Tech Sheet #CVR 410

Control Valve Sizing and Selection Considerations

Control valve sizing and selection can be a complicated process that involves a number of interrelated factors. First and foremost, it is necessary to determine if a control valve is even the appropriate piece of equipment to use. Oftentimes, depending on the application, a regulator is sufficient in lieu of a control valve. FCI's Tech Sheet #CVR 407 "Selection Considerations for Control Valves vs. Regulators" is a useful resource for determining which is more applicable. Once a control valve is confirmed to be necessary, there are several considerations to evaluate when choosing the right one.

Application Considerations – Service Conditions

The intended application must be analyzed to determine several important factors that will dictate valve requirements. The control valve industry has developed relatively standardized specification sheets, sometimes referred to as valve data sheets, that can help gather that information. IEC 60534-7 and ISA S20.50 (Figure 1) are good examples of this, and many valve manufacturers have their own versions available as well. Some of the typical parameters included are outlined below:

- Process fluid type
- Process fluid viscosity
- Process fluid specific gravity
- Min/Max/Normal inlet pressure
- Min/Max/Normal flow capacity
- Min/Max/Normal pressure drop
- Max shutoff pressure drop
- Flow characterization requirements
- Min/Max/Normal process temperature
- Noise requirements
- Piping size/schedule/end connections
- Actuation requirements

ISA S20 — **Specification Forms for Process Measurement and Control Instruments, Primary Elements and Control Valves**

PROJECT **Demo Project**	DATA SHEET ___ of ___
UNIT	SPEC
P.O.	TAG
ITEM	DWG
CONTRACT	SERVICE
MFR SERIAL*	

#		Units	Max FLow	Norm Flow	Min Flow	Shut-Off	
1	Fluid				Cr. Press Pc **3208.2148 psiA**		
	SERVICE CONDITIONS	Units	Max FLow	Norm Flow	Min Flow	Shut-Off	
2	Flow Rate	**gpm**	**250**		**50**	**-**	
3	Inlet Pressure	**psiA**	**20**		**29.4**		
4	Outlet Pressure	**psiA**	**14.7**		**14.7**		
5	Inlet Temperature	**degF**	**60**		**60**		
6	Spec Wt/Spec Grav/Mol Wt					**-**	
7	Viscosity/Spec Heats Ratio	**cp**				**-**	
8	Vapor Pressure Pv	**psiA**	**0.337**		**0.337**	**-**	
9	*Required Cv	**FpCv**	**108.64**		**13.05**	**-**	
10	*Travel	**%**	**90.1 ***		**34.2**	**0**	
11	Allowable/*Predicted SPL	**dBA**	**/ 55**	**/**	**/ 49**	**-**	
12							

LINE
13 Pipe Line Size In **2 | 40**
14 & Schedule Out **2 | 40**
15 Pipe Line Insulation

VALVE BODY/BONNET
16 *Type **ALL**
17 *Size **AUTOM** ANSI Class **ALL ANSI**
18 Max Press/Temp
19 *Mfr & Model **RE**
20 *Body/Bonnet Matl
21 *Liner Material/ID
22 End In
23 Connection Out
24 Flg Face Finnish
25 End Ext/Matl
26 *Flow Direction
27 *Type of Bonnet
28 Lub & Iso Valve Lube
29 *Packing Material
30 *Packing Type
31

TRIM
32 *Type
33 *Size
34 Rated Travel *Characteristic
35 *Balanced/Unbalanced
36 *Rated Cv **180** Fl Xt
37 *Plug/Ball/Disk Material
38 *Seat Material
39 *Cage/Guide Material
40 *Stem Material
41
42

SPECIALS/ACCESSORIES
43 NEC Class Group Div
44
45
46
47
48
49
50
51
52

ACTUATOR
53 *Type **SPRING TO CLOSE CYLINDER ACTUATOR**
54 *Mfr & Model **B1J**
55 *Size **AUTOM** Eff Area
56 On/Off Modulation
57 Spring Action Open/Close
58 *Max Allowable Pressure
59 *Min Required Pressure
60 **Available Air Supply Pressure:**
61 Max **4.2** Min
62 *Bench Range /
63 Act Orientation
64 Handwheel Type
65 Air Failure Valve Set at
66
67 Input Signal

