Alpha-I Cavitation Guide

April 2020

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Foreword

Alpha-I was originally developed in the 1980s and was one of the first PC based valve sizing programs created. The program was, and still is, based on sizing equations published in ISA S75.01. In addition to calculating the required Cv based on the system process conditions, Alpha-I calculates percentage open, velocity, predicted noise and makes the user aware of special conditions such as choked flow, cavitation or flashing. Any or all of these factors can be critical in determining the best control valve for the system.

More recent versions of Alpha-I have provided additional information based on control valve performance by calculating the installed characteristic of the valve including gain and gain ratio. This information can be critical in overall valve performance in a process control loop.

This latest version of Alpha-I (Version 20) is expanded to incorporate equations and methodology found in ISA RP75.23, Considerations for evaluating Control Valve Cavitation.

" Cavitation is a phenomenon that can accompany the flow of liquids through control valves. Failure to account for cavitation can result in potentially costly performance problems."

"To prevent this situation, it is important that personnel responsible for control valve specifications understand the nature of cavitation and fundamental abatement technology."

ISA–RP75.23–1995, 5.1

This enhancement in Alpha-I will further assist the user in making sound engineering decisions when faced with a cavitating control valve.

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Liquid Flow States

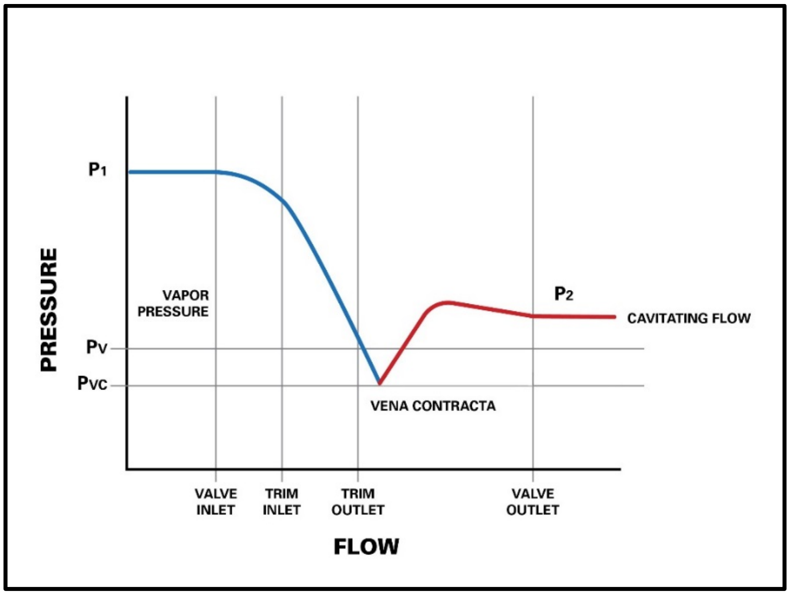

Figure 1, Cavitation Plot

The graph above shows the flow (blue line) of water as it would enter a control valve. The valve inlet, trim inlet, trim outlet and valve outlet are presented for emphasis:

- **Valve inlet** – fluid pressure is constant as it enters the valve gallery.
- **Trim inlet** – as the trim inlet approaches, fluid velocity increases due to the decrease in area.
    - The fluid passes through the seat (control point), which is the smallest mechanical constriction (area). Velocity is high and pressure drops significantly.
- **Trim outlet** - recirculation zones form **(Vena Contracta)** that further constrict the flow and drive the fluid to the lowest pressure in the process. Vapor bubbles form:
    - A rapid pressure recovery as fluid enters higher pressure P2 zone
    - As the rapid recovery continue the bubble turns inside out and rupture, releasing a micro-jet of fluid onto the pipe walls and valve internals.
- **Valve Specification Concerns**
    - Damage to valve trim, valve body and process piping is possible. Cavitation should be evaluated and controlled. Cavitation damage has a cindered and pitted surface appearance.

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The following image shows the vena contracta and the recirculation zones that further constrict the flow. *Pressure at Vena Contracta: (* $P_{VC} = F_f P_V$ *;* F_f *= liquid critical pressure recovery factor)*

