Product Note, PN 417, Rev 1
Valve Flow Coefficient (C_v) per SEMI F32

February 12, 2024

Introduction

AP Tech has adopted the SEMI F32 test method for determining valve flow coefficient. The SEMI F32 test method is based on the test procedure described in ISA S75.02. AP Tech valve data sheets now contain the C_v and x_T values determined per SEMI F32 for compressible (gaseous) fluids.

C_v and x_T

The *flow coefficient* (C_v) is a numerical constant used to characterize the flow capacity of a component. The *pressure drop ratio* (x) is the ratio of the pressure drop (ΔP) across the component to the absolute inlet pressure (P_1). The *critical pressure drop ratio* (x_T) (also referred to as *pressure drop ratio factor* or *choked flow ratio*) is the value of x such that a further decrease in outlet pressure, while maintaining constant inlet pressure, does not result in an increase in flow through the component. Figure 1 (below) illustrates a typical scenario of outlet pressure vs. flow rate. The thin vertical line represents the boundary where x equals x_T, and clearly shows how flow rate plateaus as x_T is approached even as outlet pressure continues to drop. Both C_v and x_T are required to ensure an accurate pressure drop calculation. **In the graph below Xt = .60. Meaning at a pressure loss of 60 psig or in this case 60% (Xt = .60), there is no addition increase in flow as further pressure drop is experienced.**

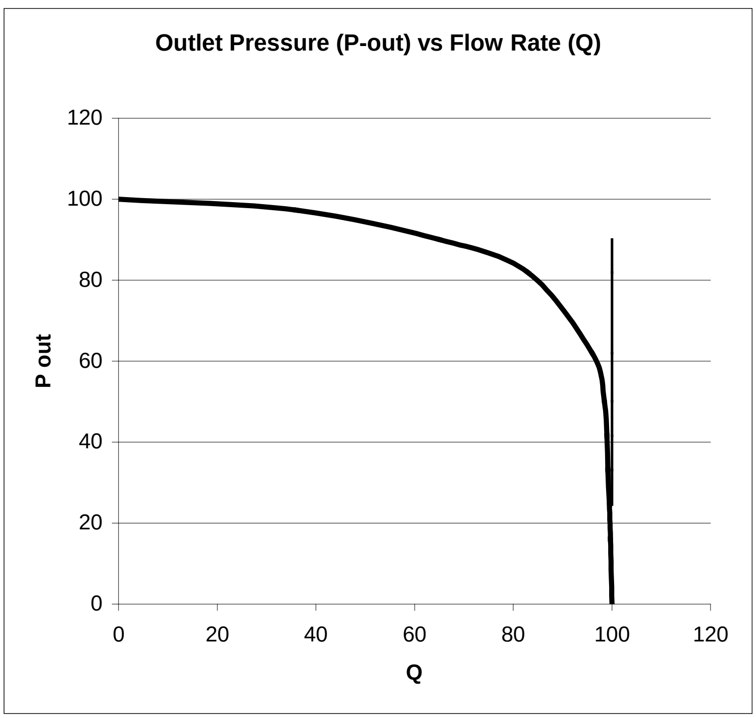

Figure 1 – Both P out and Q are given as percentages where 100% P out refers to a zero pressure differential (ie, P out is 100% of P in).

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Equations in SEMI F32

SEMI F32 contains two equations (given below for US units) for calculating pressure drop across valves. One equation is an iterative solution based on ISA S75.01 equations and uses C_v and Y (expansion factor which is based on x and x_T). The other equation is a direct solution but only a close approximation and uses C_v and x_T in the calculation. It is worth noting that the units for flow rate differ from the direct solution to the iterative one when using US units. When performing pressure drop calculations across a valve using the equations in SEMI F32, the value of x must never exceed x_T and the value of Y must be greater than 0.67. Typically, pressure drop across valves is less than 5% of the inlet pressure (x is less than 0.05) and either equation in SEMI F32 should yield satisfactory results.

Direct solution:

$$\Delta P_{psid} = \frac{P_{1psia} \times x_T}{1.125}\left[1 - \sqrt{1 - \frac{1.125}{x_T}\left(\frac{S_g \times Q_{scfm}}{16.04 \times C_v \times P_{1_{psia}}}\sqrt{\frac{T_{\circ R}}{S_g}}\right)^2}\right] \qquad \textbf{eq. 1}$$

Iterative solution:

$$\Delta P_{psid} = \left(\frac{Q_{scfh}}{1360 \times C_v \times Y \times P_{1_{psia}}}\right)^2 \times S_g \times T_{\circ R} \times P_{1_{psia}} \qquad \textbf{eq. 2}$$

Where:

$$Y = 1 - \frac{x}{3 \times F_k \times x_T} \qquad \textbf{eq. 2a}$$

$$x = \frac{\Delta P_{psid}}{P_{psia}} \qquad \textbf{eq. 2b}$$

$$F_k = \frac{k}{1.4} \qquad \textbf{eq. 2c}$$

Therefore:

$$\Delta P_{psid} = \left(\frac{Q_{scfh}}{1360 \times C_v \times P_{1_{psia}} \times \left(1 - \frac{1.4}{3 \times k \times x_T} \times \frac{\Delta P_{psid}}{P_{1_{psia}}}\right)}\right)^2 \times S_g \times T_{\circ R} \times P_{1_{psia}} \qquad \textbf{eq. 3}$$

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A sample calculation

The following is an example of calculating ΔP using first the direct method (eq 1), then the iterative method. For the iterative method, an initial guess of ΔP was made (iteration 0) then equations 2a, 2b and 3 were used to calculate x, Y, and ΔP and the process was repeated. For this example, once the calculated ΔP came within 1×10^{-4} of the initial value, the iteration was stopped. The method by which the iterations are stepped can of course vary, but in this case the calculated ΔP from one step was entered as the initial value for the following step and only required two iterations.

Part: AP3550

Cv	xt
0.29	0.6

Working Fluid: H2

T (degF)	Sg	k
60	0.0696	1.41

Flow Conditions

P1 (psig)	Q (slm)
50	150

Direct Solution

DeltaP
0.3649

Iterative Solution

Iteration	DeltaP (guess)	x	Y	DeltaP (Psi)	Does DeltaP match DeltaP (guess)
0	50.0000	7.728E-01	0.5737	1.1045	No, continue iteration
1	1.1045	1.707E-02	0.9906	0.3704	No, continue iteration
2	0.3704	5.726E-03	0.9968	0.3658	No, continue iteration
3	0.3658	5.654E-03	0.9969	*0.3658*	Yes, reached stop point

As seen from the above data, the direct solution can provide a very good estimate to the iterative one and in this example the two differ by less than 0.01% (though accuracy to this degree may not occur in every case).

Note: *AP Tech provides values of C_v for pressure regulators because customers often request this. AP Tech does* ***not*** *recommend using Cv to determine the appropriate pressure regulator for a specific application. A regulator with large stroke will have a high Cv but may have a large pressure drop that reduces the usable range to less than half of the Cv value. At best Cv can be used to narrow the possible options. A flow (droop) curve showing outlet pressure drop as flow increases should be used to select the appropriate pressure regulator for the application.*

Please consult the factory or your local distributor for further information or assistance.

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