POSITIONER
68 *Type
69 *Mfr & Model
70 *On Incr Signal Output Incr/Decr
71 Gauges By-Pass
72 *Cam Characteristic
73

SWITCHES
74 *Type Quantity
75 *Mfr & Model
76 Contacts/Rating
77 Actuation Points
78

AIR SET
79 *Mfr & Model
80 *Set Pressure
81 Filter Gauge
82

TESTS
83 *Hydro Pressure
84 ANSI/FCI Leakage Class
85
86

Rev	Date	Revision	Orig	App

*Information supplied by manufactuter unless already specified

Figure 1 ISA S20.50 Valve Data Sheet

This Tech Sheet was developed by the members of the Fluid Controls Institute (FCI) Control Valve/Regulator/Solenoid Valve Section. FCI is a trade association comprising of the leading manufacturers of fluid control and conditioning equipment. FCI Tech Sheets are information tools and should not be used as substitutes for instruction from individual manufacturers. Always consult with individual manufacturers for specific instructions regarding their equipment.

Valve Style

Many different styles of control valves have been developed, but they are generally divided into two major groups: sliding stem and rotary. Sliding stem valves, also referred to as linear valves, operate by moving the closure member up and down to change the exposed flow area in a trim set, while rotary valves rotate the closure member to adjust flow area. Additional information regarding different valve styles can be found in FCI's "Overview of Control Valves" literature.

A common example of a sliding stem control valve is the globe valve, which comes in a wide variety of options. There are numerous trim styles available for globe valves that can help the end user tailor the valve to a specific process and achieve tight process control. These valves often require relatively large face-to-face dimensions but can handle significant pressure drops. They are available in single-port or multi-port configurations and may be straight or angle bodies.

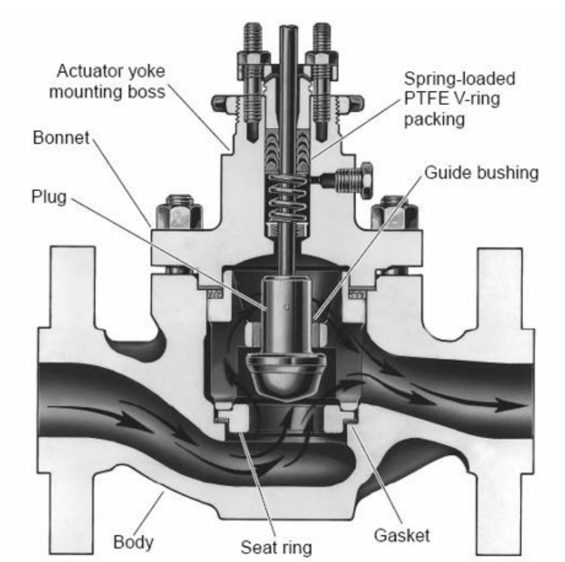

Figure 2 Globe Valve

Rotary control valves include full ball valves, segmented ball valves, and butterfly valves. Although they are oftentimes slightly less effective at controlling the process compared to a globe valve, they typically allow for higher capacity and have reduced pressure loss through the valve, particularly for full-port ball valves. There are generally fewer trim options for rotary valves compared to sliding stem valves, but they have minimal face-to-face dimension requirements, particularly butterfly valves.

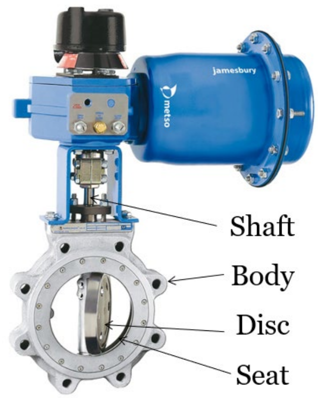

Figure 3 Butterfly Valve

Valve Sizing - Rated Capacity

Valve size is heavily dependent on the valve type – two valves may be the same nominal diameter, but they can have vastly different capacity and performance. Most valve manufacturers will have sizing software or similar tools for their specific valves available to assist in this step; expert application engineers are also generally available to provide further assistance in refining the valve requirements. The calculations necessary to determine capacity are covered by ISA S75.01.