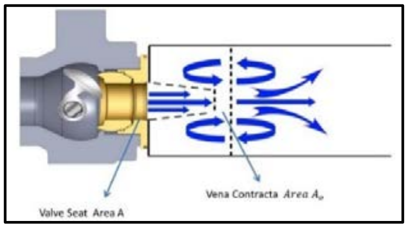

Figure 2, Vena Contracta Area A_0 = approximately 60% of Trim Area A

Flashing

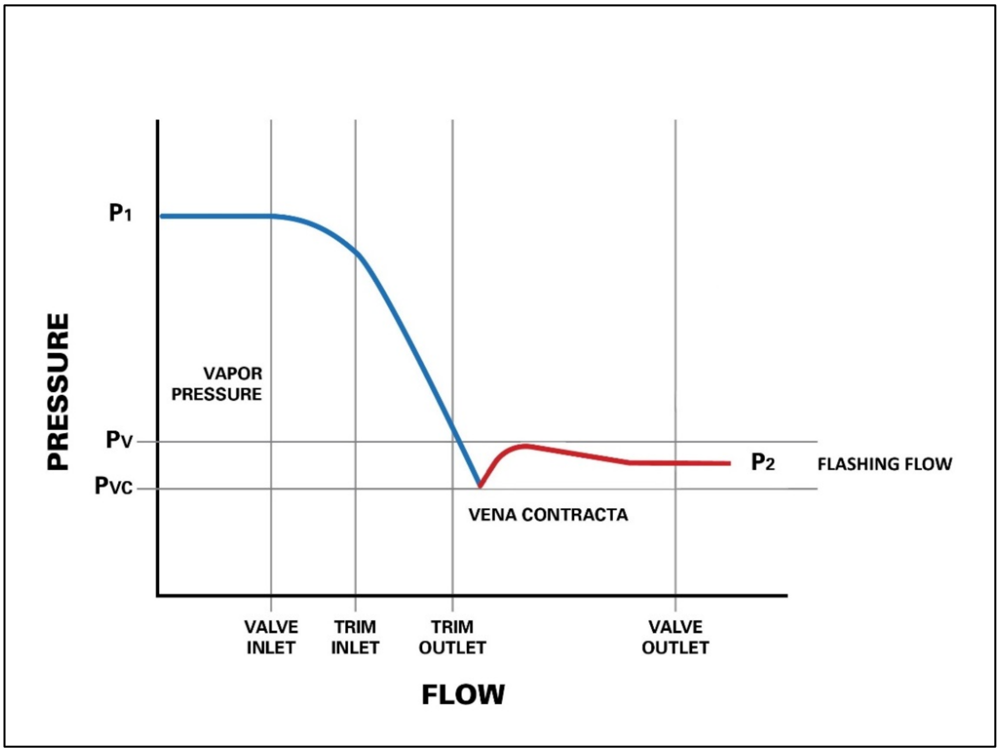

Figure 3, Flashing Flow Plot

- **Valve inlet** – same as Figure 1
- **Trim inlet** – as the trim inlet approaches, fluid velocity increases due to the decrease in area.
  - The fluid passes through the seat (control point), which is the smallest mechanical constriction (area). Velocity is high and pressure drops significantly.
- **Trim outlet** - recirculation zones form **(Vena Contracta)** that further constrict the flow and drive the fluid to the lowest pressure in the process. Vapor bubbles form:
  - The fluid pressure does not recover because the downstream P2 is less than the fluid's vapor pressure P_v . Flashing occurs. See section 3.1 to determine % flash and flash velocity.
- **Valve Specification Concerns**
  - Depending on the % flash that is occurring, damage to valve trim, valve body and process piping are possible.   Rather than a pitted cinder appearance with cavitation, flashing damage is a more localized removal of material that is often smooth and polished.
  - Sometimes upsets in the system can occur causing the valve to cavitate for a brief period as shown in Figure 1. The combination of flash and cavitation is one of the most severe process conditions to deal with in industry. See section 5.1 for more information.

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Non-Cavitating, Non-Flashing

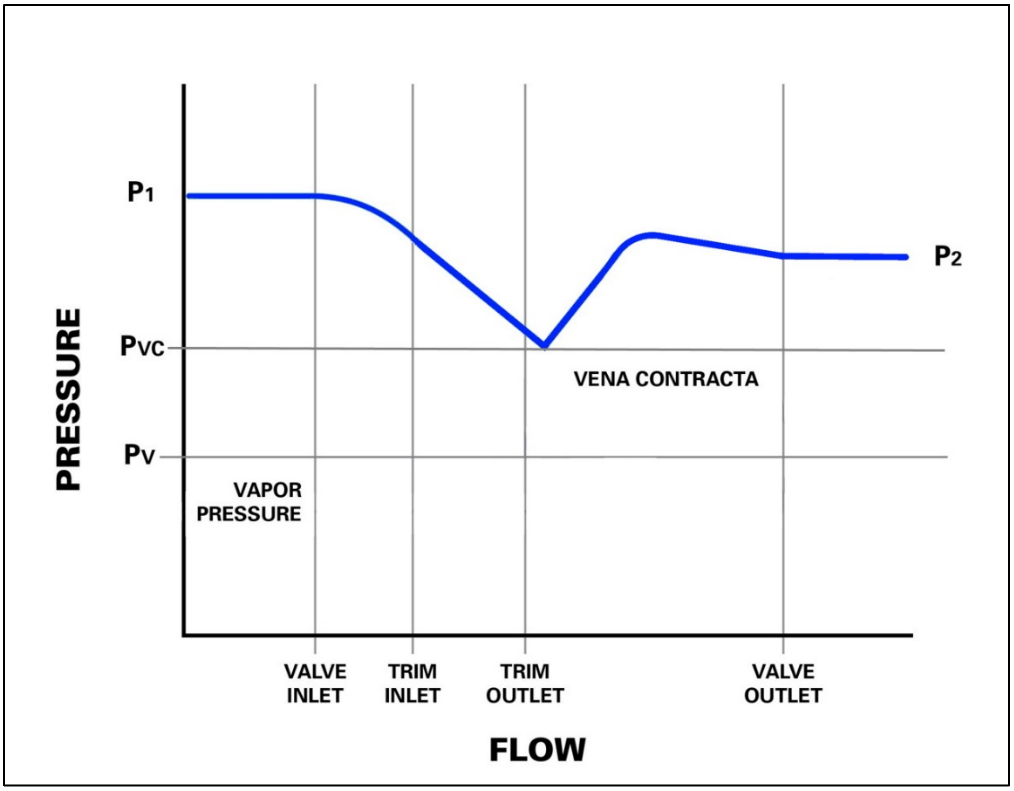

Figure 4, Non-cavitating, non-flashing plot

- **Valve inlet** – same as Figure 1
- **Trim inlet** – as the trim inlet approaches, fluid velocity increases due to the decrease in area.
  - The fluid passes through the seat (control point), which is the smallest mechanical constriction (area). Velocity increases and the pressure drops.
- **Trim outlet** - recirculation zones form **(Vena Contracta)** that further constrict the flow and drive the fluid to the lowest pressure in the process
  - The fluid pressure recovers in a region above the downstream pressure P2 and the fluid's vapor pressure P_v . No cavitation occurs. No flashing occurs.
- **Valve specification Concerns:**
  - None. Proceed in accordance with customer requirements for:
    - Valve or body style
    - Material and pressure class
    - Trim material

