rate is increased.

Full cavitation (red zone up to maximum cavitation) should be handled according to the valve type. For linear globe and eccentric rotary plug valves, full cavitation exists at these conditions and may cause damage to the valve. Noise and vibration may be objectionable for eccentric rotary plug valves (operation at above 85 dBa should be avoided). Hardened trim must be used to minimize cavitation damage. Erosion-resistant alloys (body may require chrome-moly) and/or angle configuration is recommended for the body. In hydrocarbon mixtures or liquid-gas flow at moderate pressure (P1 less than 600 psi or 41 bar), damage may be minimal or non-existent at these conditions. Hydrocarbon mixtures, mixed phase flows or cryogenic liquids at low pressure may produce enough ‘degassing’ or thermodynamic mitigation to avoid cavitation damage on hardened materials, but noise and vibration may still be a hazard.

For v-ball and butterfly valves, full cavitation may cause damaging vibration and noise making cavitation erosion of downstream piping likely. Butterfly or v-ball valves should not be used at these conditions unless the condition occurs only in rare process upsets and in piping structures designed to resist damage from severe vibration, high-noise levels and erosion.

Super Cavitation (maximum red one cavitation) - indicates that conditions are at or approaching choked flow. Standard valve operation should be avoided at these conditions. Water and other refined liquids will cause severe cavitation erosion in the valve or downstream piping, while vibration and noise may be hazardous to the structure, equipment and people. Hydrocarbon mixtures, mixed-phase flows or cryogenic liquids at low pressure may produce enough ‘degassing’ or thermodynamic mitigation to avoid cavitation damage on hardened materials, but noise and vibration may still be a hazard. Rotary valves should never be operated at these conditions. Linear globe valves or angle valves may be required with cavitation-resistant trim and body materials. Multi-stage anti-cavitation trim most likely will be required.

Flashing

Flashing occurs when the downstream pressure of a control valve is less than the upstream vapour pressure, part of the liquid changes to a vapour and remains in a vapour state, and the fluid continues downstream as a liquid-gas mixture. The result is a two-phase mixture (vapour and liquid) at the valve outlet and in the downstream piping. The increased volume of this mixture increases the overall velocity, which leads to excessive noise and erosion. Small amounts of flashing (even 1-3% by weight) can significantly affect valve sizing and selection. Large amounts of flashing (e.g. 10-15% by weight) require special valve design and materials.

Eliminating flashing completely involves a modification of the downstream pressure or the vapour pressure. Other alternatives include using hardened materials for affected surfaces or relocating the valve so that it discharges into a larger vessel and away from critical surfaces.

Flashing is defined by the liquid vapour pressure and downstream pressure and is not something that can be prevented.

