AVOID PITFALLS WHEN SPECIFYING CONTROL VALVES

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Widespread availability of valve-sizing software has made customers' purchasing of modulating control valves deceptively easy. However, the sizing calculations are not the whole story when specifying the valve — it is also necessary to take into account a variety of practical considerations. Accordingly, keep the following guidelines in mind whenever selecting control valves:

1. Anticipate possible variations in process conditions

A valve's flow coefficient (C_V; box, p. 77) must be chosen so as to allow the valve to perform at the intended flowrates even if unexpected changes in the process conditions arise. Take particular care to anticipate any possible shifts in the temperature and the upstream and downstream pressure of the flowing fluid.

The directions of such changes (increase or decrease) may not always be consistent. They may or may not be time-dependent. And as the example in Figure 1 brings out, they may well vary according to how widely the valve is open. In any case, the best way to anticipate changes is to develop a full understanding of the process system within which the valve is to perform.

2. Take into account the overall process setting

Similarly, future operating problems are likely to arise if the engineer specifying the control valve is not provided with a description of the physical setting in which the valve is to perform. Before trying to specify the valve, insist on being given the line sizes, pump flowrates, elevations and pressure drops of individual pieces of equipment in the process unit, and similar data.

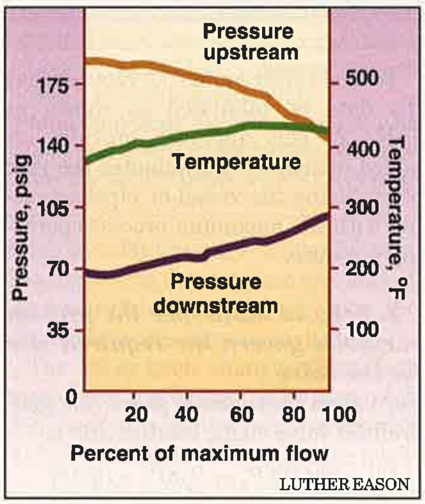

FIGURE 1. Often overlooked is the impact that the extent of the valve opening can itself have upon the process varilables

Consider process layout, fluid properties, the risk of cavitation, and a variety of other factors

Armed with that information, adhere to these guidelines and good practices:

a. At full flow, the pressure drop across the valve should be at least 50% of the friction pressure drop across the rest of the system (i.e., excluding the valve). In typical systems, this friction drop is about one-third of the total system drop [1].

For example, consider a process setting with these conditions:

Δp due to elevation: 15 psi
Δp across process equipment: 30 psi
Δp due to system friction: 35 psi
Δp across valve at max. flow: 20 psi
Total Δp for system: 100 psi

In this example, 50% of the 35-psi friction pressure drop is 17.5 psi, so the 20 psi allocated to the valve is acceptable.

b. At full flow, the pressure drop across the valve should be at least 33% of the total pressure drop (due to friction, elevation, and process equipment) across the rest of the system (excluding the valve) [1, 6, 8]. If that guideline cannot be met, here are the minimum conditions upon which to insist:

- With equal-percentage-trim valves: 10% of system pressure drop [4, 5]
- With linear-trim valves: 25% of system pressure drop [4, 5]
- With pumped systems: 15 psi [6, 8]

In all cases, the more pressure drop that is allocated to the valve, the better is the control.

In the above example, 80% of the total system drop is other than across the valve. The recommended pressure drop allocated to the valve would be: 33% × 80%, or 26% of the total system drop. Because only 20 psi (20%) was allocated, use equal-percentage trim. (See also Point f in this section).

c. Specify a C_V large enough so that the maximum process-flow requirement will be equivalent to no more than 80-90% of that C_V. This guideline provides for modulating overshoot [6].

d. Conversely, the minimum process

	Min.	Max.	Norm.
Flow			
Inlet pressure			
Outlet pressure			
Temperature			

The conventional data format shown in **TABLE 1**, left, can mislead

	At min. flow	At max. flow	At normal flow
Flow			
Inlet pressure			
Outlet pressure			
Temperature			
Maximum possible inlet pressure			

The format of **TABLE 2**, at right, is preferable because it is not ambiguous

flow should require a C_v greater than 10% of the C_v of the valve selected. This is essential with wet steam to avoid damage to valve trim [6].

e. To forestall materials problems, select valves large enough so that the maximum liquid inlet velocities are as follows [7]:

cast-iron valve body: 18 ft/s
carbon-steel valve body: 25 ft/s
Type 316 stainless-steel valve body: 35 ft/s

f. Equal-percentage trim is more forgiving if valve sizing proves to be incorrect, if process conditions change, or if insufficient pressure drop is allocated to the valve.

g. The valve inlet and outlet can be the same size (diameter) as the pipe line, or one size or two sizes smaller, but in no case less than 50% of the line size.