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Choked Flow

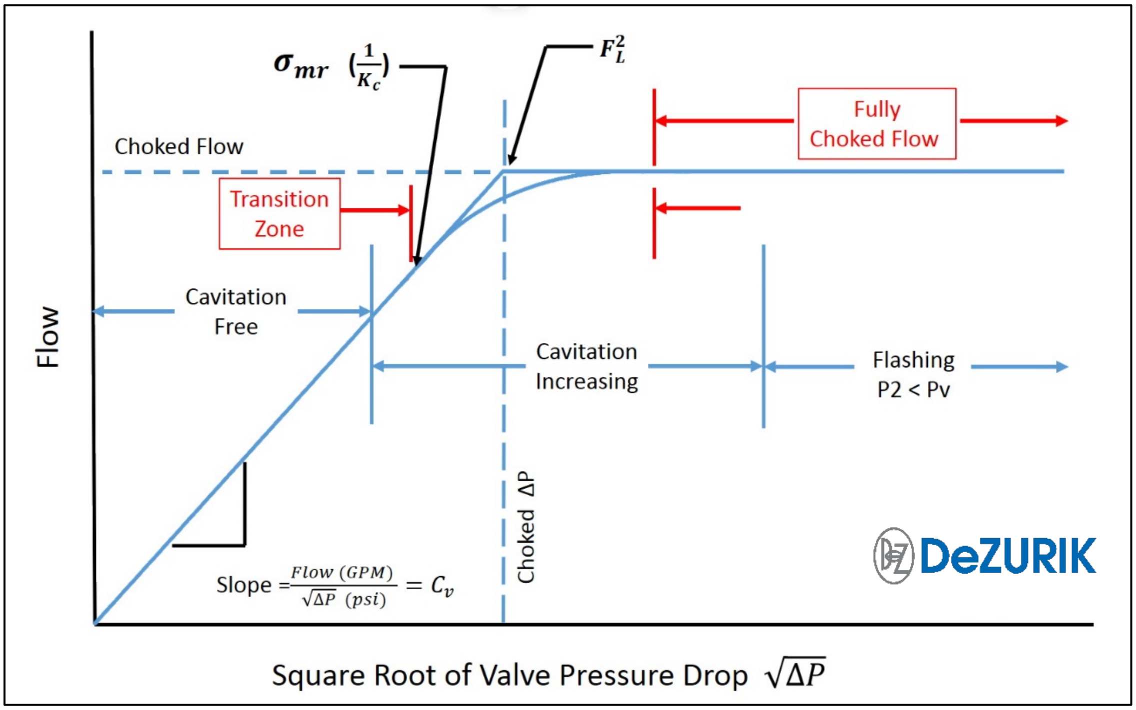


Figure 5, Flow plot - from Cavitation Free to Flashing

As the Δ_p through a control valve increases, flow also correspondingly increases. However, as the plot in Figure 5 demonstrates this is not limitless. Increasing Δ_p will eventually reach a point where vapor bubbles will form and cause a crowding condition in the vena contracta which limits the flow through a valve. This is the point where the curve stops progressing linearly and starts to bend, or the start of the transition zone. $\mathrm{K_c}$ is defined at this point as shown in Figure 5. It is the point where the actual Cv measured is 2% less than the projected Cv. The inverse of this is σ_{MR}. *(see section 5 for more detail)*

Further down where cavitation starts is σ_i, which is where incipient cavitation starts to occur. From σ_i to the start of the transition zone is the region of non-choking cavitation. At the point where the slope goes flat or zero, the valve is fully choked. Flashing can also occur if the downstream pressure is lower than the fluids vapor pressure.

F_L^2 is also shown, and is defined as the valves recovery coefficient or recovery factor, and is located at the point where the theoretical horizontal and vertical lines intersect. The location of intersection of these lines is different for different styles valves from different valve manufacturers.

Sigma

The principle of σ (sigma) is now the fundamental means of determining the presence and intensity of cavitation in Alpha1 V20. Before the implementation of σ (sigma) and the associated equations, the method of $K_c = \frac{\Delta P}{P_1 - P_v}$ was used. Expanding this further:

$\Delta P_{allowable} = f_l^2 (P_1 - P_{VC})$
P_{VC} = pressure at the vena contracta
where
$\Delta P_{allowable}$ = maximum allowable pressure drop
f_l^2 = valve recovery coefficient
"$K_c = \frac{\Delta P}{P_1 - P_v}$ . . . The basic problem with cavitation index K_c is that it does not take into consideration any pre-choked cavtitation conditions." *Skousen, Valve Handbook, page 508*

The equations and methods set forth by ISA 75.03 1995 in this document take into account pre-choked cavitation, including additional influences caused by high pressures, large sizes and pipe reducers. It also determines the presence and intensity of cavitation in pre-choked conditions.