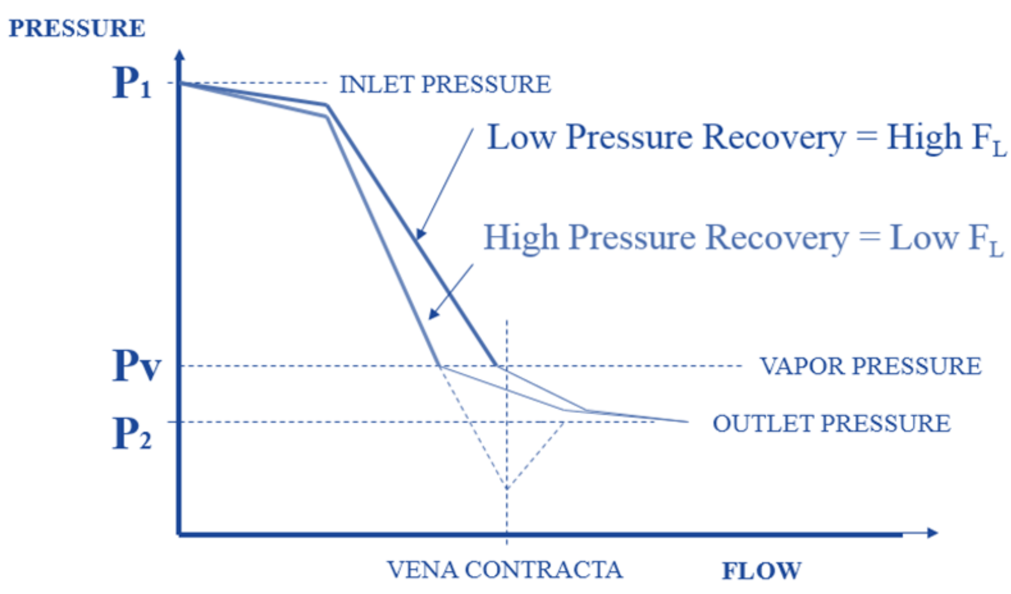


Figure 9. Pressure profile for control valve in flashing service

Flashing damage is a form of Erosion damage caused by two-Phase flow stream, it can produce serious erosion damage to the valve trim parts and is characterized by a smooth, polished appearance of the eroded surface, with furrows parallel to the flow path; and is typified by local area material removal, in areas of high velocity or turbulence.

The eroded areas are generally broader areas of attack then with Cavitation damage with a feathering of the wear areas to unworn areas.

Since flashing occurs over a discrete time phase, the damage extends over a large area.

Figure 10. Flashing erosion damage in control valve trim.

Flashing damage is common on Carbon Steel valve and piping materials. Damage can be reduced by upgrading piping and valve materials, hardening the surface of the parts and reducing the angle of impact.

Back pressure plates can be used to increase P2 pressure and prevent the Flashing from occurring in the valve and pipe or use fixed capacity restrictor downstream of the valve.

However, in most applications flashing damage can only be contained.

- Harder materials – erosion damage can be limited by using chrome-moly body material (ASTM A217 Grades C5 of WC9) and hardened trim are frequently required when flashing velocity exceeds a few hundred feet per second. Careful consideration is required for alloy piping immediately downstream of a severe flashing valve.
- Angle body valve - Maximum material loss is seen at different impact angles for both ductile and brittle materials. Wear on ductile material is a cutting type (i.e. wire-draw) while brittle material exhibits impact damage. Angle control valve keeps the fluid moving parallel to the surface, a feature that is critical to slowing erosion. The Angle valve body provides for a smooth transition in flow direction and reduces the fluid velocity and hence wear in the valve body. The sweep angle design allows the process fluid to flow cleanly, without sharp turns or stagnant points. This design directs the energy of flashing process fluids away from critical equipment.
- Lower outlet velocity. The key to containment of flashing damage is energy management, high fluid velocities at controlling surfaces equals high particulate impact energies. It is important to keep velocities below 500 feet per second. Expanded outlet style valves – such as the Mark One-X – help to control outlet velocities on such applications. If possible, mount valve outlet directly on flash vessel inlet Increase outlet piping to reduce velocities. On smaller valve applications which remain closed for most of the time – such as heater drain valves – higher velocities of 800 to 1500 feet per second may be acceptable with appropriate materials.

- Straight pipe extension following valve - avoid elbows immediately downstream a severe flashing valve.

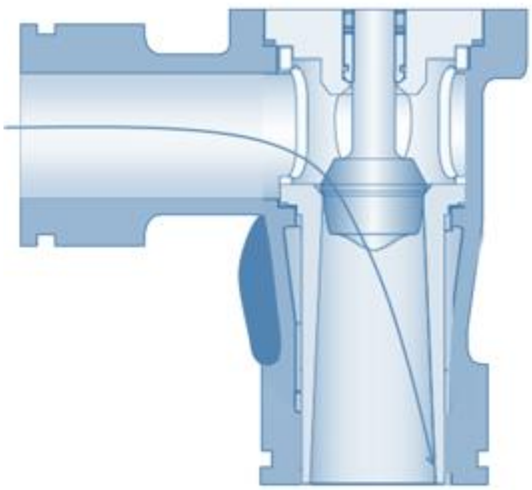


Figure 11. Angle Body / Venturi Liner

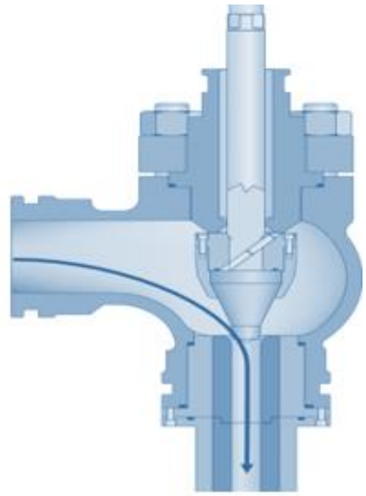


Figure 12. Sweep Angle Body Type

As mentioned above, velocities in the valve and downstream pipe are a primary consideration for making proper valve and trim selections. Excessive velocity in the downstream pipe can build up significant back-pressure on the valve, such that very small pressure variations could cause cavitation rather than flashing in the valve. If the valve trim is not designed for this possibility, severe damage to the valve will result.