When describing valve capacity, an experimentally determined flow coefficient, C_V (standard units) or K_V (metric units), is used to convey how much fluid the valve can pass through it for a given set of flow conditions. One C_V is the ability to pass one gallon of water at 60°F through the valve over the course of one minute with a 1 psid pressure drop across the valve. This coefficient can be applied under different pressure and temperature conditions to determine what the flow rate would be using the below simplified equation:

$$Q = \frac{C_V}{\sqrt{\frac{S_g}{\Delta P}}}$$

C_V = valve flow coefficient
Q = flowrate (GPM)
S_g = process fluid specific gravity
ΔP = pressure drop (psid)

Once the required flowrate at a given set of process conditions is identified, the C_V needed to achieve that flowrate can be calculated. Then it's a matter of finding an appropriate valve that can provide that C_V.

However, the above equation is an overly simplified version. There are several additional factors that can play into the calculation. For example, this equation assumes turbulent flow, but if flowrates and Reynolds numbers are low enough, the valve may be operating in a laminar flow regime. FCI's Tech Sheet #CVR 403 "Laminar Flow Valve Sizing Made Easy" provides guidance for this particular situation. Similarly, the equation assumes the valve's capacity is sufficiently lower than a bare pipe of the same diameter, so it starts to break down when calculating high-capacity valves like full-bore ball valves. Other things like compressible vs incompressible flow will also factor into an accurate calculation, as well as the piping that is installed upstream and downstream of the valve.

Trim Selection - Flow Characteristics

Finding a valve that has the required maximum capacity is only the first step. Control valves are meant to throttle a process to maintain setpoints across a range of process conditions. Unlike isolation valves that are either fully open or fully closed, control valves are intended to regularly operate in their mid-travel regions. The trim installed in a valve will dictate the valve's performance, or flow characteristic. The flow characteristic for a valve determines how the valve's capacity changes across the travel range. Most valves will have published values for the inherent flow characteristic, which refers to the capacity curve observed with a constant pressure drop across the valve. Alternatively, installed characteristic refers to the curve actually observed in service with varied pressure drops and other changes in the flow system.

There are several different types of common flow characteristics, including linear, equal percentage, quick opening, modified parabolic, hyperbolic, etc.

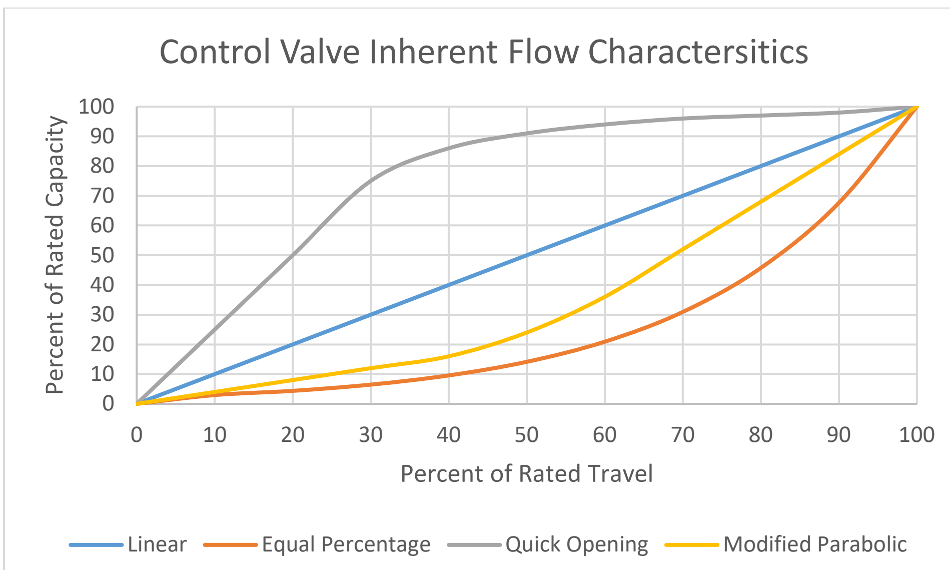

Figure 4: Inherent Flow Characteristics

Ideally, a thorough dynamic analysis of a flow system would be conducted to determine the necessary controls performance and therefore the necessary flow characteristic. In general, an inherent flow characteristic that results in a linear installed flow characteristic is ideal.

In addition to the flow characteristic, rangeability (or turn-down) of the valve should be considered. This refers to the ratio of maximum capacity relative to minimum controllable capacity. Some valves struggle to accurately maintain control at very low travels, so it cannot necessarily be assumed that the full range of the flow curve is available for use in throttling scenarios.