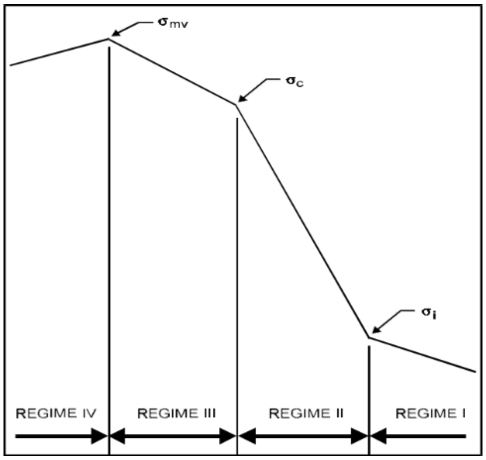


Figure 6, ISA–RP75.23–1995, 5.1

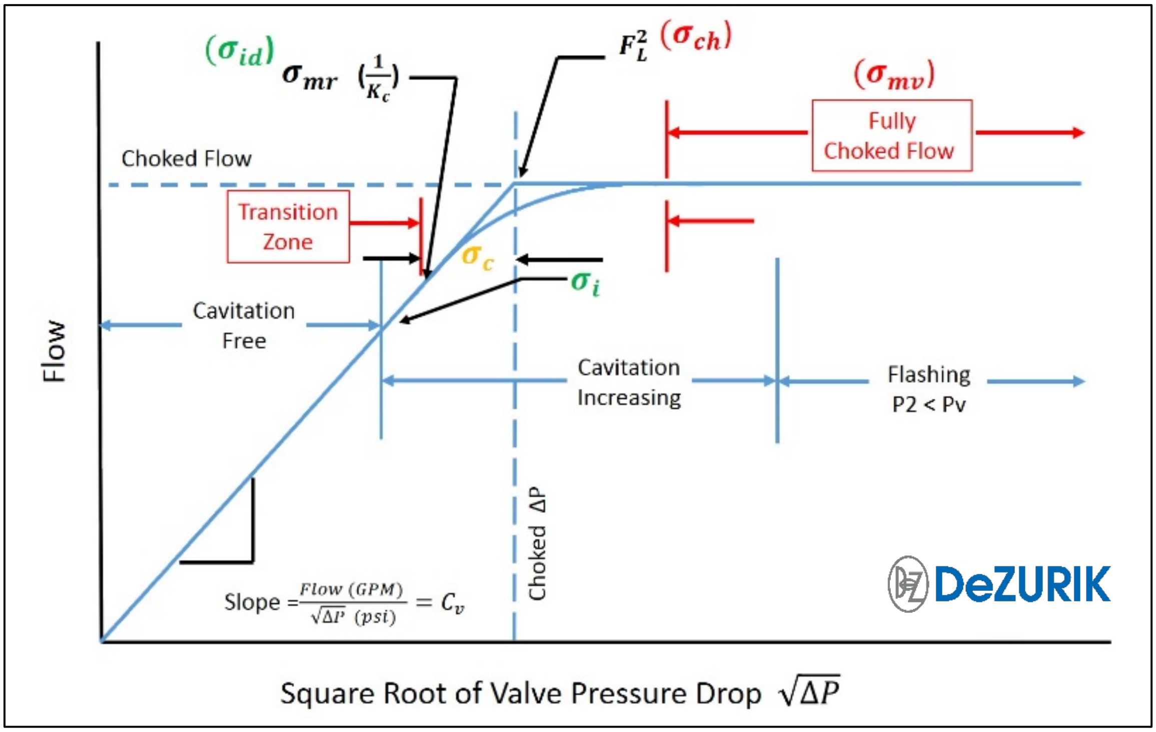
Cavitation index $\sigma = \frac{P_1 - P_v}{P_1 - P_2}$

P1 = inlet pressure
P2 = outlet pressure
P_v = vapor pressure

The chart on the left is from ISA–RP75.23–1995, which benchmarks levels of cavitation that can be present in a control valve. Some of these levels are:

a) Regime I Incipient cavitation
b) Regime II Incipient damage
c) Regime II Full or constant cavitation
d) Regime III Choking
e) Regime IV Maximum vibration
f) Flashing

a) **Incipient cavitation** σ_i The point where incipient cavitation starts to occur.
b) **Incipient cavitation damage** σ_{id} The onset of cavitation damage. Minor, observable indications of pitting can occur.
c) **Full or constant *(Mild, Moderate and Severe Cavitation)*** σ_c The degree to which cavitation is occurring. *(Pre-choked)*
d) **Choking cavitation** σ_{ch} Vapor formation is enough to limit the flow rate through the valve.
e) **Max Vibration cavitation** σ_{mv} Cavitation so severe that pipe and valve catastrophic damage can occur. Typical in larger valves.
f) **Flashing** Vapor formed inside valve persists downstream because the outlet of the valve is at or below the vapor pressure of the fluid.


(σ_{id})
σ_{mr} $(\frac{1}{K_c})$
F_L^2 (σ_{ch})
(σ_{mv})
Fully Choked Flow
Choked Flow
Transition Zone
σ_c
σ_i
Cavitation Free
Cavitation Increasing
Flashing P2 < Pv
Flow
Choked ΔP
Slope $= \frac{Flow\ (GPM)}{\sqrt{\Delta P}\ (psi)} = C_v$
DeZURIK
Square Root of Valve Pressure Drop $\sqrt{\Delta P}$

