Introduction

The procedure used to size control valves for liquid service should consider the possibility of cavitation and flashing since they can limit the capacity and produce physical damage to the valve. This recommendation introduces a critical pressure ratio factor, r_c, that not only broadens the scope of our valve sizing techniques but also increases the sizing accuracy. When used in Equation 1, r_c will help to determine more accurately the maximum allowable pressure drop for sizing purposes. In order to understand the problems more thoroughly, brief outlines of the cavitation and flashing processes are presented.

Cavitation

In a control valve, the fluid stream is accelerated as it flows through the restricted area of the orifice, reaching maximum velocity at the vena contracta*. Simultaneously, as the velocity increases, an interchange of energy between the velocity and pressure heads forces a reduction in the pressure. If the velocity increases sufficiently, the pressure at the vena contracta will be reduced to the vapor pressure of the liquid. At this point, voids or cavities, the first stage in cavitation, appear in the fluid stream. Downstream from the vena contracta, the fluid stream undergoes a deceleration process resulting in a reversal of the energy interchange and raising the pressure above the liquid vapor pressure. The vapor cavities cannot exist at the increased pressure and are forced to collapse or implode. These implosions, the final stage in the cavitation process, produce noise, vibration and physical damage. In order to avoid cavitation completely, the pressure at the vena contracta must remain above the vapor pressure of the liquid.

Flashing

The first stages of cavitation and flashing are identical, i.e., vapor forms as the vena contracta pressure is reduced to the vapor pressure of the liquid. In the second stage of the flashing process, a portion of the vapor formed at the vena contracta remains in the vapor state because the downstream pressure is equal to or less than the vapor pressure of the liquid.

Sizing Information

After the first vapor cavities are formed, the increase in flow rate will no longer be proportional to an increase in the square root of the body differential pressure. When sufficient vapor has been formed, the flow will become completely choked. As long as P_1 remains constant an increase in ΔP will not increase flow. The following equation should be used to determine the maximum allowable pressure drop that is *effective in producing flow*. It should be noted, however, that this limitation on the sizing pressure drop, $\Delta P_{(allow)}$, does not imply that this is the maximum drop that may be handled by the valve.

$$\Delta P_{(allow)} = K_m(P_1 - r_c P_v) \qquad (1)$$

After $\Delta P_{(allow)}$ has been calculated, it is used in the standard liquid sizing equation, $Q = C_v\sqrt{\Delta P/G}$ to determine either Q or C_v. If the actual ΔP is less than $\Delta P_{(allow)}$, then the actual ΔP should be used in the liquid sizing equation.

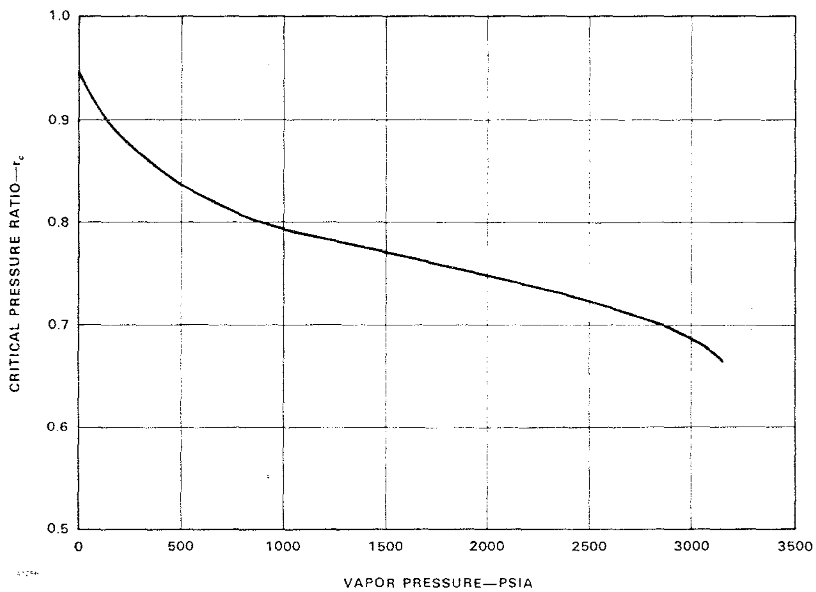
Equation 1 should also be used to calculate the body pressure drop at which significant cavitation can occur. It is recognized that minor cavitation will occur at a pressure drop slightly less than that predicted by Equation 1. However, any cavitation under that pressure drop condition should produce negligible damage in globe valves. Follow the recommendations for **Vee-Balls®** given in Section 1 page 1-132.