Trim Selection - Cavitation and Flashing

Beyond capacity, the valve trim can also help with other issues that may be caused by process conditions. One of the most common such issues is cavitation and flashing. Cavitation is a phenomenon that occurs when the pressure downstream of a valve, generally at the vena contracta, drops below the vapor pressure of the liquid process fluid. This causes the fluid to transition to a vapor and create bubbles. If the pressure remains below the vapor pressure after the flow recovers, it results in flashing. If the pressure recovers above the vapor pressure, the bubbles that had formed collapse and create high velocity jets that can damage valves and piping. It also results in significant noise, which can be further explored in IEC 60534-8-4.

If possible, these pressure conditions should be avoided. However, that is not always possible, so several valve manufacturers have anti-cavitation trims available that reduce or eliminate the effects of cavitation. This can be accomplished by such methods as using a special geometry for the cage itself or by introducing staged pressure drops. Special materials or coatings that can stand up to the abuse of cavitation or flashing may also be available.

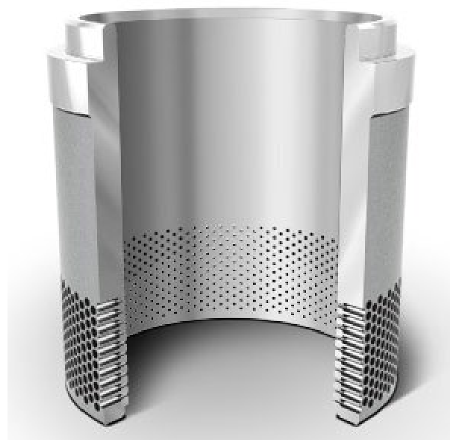

Figure 5: Cutaway of Multi-Hole Anti-Cavitation Globe Valve Cage Trim

Trim Selection - Aerodynamic Noise

While cavitation is a significant source of noise for control valves, it is not the only source. Compressible fluids produce aerodynamic noise that can also cause issues. IEC 60534-8-3 provides guidance for predicting aerodynamic noise, but most valve manufacturers will also provide their own predictions. The following is a simplified overview of how to predict noise:

1. Determine stream power at vena contracta based on flow velocity
2. Convert to noise power at valve outlet using acoustic efficiency for chosen valve
    a. IEC provides general efficiency coefficients for given valve types, but some manufacturers will experimentally determine them
3. Convert sound power to sound pressure level (SPL)
4. Determine A-weighted external SPL based on transmission loss through pipe
5. Translate SPL to standard observer location based on distance from piping

When examining aerodynamic noise, it is important to take into account a number of factors. Process conditions, particularly pressure drop ratio and flow velocity, will have a large impact on the resulting noise, but things like piping will also play a role, particularly when looking at valve outlet noise. Another thing to consider when proscribing valve noise requirements is nearby equipment, like pumps and compressors, or other environmental conditions, e.g., wave noise on offshore platforms, that may be contributing more noise than the valve itself.

If aerodynamic noise is an issue, however, there are noise attenuation trims that can minimize it. Similar to anti-cavitation trims, these are largely based on the geometry of the valve. Smaller flow passages can help to minimize exit jet size and prevent jet coalescence, both of which contribute to higher noise levels. Pressure staging can also help to reduce noise, as well as torturous path or multi-turn trims. These source treatment options may also be used in conjunction with path treatment options like acoustic insulation or in-line silencers to further reduce noise.

Figure 6 Globe Valve Cage Trim Utilizing Pressure Staging for Aerodynamic Noise Attenuation

Fugitive Emissions

Flow performance is not the only thing to consider when selecting a control valve. Fugitive emissions are minute leaks from valves, measured in parts per million, that introduce volatile organic compounds straight to the atmosphere. While the individual leaks are generally very small for a given valve, when viewed in the aggregate for an entire facility, they can represent a significant source of greenhouse gas emissions. Carbon dioxide is easily the largest source of emissions, but methane, which is a common source of emissions during natural gas production and processing, is capable of trapping significantly more warmth, particularly in the short term. As a result, environmental regulatory agencies around the world are imposing increasingly strict requirements for the level of allowable emissions. In order to reduce these emissions, the valve packing, sometimes referred to as stuffing, must be exceptionally effective at sealing while not significantly impacting the controllability of the valve.