3. *Insist on data that relate the process conditions properly*

The customary formatting of tabulated data often implies a relationship between temperature, pressure, and flow that is incorrect. Such tabulation should always be questioned or, preferably, avoided.

In particular, valve sizing information is often tabulated as in Table 1. This tabulation leads to a common mistake: calculating the maximum C_v using the maximum flow, temperature, inlet pressure, and outlet pressure. In practice, maximum temperature and pressure rarely occur simultaneously with maximum flow. Similar problems occur with sizing for normal and minimum flow.

To avoid such confusion, request that the data be tabulated as shown in Table 2. This approach provides an added benefit — it eliminates the risk of confusing the vessel or pipeline rating with the maximum process operating pressure.

4. *Keep in mind how the process variables govern the required size for the valve*

For valves that handle gases, the generalized valve-sizing relationship is

$$Cv \sim Q[GT/(P_1 - P_2)(P_1 + P_2)]^{1/2}$$

where Q is the maximum volumetric flowrate, G is the specific gravity, T is the absolute temperature, and P_1 and P_2 are the inlet and outlet absolute pressures, respectively.*

As this expression brings out, the required C_v varies directly with flowrate and with the square roots of specific gravity and temperature, and inversely with the square root of system pressure (as represented by [P1 + P2]), and differential pressure.

With liquids, the generalized valve-sizing relationship is

$$C_v \sim Q[G/(P_1 - P_2)]^{1/2}$$

Thus, for control valves that handle liquids, the required C_v varies directly with the flowrate and with the square root of the specific gravity, and inversely with the square root of the differential pressure.

This relationship is simpler than the one for gas flow. However, specifying a valve for liquid flow entails a serious risk that does not arise with gases: the

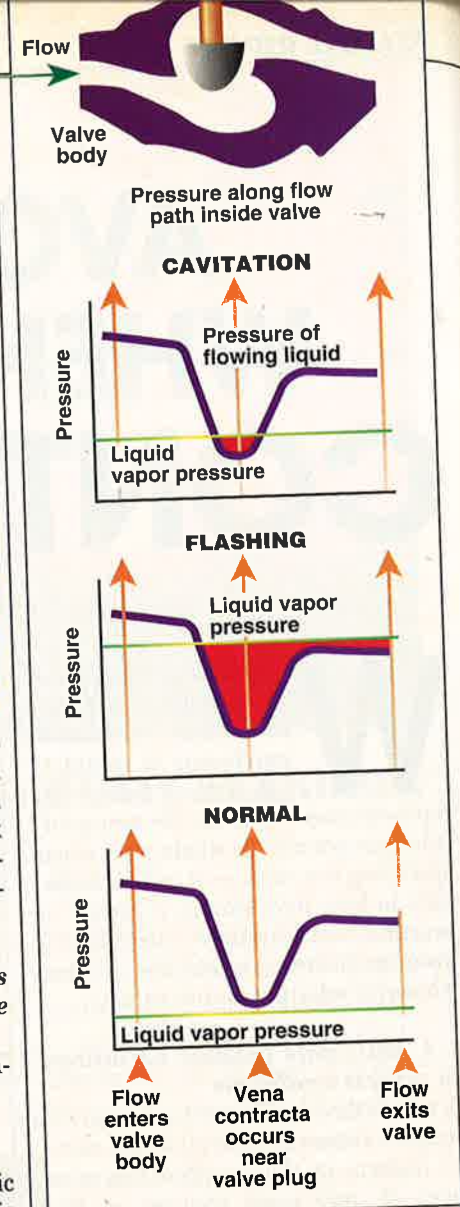

FIGURE 2. Presence of cavitation, flashing or normal valve operation (respectively, top to bottom graphs) depends on the relative values of the flowing liquid's actual pressure and vapor pressure

possibilities of cavitation or flashing within the valve.

5. *Take account of any potential for cavitation and flashing*

Each of these problems occur because the fluid pressure inside the valve drops below the fluid vapor pressure. Cavitation (upper graph, Figure 2) prevails only at the vena contracta and immediately downstream, the fluid "collapsing" back into liquid as it continues downstream. With flashing (middle graph, Figure 2), the fluid remains a vapor after leaving the valve. Both situations are at odds with the

*Various more-complex versions of this expression, and of the one that follows for liquid flow, are used by different valve vendors, as well as by the International Soc. for Measurement and Control (ISA).