Since this paper focuses on practical guide for Severe Service control valve selection, we will not go into details of calculating flash fraction and flashing flow velocity.

Valtek has established our own methods to evaluate flashing, which include limitations on velocity. The flowrate is assumed to be the same as it would be when the valve is fully choked. The calculations are less accurate if the vapour pressure is much higher than the downstream pressure and approaches the upstream pressure. (P166 Les Driskell: Control valve selection and sizing: Published by ISA)

For fluids other than water, we prefer to use the fluid properties supplied by the user. We will use other available fluid data if needed. Flashing is then calculated using the standard sizing equations

For three phase flashing applications we use a mass/ flux methodology, which assumes choked flow, Flux is the amount of change, we calculate the mass.

Since this paper focuses on practical guide for Severe Service control valve selection, we will not go into details of calculating flash fraction and flashing flow velocity.

Valve style and trim type selection process depicted below comprises proven standards and methods with applied sound engineering experience, the aim is always to enhance the reliability of control valves.

Flashing applications are often the ones where Total cost of ownership gets overlooked - either fluid properties are incomplete and hence there is low likelihood of predicting flash fraction and velocity accurately, or other assumptions are made during sizing and selection process leading to selecting V-ball type or another rotary valve to throttle in flashing application. Clear and direct communication is a key for selecting technically sound solution. In our experience we have seen V-ball and rotary plug valves in flashing Black Liquor applications with trim completely disappeared down the pipeline in the matter of hours after start-up, despite having “heavy-duty” hardened trim configuration.

This brings up back to the maxim that the “application dictates the valve”.