"Low-E" packing technology must result in emissions below 100 PPM. There are various standards that allow manufacturers to type-certify their valve/packing systems, including ANSI/FCI 91-1, *Standard for Qualification of Control Valve Stem Seals* and ISO 15848-1, *Industrial Valves – Measurement, Test and Qualification Procedures for Fugitive Emissions* for control valves. Tests conducted in accordance with these standards evaluate the packing and valve as a system through a range of temperature and pressure conditions while accumulating up to 100,000 mechanical cycles. Methane and/or helium may be used as a test fluid. Note there are several other standards that exist for fugitive emissions, but they are primarily intended for isolation valves and have much lower mechanical cycle requirements.

Material Selection

Valve body and trim material is an important consideration when selecting a control valve. In general, there are four primary concerns that will dictate what materials are required: process pressure, process temperature, flow media corrosiveness, and the erosive properties of the flow media. There are a large number of possible material combinations that can be used to balance the needs of those four different variables, including exotic alloys and metals. These will almost certainly be more expensive options, so cast carbon steel, such as WCC, is generally used whenever possible due to its ability to handle relatively high temperatures and pressures. Corrosive service is usually the biggest factor that prevents the use of carbon steel; high nickel alloy castings are commonly used in these scenarios. To combat erosive flow media, hardened trim materials are often chosen. ASME B16.34 covers pressure-temperature limitations for most of the common materials used in valves.

While extremely high temperatures can be a limiting factor for some metals, temperature is more commonly an issue for the "soft parts" included in valve constructions, such as bearings, gaskets, packing, and seals. These parts frequently use elastomers and other materials, like PTFE, that are not intended for high-temperature applications. Fluid compatibility of materials on any wetted surfaces must also be considered, particularly for elastomers. Overall, it is imperative to review the *entire* valve assembly when determining temperature capabilities, not just the body and trim parts.

Piping Considerations

When selecting the valve body style, it is important to consider the piping that will be installed upstream and downstream of the valve. The first consideration is the face-to-face dimension of the valve. This will dictate how much space in the pipeline the valve will occupy. Next, the end connections must be considered. Valves can come with several different connection styles, including raised face flange (RF), ring-type joint flange (RTJ), butt-weld end (BWE), socket-weld end (SWE), screwed (NPT), etc. Most valve manufacturers will offer their valves with a wide variety of connection type options. The schedule of the piping is also important to consider as it dictates the inside diameter of the pipe leading into and out of the valve. Finally, any reducers or expanders that are installed need to be identified, primarily due to their impact on valve capacity and valve noise.

Production Testing

Once the valve has been selected and sized with the appropriate materials, there is one final step – determining what production tests need to be conducted by the manufacturer prior to shipping the valve to the end user. Two of the most common production tests are seat leakage and hydrostatic testing to confirm pressure retention capabilities.

Allowable seat leakage is an important factor to determine. Control valves, unlike isolation valves, are not meant to shut off completely. They are going to leak, but how much they leak will vary depending on factors like pressure conditions, duty cycles, and seal materials. Industry standards, such as ANSI/FCI 70-2, *Standard for Control Valve Seat Leakage Testing* exist to help end users determine acceptable leakage rates. FCI's "Seat Leakage Overview" presentation can be referenced for additional information on this topic as well.

When valves are first designed, they go through rigorous hydrostatic testing called proof-of-design tests. These tests intentionally over-pressurize the valve until yielding occurs and are used to establish the pressure rating of the valve design. Production hydrostatic tests are done at lower pressures to ensure that each individual valve that is manufactured is capable of maintaining the rated pressure without external leaks. These tests will catch any quality issues, such as casting defects, that may have occurred during the manufacturing process that could prevent the design from performing as intended.

Other more specific or custom tests may also be requested for production valves. For example, many valves intended for low-E service will go through the ISO 15848-2, *Industrial Valves* production test to ensure initial fugitive emissions are within limits. Sanitary valves may also have additional requirements upon manufacture, such as those covered in FCI's 17-1, *Standard for Production Testing of Sanitary Pressure Regulators*.

Summary

Finding the right control valve for a given application is a very complicated process that involves a multitude of variables. While this tech sheet covers a large portion of the considerations that must be taken into account, it certainly does not cover all of them and does not provide the detail necessary to make all the required decisions. As always, close cooperation between the end user and the valve manufacturer is the best way to ensure that the right product is chosen for the right application.