Calculating Pressure Drop Across Valves

Calculating pressure drops can be very helpful in identifying more accurate pressure profiles during a Process Hazard Analysis (PHA) / Hazard and Operability Study (HAZOP) study. There are scenarios during a PHA/HAZOP where taking a conservative estimate ends up overstating the severity of a potential incident significantly.

Facilitators and team members need to remember that taking credit for the laws of physics is allowed and can be significantly more accurate. In cases such as blowthrough due to level valves going wide open, Teams should analyze pressure drops across valves. This allows for a more realistic analysis of what pressure the downstream vessel can reach. This calculation is not difficult if valve information is readily available. In this Tech Tip, we will provide a simplified discussion on pressure drops and how to calculate pressure drops across valves.

Pressure Drop

What do we mean when we say pressure drop?

Pressure drop is the difference in pressure between two points in a system, caused by resistance to flow. An example of difference in pressure across a valve is shown below

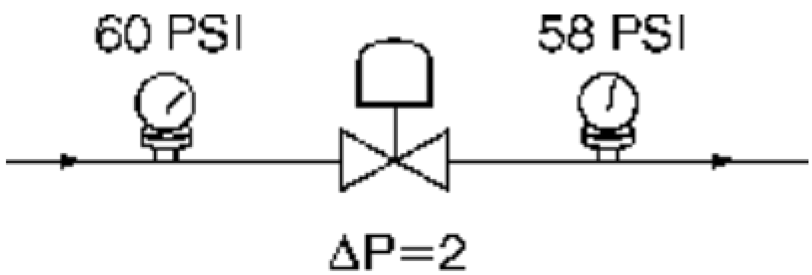

Figure 1: Pressure Drop Example

Where (P1) – (P2) = ΔP. Δ (from Greek Delta) is a change in something; in the case above, it is a change in pressure at the valve as a result of system demand. Pressure gauges are not always across the valve to give an easy indication of the delta. So how do we calculate the pressure drop without obvious data?

Calculating Pressure Drop Across a Valve

What factors determine pressure drop?

Critical factors are orifice size and internal flow path which determines a valve's Valve Flow Coefficient (Cv). This is a relationship between flow and the pressure drop across the valve. It is technically defined as the volume of water at 60°F (in US gallons) that will flow through a valve per minute with a pressure drop of 1 psi across the valve. Water is utilized in the definition as it has a specific gravity of 1. Specific gravity of the fluid medium has an effect (if not pure water at STP)

Resources

Calculations Methodology
instrumentationtools.com

Figure 1
wattswater.com

Figure 2 and Table 1
flowserve.com

on the total pressure drop as shown by the calculation below:

$$\Delta P = \left(\frac{GPM}{Cv}\right)^2 * S.G.$$

Where GPM is flow rate of the medium at the valve in gallons per minute, Cv is the Valve Flow Coefficient and S.G. is the specific gravity of the medium.

To calculate the ΔP, we would have to know Cv, flow rate, and specific gravity. The last two should be known as part of process dynamics (e.g. known pump discharge flow, etc.). Cv is where good practices of maintaining and keeping process safety information of equipment will help. Normally the vendor or manufacturer will have the known Cv values listed as part of design information. An example of a Cv data sheet is below for a Flowserve unbalanced ball valve.

Table 1: Example of Valve Cv Table

FLOWSERVE — Flow Control Division

TABLE 95

Manufacturer: Valtek
Valve Type: Mark One, Unbalanced
Pressure Class: 150#-600#
Trim Characteristic: Equal Percentage
Flow Direction: Over/Upstream

Valve Size (in.)	Trim Size (in.)	Stroke (in.)	Cv At Percent Open										
			5	10	20	30	40	50	60	70	80	90	100
4	3.50	2.5	6.5	13	20	26	35	57	96	130	154	169	179
	2.62	2	3.7	7.4	11	16	24	39	63	89	111	124	133
	2.25	2	2.3	4.6	7.4	12	15	24	40	63	83	96	104
	1.62	1.5	1.3	2.5	3.6	5.7	8.4	11	16	25	37	48	55

Figure 2: Flowserve Valve

So let's make an example. Say we know we have No. 2 diesel fuel oil with a specific gravity of about 0.85 with a process temperature of ~60F. Our flow rate an upstream pump is supplying is ~400 GPM at normal suction pressures. We have a 4" valve with a 3.5 (in.) trim size and we want to know the pressure drop across the valve in the case of it being wide opened. Utilizing the known information and the equation above we get the following answer:

$$4.2\ psi = \left(\frac{400}{179}\right)^2 * 0.85$$

We determined the pressure drop across the valve when it is wide open as 4.2 psi. Although this value is small, this information can potentially bring down a loss of containment event due to high pressure below the hydrotest value of a vessel. Utilizing API guidance, that would mean a loss of containment is not likely, and an advanced discussion of safeguards is no longer necessary. In some cases, this may mean a recommendation is not required, saving money on unnecessary advanced safety features.

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Michael Pfaff is a Project Engineer with Risk Management Professionals. He has supported a variety of activities associated with the Environmental Protection Agency's Risk Management Plan (EPA's RMP) and Occupational Safety and Health Administration's Process Safety Management (OSHA's PSM) Program and is well versed in regulatory compliance.