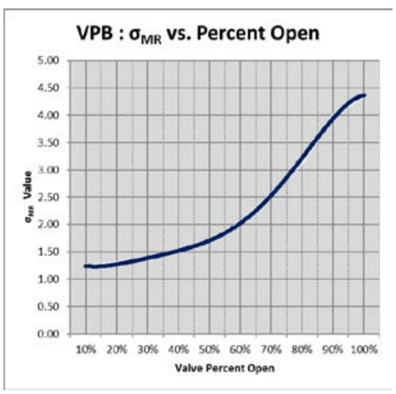
Manufacturer’s Recommended Sigma σ_{mr}

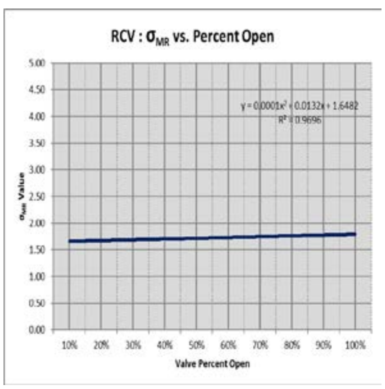
The manufacturer's recommended limit for cavitation σ_{mr} is the limit suggested by the manufacturer for a given valve. It may or may not coincide with other cavitation coefficients such as incipient damage or constant cavitation. Published values of this limit are based on experience and on the normal type of application for the valve. Published values may not be suitable for all applications. The manufacturer also should publish the criteria for the selection of σ_{mr}. The manufacturer always should be contacted to verify the recommended limit for each type of valve application. ISA 75.23 7.4.1

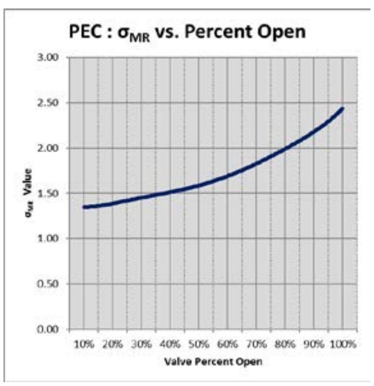
DeZURIK σ_{mr} Curves

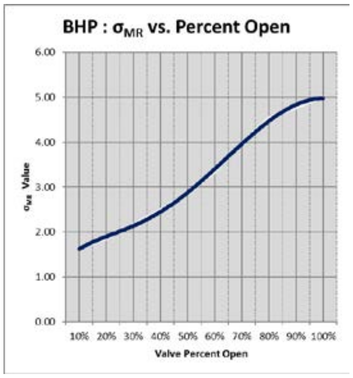
Manufacturers like DeZURIK use $K_c = \frac{P_1 - P_2}{P_1 - P_v}$ as a cavitation index. The inverse of K_c is actually used to create a manufacturers recommended cavitation limit σ_{mr}, which varies as a function of the valve opening:

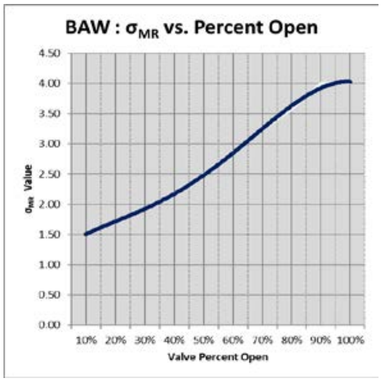
$$\sigma_{mr} = \frac{1}{K_c}$$

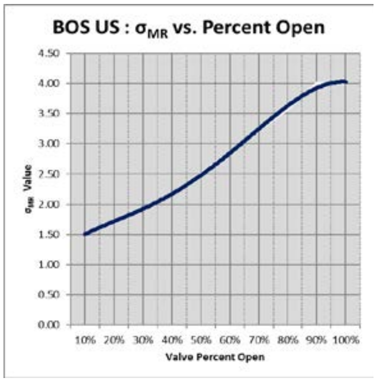












After the valve opening is determined for the given DeZURIK valve, the corresponding σ_{mr} is then used with other calculations as set forth in ISA–RP75.23–1995.

The curves and values are unique to the DeZURIK products as shown.

Thermodynamics of Control Valves

It is important to understand how a control valve applies in the first law of thermodynamics:

$$h_i \; + \frac{v_i^2}{2g_cJ} \; + \frac{gz_i}{g_cJ} = h_e \; + \frac{v_e^2}{2g_cJ} \; + \frac{gz_e}{g_cJ} + W - Q$$

W and Q = 0; *Control valves perform no work, and they Adiabatic.* The velocity terms are too close to be appreciable so they cancel, thus $h_i \; = h_e$ or Enthalpy at the valve inlet equals enthalpy at the valve outlet. This is a special case of the first law, and it is important to understand. The next section will demonstrate how to calculate this.

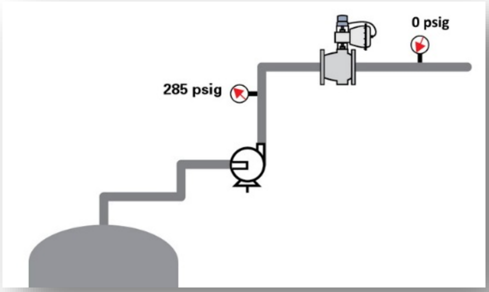
Flashing

Consider again Figure 3. Alpha1 V20 will provide a warning that flashing is present, but it does not calculate the % flash. The % flash can be calculated as follows with Steam Tables using the following method:

Gauge reads 285 psig = 300 psia

2" Sch 40 Pipe, Flow = 150 GPM

T = 250°F



Inlet pressure = 300 psia saturated water.
Outlet Pressure = 0 psig or 14.7 psia.
What is the quality of the exit steam or % flash?

$$X = \frac{h_{water-}h_f}{h_{fg}}$$

X = % flash
h_{water} = enthalpy of P1 (water)
h_f = saturated liquid enthalpy at the exit
h_{fg} = enthalpy of evaporation at the exit