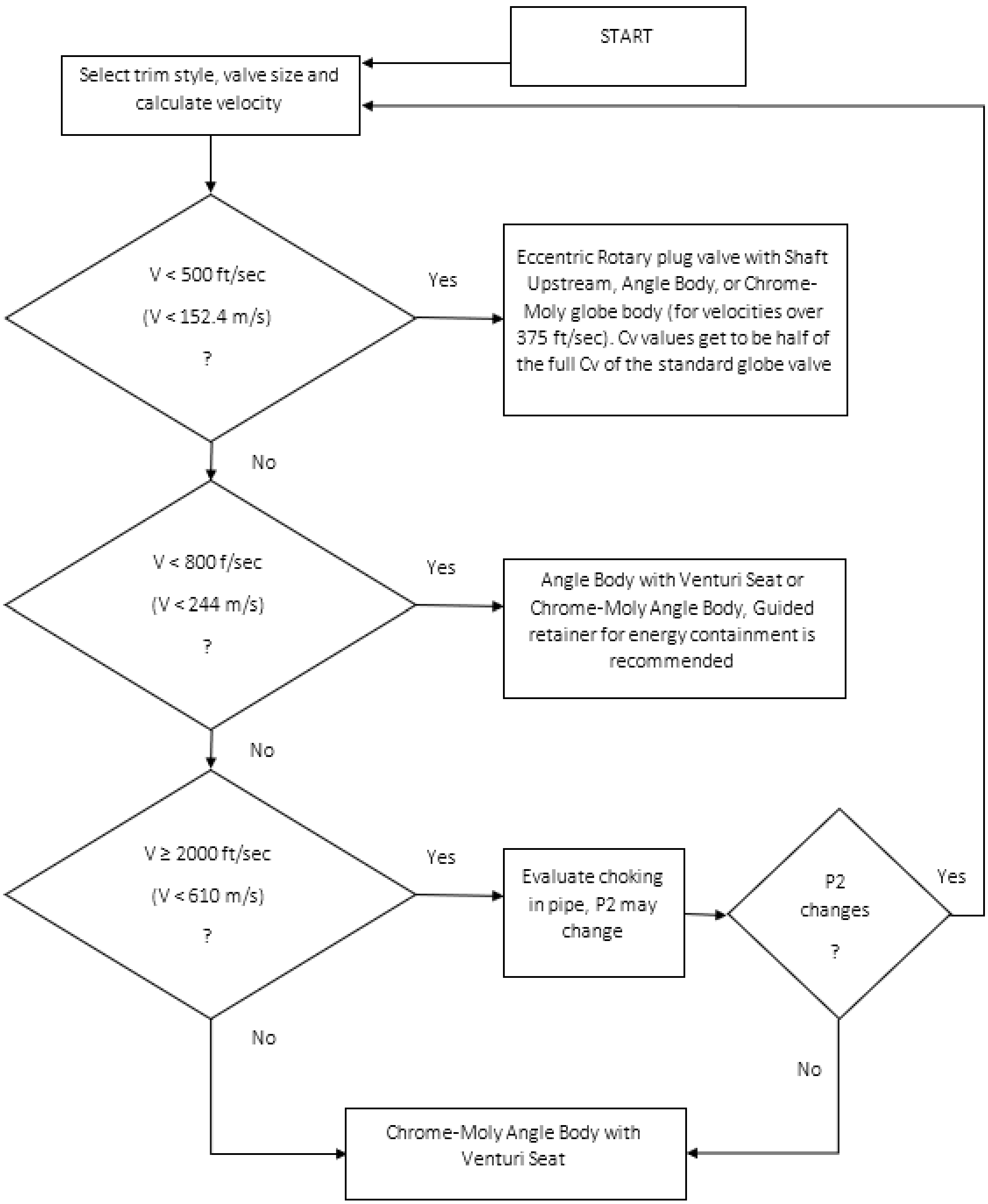


Figure 13. Flow chart for selecting valve type, body and seat for flashing service