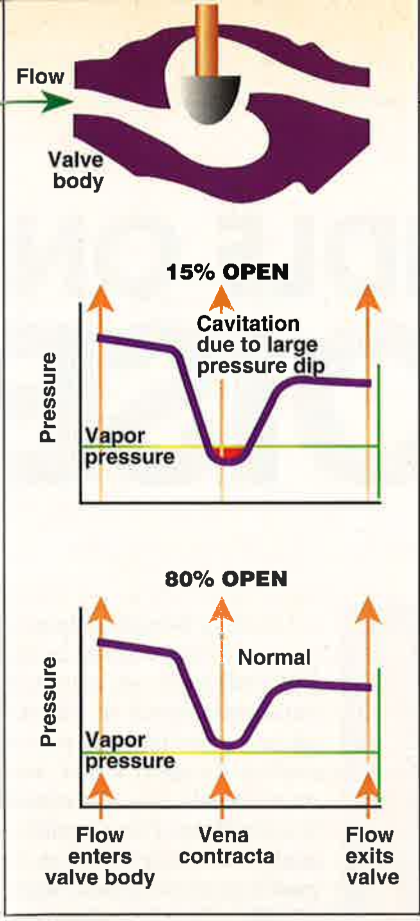

FIGURE 3. The extent of valve opening (shown here for 15% open and 80% open) can not only affect process properties, as shown in Figure 1, but also mean the difference between cavitation and normal flow

desired flow-vs-pressure profile through the valve (lower graph, Figure 2), and thus limit the effectiveness of the valve.

Cavitation or flashing occur because pressure energy in the fluid converts to kinetic energy as the contraction in the valve causes an increase in velocity. (Some energy in the stream is also dissipated as friction and heating, as well as noise. For information related to the noise problems with gaseous flow through a valve, see pp. 78-81.) As the temperature of the liquid increases, cavitation and flashing become more likely, due to increased vapor pressure.

Cavitation and flashing greatly increase the C_v requirement, often to the point where no additional flow is possible even with additional differential pressure across the valve. This condition is known as choked flow.

Cavitation can also damage the valve and piping. The damage is due to localized mechanical forces (up to 5,000 psi), which can rapidly erode metal surfaces.

The extent of cavitation depends mainly on the downstream pressure and the differential pressure across the valve. Cavitation is not normally damaging at inlet pressures under 50 psig. The higher the downstream pressure or the lower the differential pressure, the less likely is the valve to cavitate.

The valve itself changes these last-named two conditions, as its plug positions vary through its range of opening (10% to 90% open) while the valve modifies the flow rate in the system. Accordingly, cavitation does not always occur through the full range of valve opening (Figure 3).

Flashing is usually due to conditions downstream from the valve, so it is difficult to generalize about strategies for preventing it. The engineer can more-readily avoid cavitation, with the help of one or more of the following actions:

1. Specify a valve with lower recovery coefficient than would otherwise be needed, or use anti-cavitation valve trim. (In such trim, the fluid undergoes several small pressure drops rather than one large drop.)
2. Increase the downstream pressure, by: placing the valve farther upstream in the pipeline than would otherwise be expected; moving the valve to a lower elevation; or installing a flow restrictor downstream
3. Decrease the liquid temperature
4. Decrease the upstream pressure (however, this option usually brings about only a minimal improvement) ■

Edited by Nicholas P. Chopey

A CONTROL-VALVE GLOSSARY

Cv: a flow coefficient, initially defined as the number of the U.S. gallons-per-minute of water that will pass through a flow restriction under a pressure drop of 1 psi. Since its introduction by Masoneilan in 1944, Cv has also been adapted for use in sizing valves for gases and steam

Cavitation: a condition in which a liquid vaporizes into bubbles near the plug and seat of a valve, or other pipeline flow obstruction, then collapses back to a liquid as pressure recovers (increases) downstream of the valve (see also Vena contracta)

Equal-percentage trim: a valve trim with a flow response that is non-linear under preferred process conditions (those recommended in this article), so that a plot of the flowrate vs. the lift of the plug is a curve. When conditions are not thus, the plot of the actual response tends to become a straight line. Accordingly, the valve retains good control from 20% to 90% of the valve opening

Flashing: a condition similar to cavitation, except that the downstream pressure and temperature are such that the process fluid remains a vapor downstream of the valve.

Linear trim: a valve trim with a flow response that is linear under preferred conditions — a plot of flowrate vs. the lift of the plug is a straight line. If conditions are not thus, the plot of the actual response is no longer linear and poor control will result at 70% to 100% of valve opening

Pressure recovery: an increase in system pressure, due to change from kinetic to pressure energy downstream of the vena contracta

Valve-recovery coefficient: a numerical factor that represents a valve's flow-vs.-pressure curve and thus the valve's tendency to cavitate. Typical values range from 0.6 to 0.99. A value of 0.6 is a high recovery factor, indicating a deep pressure dip and a higher possibility of cavitation than with a factor nearer to 0.99. Most globe valves have a recovery factor of 0.9

Vena contracta: the point in a valve where the fluid flow reaches a maximum fluid velocity and minimum fluid pressure. The vena contracta occurs just downstream of the valve plug flow obstruction posed by the valve plug

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