Figure 7, Flashing damage to valve trim

$\frac{h_{i-}h_f}{h_{fg}} = \frac{220-180}{970}$ = 0.04 or 4% flash

This means that 4% of the liquid has turned to vapor and is causing an extreme crowding condition in the valve. To mass balance the inlet conditions with the extra volume the vapor occupies at the outlet, the velocity has to increase. The resultant downstream flow is very erosive and can wear away valve trim in a matter of hours. Rather than a pitted cinder appearance with cavitation, flashing damage is a more localized removal of material that is often smooth and polished. Because the enthalpy at the inlet of a throttling valve equals the enthalpy at the exit of the same throttling valve, evaluating the conditions at the exit are possible using the PH diagram as shown:

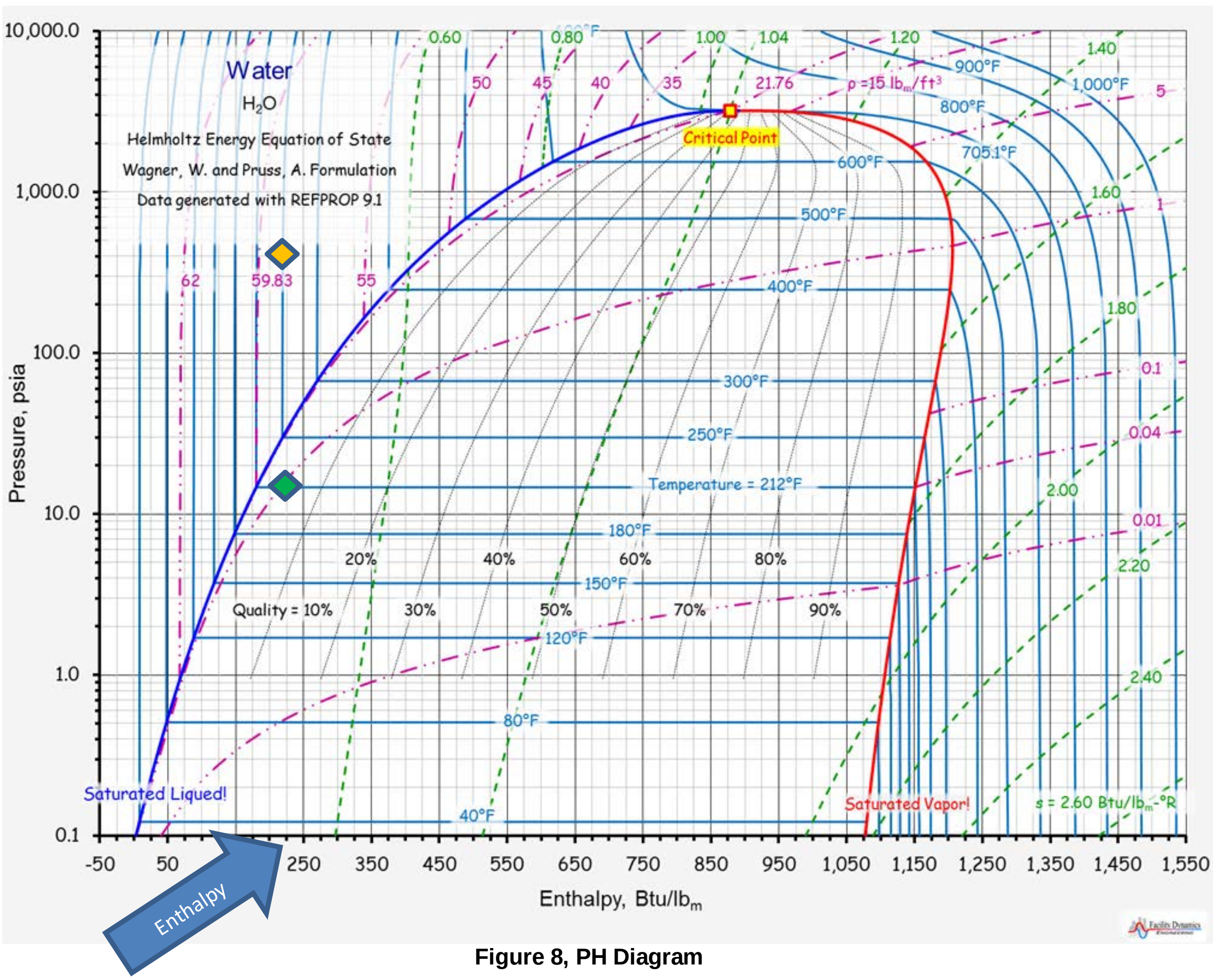


Figure 8, PH Diagram

Represents the water condition at the inlet of the valve, 250°F and 300 psia. Draw a line straight down to the x axis – and this is the enthalpy = 200 $\frac{Btu}{lb_m}$.

..Represents the water condition at the exit. Because the enthalpy is the same $h_i = h_e$ drop a line straight down from until 14.7 psia - this is the exit condition and location of 4% flash; h_f and h_{fg} are found in steam tables for 14.7 psia. Note that 4% has flashed to steam which also means 96% is still liquid; however, the overall volume of the mass flow through the valve has changed.