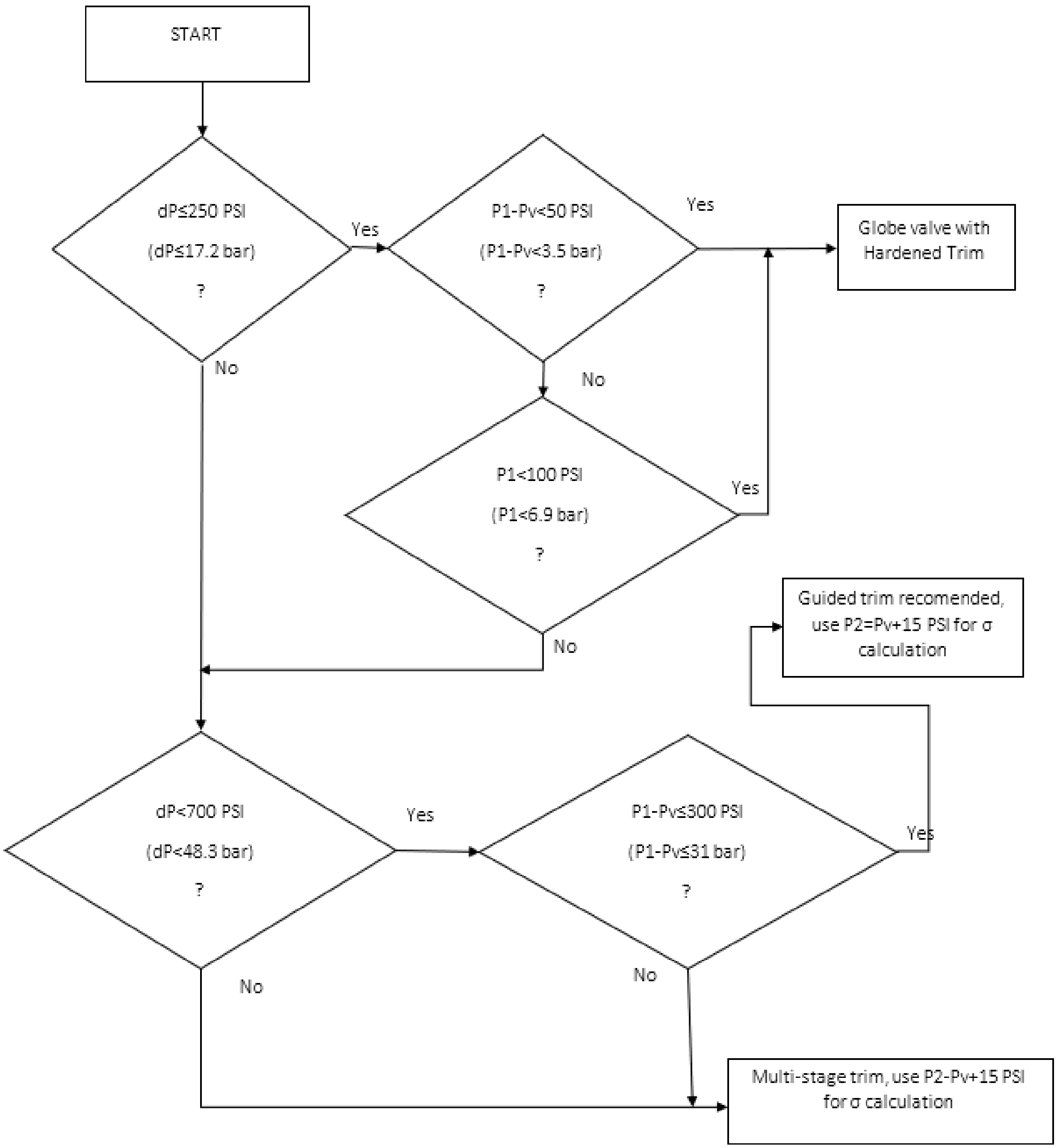


Figure 14. Flowchart for selecting trim styles for flashing service

Noise

Control valve noise is generated by high pressure drops across the valve, and by the subsequent turbulence downstream, it radiates to the surroundings by the down-stream piping system. There are three major sources of control valve noise generation: mechanical, hydrodynamic, and aerodynamic.

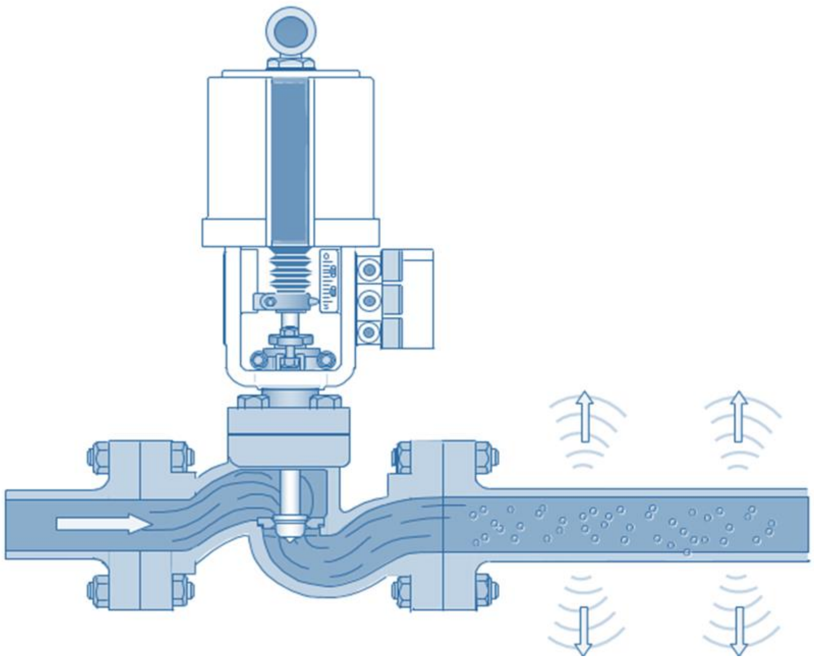


Figure 15. Control Valve noise generation

High flow velocity, the main component in control valve noise generation, is caused by the sharp pressure reduction at the vena contracta. Although velocities can be very high at the vena contracta, very little noise is generated up to this point. Although, the high velocities generated are the major contributors to noise generation, only a very small fraction of the energy converted is converted to noise. The noise energy, however, can be so apparent that it seems like it must be a much higher percentage of the energy. Tests have demonstrated that control valve noise increases proportional to the velocity cubed ($SPL \approx V^3$). Noise is generated as velocities in the valve increase and substantial noise can be generated even where velocities are significantly less than sonic.