Nomenclature

C_v = liquid sizing coefficient
Q = flow rate, gpm
ΔP = body differential pressure, psi
$\Delta P_{(allow)}$ = maximum allowable differential pressure for sizing purposes, psi
P_1 = body inlet pressure, psia
P_v = vapor pressure of liquid at body inlet temperature, psia
K_m = valve recovery coefficient—see Section 1 of this catalog
r_c = critical pressure ratio—see Figures 1 and 2
G = specific gravity (water at 60°F = 1.0)

*In flow through an orifice, the fluid streamlines converge before and slightly after the orifice. The section of minimum diameter of the fluid stream after the orifice is known as the vena contracta.

Valve Sizing for Cavitating and Flashing Liquids Continued

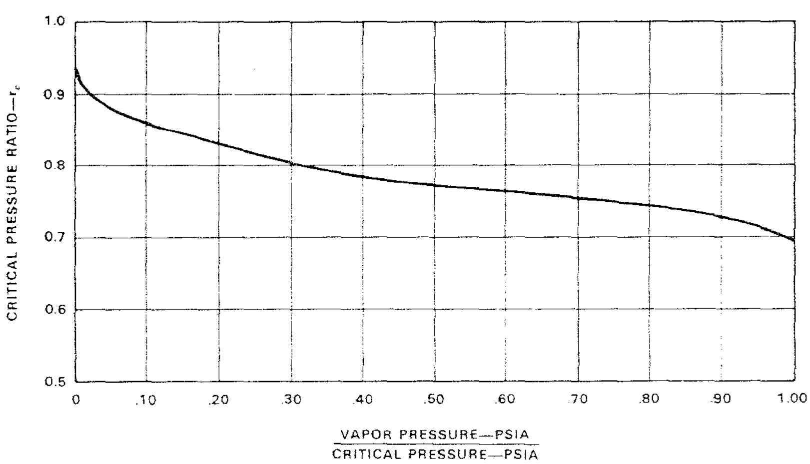


Use this curve for water. Enter on the abscissa at the water vapor pressure at the valve inlet. Proceed vertically to intersect the curve. Move horizontally to the left to read the critical pressure ratio, r_c, on the ordinate.

Figure 1. Critical Pressure Ratios for Water

Critical Pressure of Various Fluids, Psia*

Ammonia	1636
Argon	705.6
Butane	550.4
Carbon Dioxide	1071.6
Carbon Monoxide	507.5
Chlorine	1118.7
Dowtherm A	465
Ethane	708
Ethylene	735
Fluorine	808.5
Helium	33.2
Hydrogen	188.2
Hydrogen Chloride	1198
Isobutane	529.2
Isobutylene	580
Methane	673.3
Nitrogen	492.4
Nitrous Oxide	1047.6
Oxygen	736.5
Phosgene	823.2
Propane	617.4
Propylene	670.3
Refrigerant 11	635
Refrigerant 12	596.9
Refrigerant 22	716
Water	3206.2



Use this curve for liquids other than water. Determine the vapor pressure/critical pressure ratio by dividing the liquid vapor pressure at the valve inlet by the critical pressure of the liquid. Enter on the abscissa at the ratio just calculated and proceed vertically to intersect the curve. Move horizontally to the left and read the critical pressure ratio, r_c, on the ordinate.

Figure 2. Critical Pressure Ratios for Liquids Other than Water

*For values not listed, consult an appropriate reference book.

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