To calculate the velocity of the 4% flash:

1. (from steam tables, or PH diagram for inlet P1 water)
   - specific volume of the water inlet: $v_{inlet} = 0.017 \frac{ft^3}{lb}$,
   - specific volume of the water outlet: $v_g = 26.8 \frac{ft^3}{lb}\, v_f = 0.0167 \frac{ft^3}{lb}$

2. At the outlet specific volume of the water/vapor mix $v_{oulet} = v_f + 0.04(v_g - v_f) = 1.088 \frac{ft^3}{lb}$

3. Area of a 2" VPB at the inlet = 0.2 ft^2, area at the exit = 0.19 ft^2

4. The velocity V of the water at the inlet = $\frac{Q_{gpm}}{2.45 * {d_{in}}^2}$ = 15$\frac{ft}{sec}$

5. The velocity of the flash at the exit = $\frac{A_{inlet}\, V_{inlet}\, v_{oulet}}{v_{inlet}\, A_{outlet}}$ = *Mach 0.20 (1,011* $\frac{ft}{sec}$*)*

This exit velocity is very high. Changing to an angle style valve with hardened trim and increasing the downstream pipe size is recommended. 100% steam applications are actually easier to address in control valves than flashing.

Formula for velocity of steam in pipes:

$$V = \frac{2.4 Q V_s}{A * 60}$$

V = Velocity in $\frac{ft}{sec}$

Q = Flow rate $\frac{lb}{hr}$ steam

V_s = specific volume of steam (from steam tables)

A = Internal are of the pipe in^2

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Recovery Factor F_l

A critical component is a valve's *recovery factor*, and sometimes referred to as its *resistance* to cavitation. The F_l number for a particular valve is valuable to know. It is used to determine choked flow as seen in section 4.7. Moreover, considerable cost savings in mild cavitation can be realized by simply changing the orientation of the control valve in the line. In other words, a globe valve's resistance or F_l is increased by changing the flow to under the plug – thereby averting the need for expensive cavitation trim. Consider the following graph:

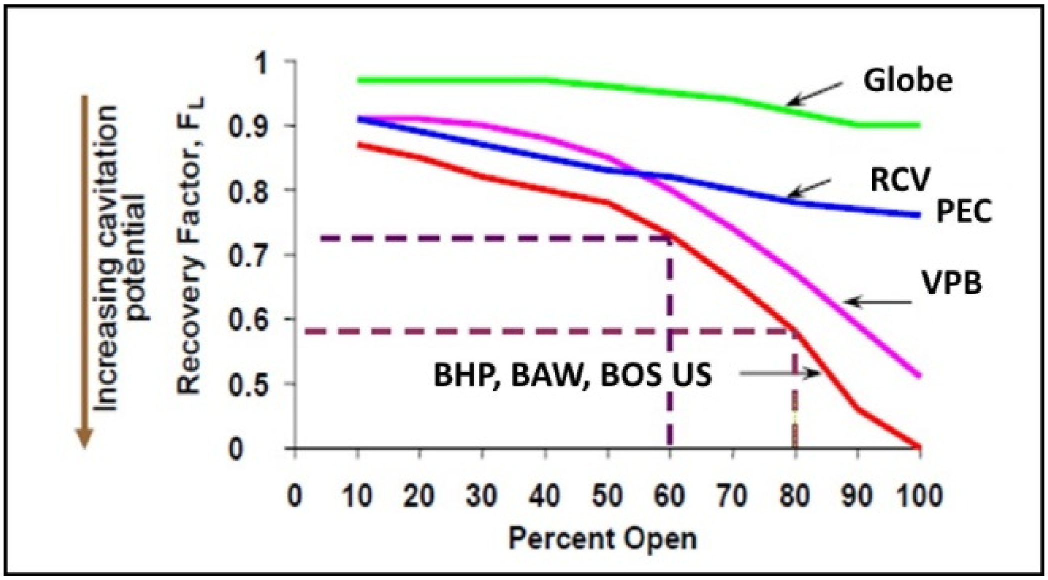
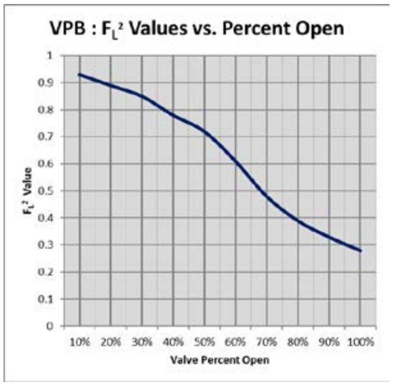
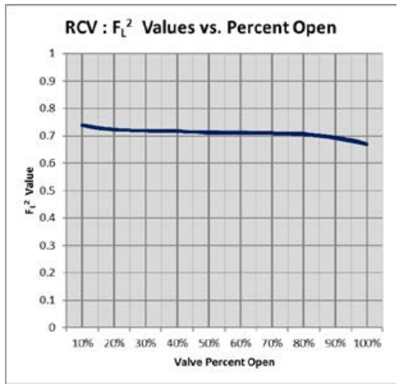


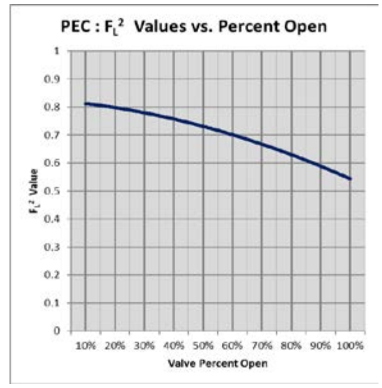
Figure 9, Recover factor comparisons by valve type

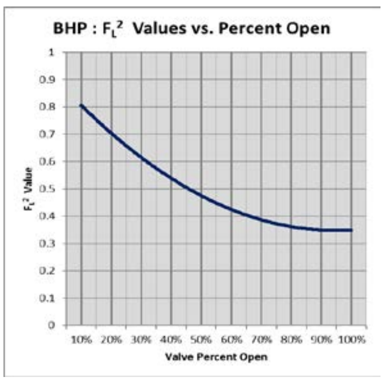
A globe has the highest F_l of all the types of control valves presented, and it maintains its F_l through full open with some decay. Valve geometry is the dominant factor that influences F_l. It is much different with a butterfly valve. While its F_l value is favorable at opening, its decay or "drop off" is pronounced as it continues to open, and at full open it can be said it has little or no resistance at all.