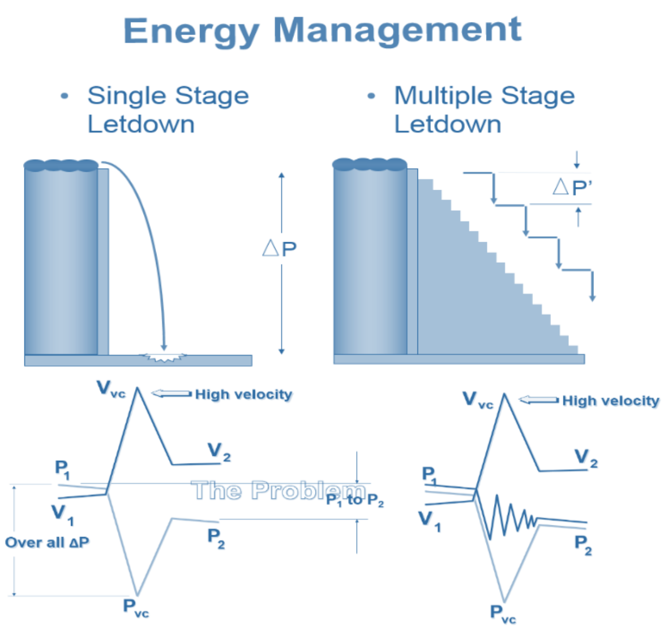
High mechanical vibration levels accompany high acoustic noise levels. These vibrations are often main reason for control valve failures, as it causes wear, broken parts, and flow instabilities. Mechanical linkages connecting valve to positioner for stem position control are usually heavily impacted causing valve hunting and eventually loss of control. Constant high vibration can also lead to actuator failures and premature trim erosion through constant mechanical contact. Most importantly high noise levels can cause hearing damage to nearby workers.

In summary, common issues caused by high noise levels:

- Trim and Body Wear
- Downstream Piping Erosion
- Pipe Vibration
- Acoustic Noise
- Poor Control
- High Maintenance Costs and Time
- Expensive Downtime
- Lost Production
- Damage to System Components

In situations where equipment damage or personal injury could be caused by a noise source, noise attenuation is not only desired, it is mandatory.

IEC 60534-8-3 aerodynamic and IEC 60534-8-4 hydrodynamic noise prediction methods are integrated into most control valve sizing software. It is important to keep in mind that the standard itself states in the introduction, “Although this prediction method cannot guarantee actual results in the field, it yields calculated predictions within 5 dB(A) for the majority of noise data from tests under laboratory conditions.” In some instances, the 5 dBa difference in predicted noise level can decide a choice of one control valve over another.



The solution to high levels of control valve noise is to reduce the pressure from the valve inlet to outlet gradually, avoiding the effects of a large pressure drop at any vena contracta.

Thus, velocities are maintained at acceptable levels throughout the valve and high noise levels are not generated. This requires not only controlling the velocity through the valve trim but at all points from the inlet to the outlet of the valve.

Several of the following factors must be considered before multi-stage noise suppression equipment is chosen:

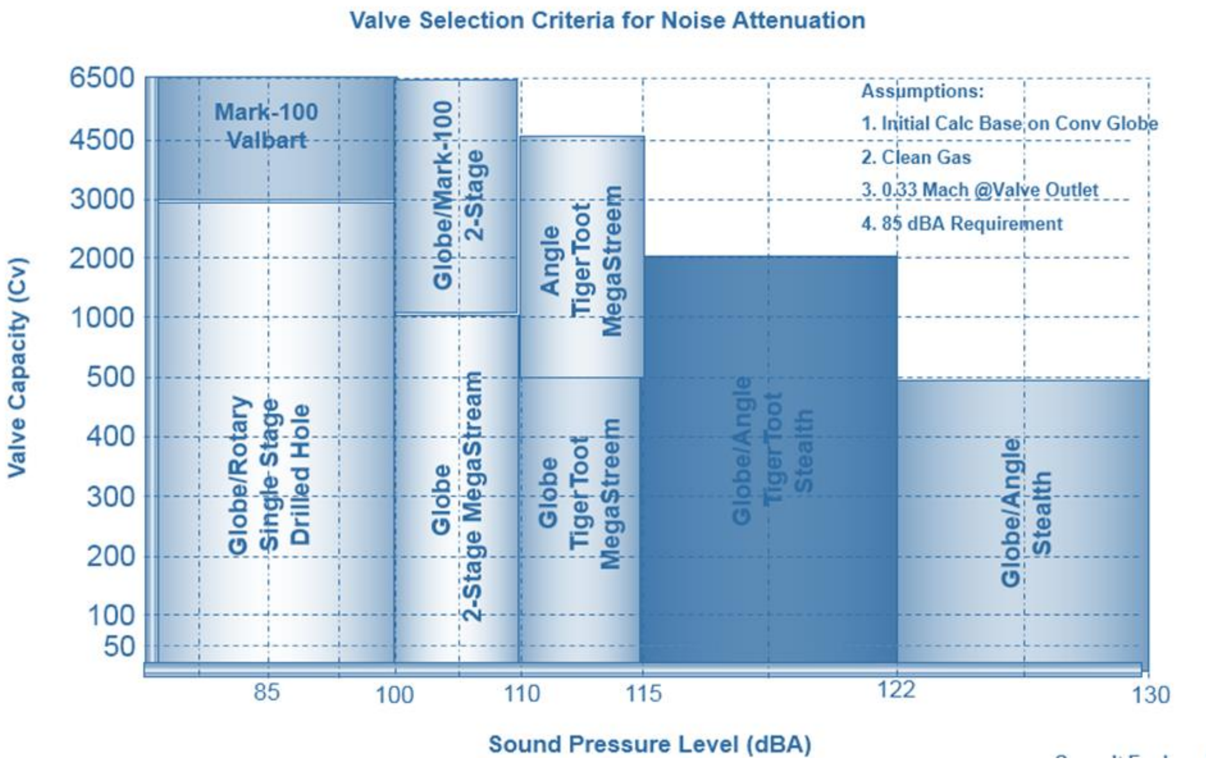
- How much noise attenuation is required?
- Are the alternative ways for noise attenuation?
- If noise attenuation devices are necessary, what lower-cost equipment can be specified?

If the predicted sound pressure level (SPL) exceeds 85 or 90 dBA, noise suppression devices should be considered. However, higher noise levels may be acceptable if the noise is not associated with equipment damage and is in a remote location away from people.

Noise Abatement control valve selection considerations:

- Valve style selection plays an important role in noise control. For example, 50% of the noise generated in butterfly valves is transmitted downstream, but only 25% of the noise created by globe valves is transmitted downstream.
- Resonant effects of piping systems can substantially amplify the sound pressure level of a system. At certain frequencies (it varies for different systems) downstream pipe acts as a wave-guide allowing noise to exit the system without any attenuation from the pipe walls. This effect can be controlled by changing the frequency of the sound waves, accomplished by reducing (in some cases increasing) the size of the outlet orifice.
- Small exit orifice can be engineered to produce sound frequencies above audible levels (much like a dog whistle), effectively reducing the noise generation of the process.
- Noise generation is a function of velocity or Mach number, which correlates with the P1/P2 ratio. Reducing the velocity through the valve is an effective means of noise attenuation.
- High Mach levels at the valve exit can generate high sound pressure levels eclipsing the noise generated by the valve itself. For this reason, it is recommended to maintain exit velocities less than 0.30 mach.
- Pressure drops in small stages, as mentioned above, mitigate noise generation by reducing the process velocity.
- Direction Angles can result in up to 15dBA noise reduction in venting applications.
- Sound Pressure Levels are normally reduced 5 dBA for each doubling of the distance from the source. Long distances will reduce noise even more due to the atmospheric absorption and attenuating effects of surrounding objects, walls and ground.
- Pipeline wall thickness and insulation - Pipes that are thicker are less excitable by these compressions and allow less noise energy to pass through and therefore less noise is propagated to the atmosphere. Also, some pipe coatings such as thermal or acoustic insulation dampen pipe vibrations and impede the transmission of noise to the atmosphere.
- Some valve applications benefit significantly by using a downstream plate to assist with the pressure drop in the system. Downstream noise reduction devices can be selected in series with a valve to attenuate noise to the acceptable SPL required. For example, a downstream plate or diffuser, when installed downstream from a standard control valve, provides about the same dBA reduction as a one or two-stage Noise-attenuating valve, but at a lower cost. For extremely high-pressure drops where multistage valve trim should be considered, it may be a cost-effective option to install a plate, diffuser, silencer or vent element downstream from a smaller one or two-stage noise-attenuating valve.

Most of the measures mentioned above allow noise attenuation usually up to 15 dBA, high noise attenuation requires multi-stage trims. Various trim designs for multi-stage pressure drop are commercially available, the more noise level reduction is required the more sophisticated specialized trim can be used. Some trims utilize multiple pressure reducing mechanisms allowing them to reduce noise more efficiently, below just shows an example of how various levels of engineered trims can be employed depending on level of noise reduction required:

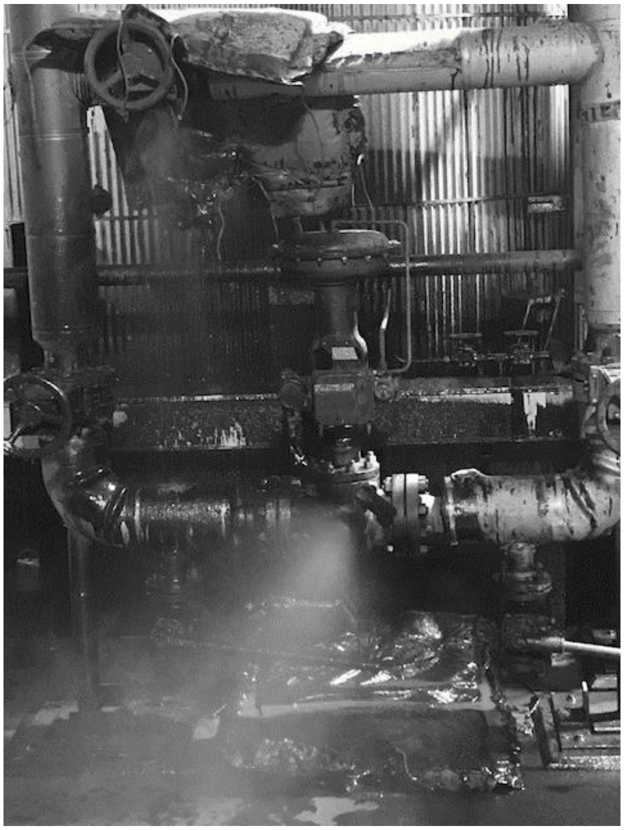


There are applications that do not allow any significant flow area reductions usually employed by noise attenuating trims due to high clogging potential. Such applications include Natural Gas pressure reduction stations where elemental sulphur deposition phenomena occurs, or Joule Thomson valves with potential for hydrate crystal deposition. Such valves should be designed using the approach of modifying the geometry or materials to handle high velocities and high pressure drops. There are examples of valves that have operated successfully at very high velocities and pressure drops, e.g. in *Control Valves*, *Practical Guides for Measurement and Control*, edited by Guy Borden Jr., published by ISA, a case is given of a valve with one pressure-reducing stage which successfully handled letdown pressures over 3,000 psi, temperatures as high as 454°C (850 °F) and with a high concentration of entrained solids by using a low-impingement angle valve and with hardened trim materials. This approach may have saved the customer significantly in cost and operability.

Conclusion

Control valve applications are generally considered severe if they are likely to cause equipment damage, or if conditions are beyond the scope of standard designs. We have prediction methods at our disposal to identify existence of this type of conditions in control valves, and MSS will give a clear indication of severe service thresholds for control valves. The proper selection is crucial to the successful performance of any Severe Service Control Valve. Major expenses for equipment and future maintenance hang in the balance over making the right selection. Although some attempts have been made to clearly identify Severe Service Valves at a project design stage, for example through reliability index R_I, it is crucial to maintain a level of expertise between suppliers, users and contractors in selecting correct control valves for the most challenging applications, since as shown above, even accuracy of incipient cavitation prediction largely depends on the quality of information provided, as well as calculation methods used by the valve manufacturer.

New industrial process systems are operating at higher pressures and with higher pressure drops, there is also greater emphasis in industry on safety and on efficient resource management, hence providing the industry with helpful information and methods for identifying and finding solutions for severe service applications is seen by the authors as a critical task. There is no expectation for the end users to manage sizing and selection process, yet an ability to predict reliability challenges through awareness of abnormal conditions and severe service phenomena like cavitation, flashing and high noise, is critical. Too often in the field we see unfit general service control valves, supplied for, for example, severely cavitating conditions, like the screen wash water tank recycle below:



This type of failures can and should be prevented through selecting correct control valve for the application.