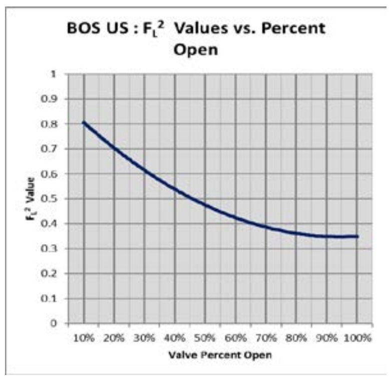
Recovery Factor f_l^2 Curves

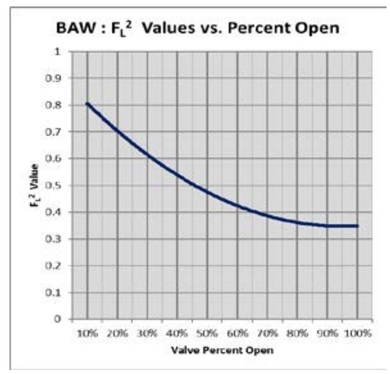












Pressure and Size Scale Effects

Historically, the control valve industry has adopted the practice of describing cavitation applications in terms of a single, unadjusted parameter…the suitability of a given control valve is determined by comparing the value of this parameter evaluated at operating conditions to an "operating limit" for that control valve.

While appealing from a user standpoint, the approach described above suffers from some major drawbacks…the complexity of cavitation renders it difficult to predict the exact behavior in any given service on the basis of a single, unadjusted parameter. Many service factors can affect the apparent level of cavitation. From ISA 75.23 1996 pgs. 15 -16

Factors such as pipe reducers and further influences from valve type, valve size and pipe size, and high process pressures are taken into account with what is known as: Pressure and Size Scale Effects (PSE and SSE).

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PSE & SSE Equations and Variables ISA 75.23

For effects due to pressure ($P1_{valve}$ is in absolute units):

$PSE = \left(\frac{P1_{valve} - P_v}{P_R}\right)^a$ $SSE = \left(\frac{d}{d_R}\right)^b$ where $b = 0.068\left(\frac{C_v}{N*d^2}\right)^{0.25}$ ***a** = Empirical characteristic component for calculating PSE,* ***d** = valve size in inches,* ***D** = pipe size in inches,* $\boldsymbol{d_R}$ ***=** valve inlet inside dia. of tested reference valve in inches* $\boldsymbol{P_R}$ = or < 100 psi. Rotary valves $\boldsymbol{P_R}$ could be equal to 40 psi, $\boldsymbol{N_2}$ **=** numerical constants for units of measure uses in equations

Table 1, ISA Constants and Variables for PSE and SSE

DeZURIK Product	a	d_R	P_R	N	N_2 (in)	N_2 (mm)
BAW all sizes	0.22	6	100	1	890	$2.14e^{-3}$
BHP through 5”	0.22	3	100	1	890	$2.14e^{-3}$
BHP 6” and larger	0.22	6	100	1	890	$2.14e^{-3}$
BOS US	0.22	3	100	1	890	$2.14e^{-3}$
PEC through 5”	0.3	3	100	1	890	$2.14e^{-3}$
PEC 6” and larger	0.3	3	100	1	890	$2.14e^{-3}$
RCV through 4”	0.3	3	100	1	890	$2.14e^{-3}$
RCV 6” and larger	0.3	6	100	1	890	$2.14e^{-3}$
VPB through 4”	0.3	3	100	1	890	$2.14e^{-3}$
VPB 6” and larger	0.3	6	100	1	890	$2.14e^{-3}$

$\boldsymbol{\sigma_v}$ Pipe Reducers and $\boldsymbol{\sigma_p}$ ISA 75.23

Pressure and size scale effects are combined with $\boldsymbol{\sigma_{mr}}$ to form a new σ called σ_v.

a) $\sigma_v = (\sigma_{mr} * SSE - 1) * PSE + 1$

The following equations are theoretical expressions that account for the combined head losses associated with the upstream and downstream reducers. Other potential effects of close-coupled reducers are not included.

b) $K_{B1} = 1 - \frac{d^4}{D_1^4}$ *Upstream reducer*

c) $K_{B2} = 1 - \frac{d^4}{D_2^4}$ *Downstream expansion*

d) $K_1 = 0.5\left(1 - \frac{d^2}{D_1^2}\right)^2$

g) $K_2 = 1.0\left(1 - \frac{d^2}{D_2^2}\right)^2$

h) $\sum K = K_{B1} + K_{B2} + K_1 + K_2$

i) $F_p = \left(1 + \frac{(\sum K) * C_v^2}{N_2 * d^4}\right)$

Now all of this is taken into account with σ_v , and the resultant σ_p is generated as follows:

j) $\sigma_P = F_p^2 * \left(\sigma_V + \frac{(K_1 + K_{B1}) * C_v^2}{N_2 * d^4}\right)$

If there are no upstream reducers and downstream expanders, then σ_P and σ_v will be the same, Otherwise, σ_P will be used to compare with the original calculated process. Therefore, if

$\sigma = \frac{P_1 - P_v}{P_1 - P_2}$ is less than σ_P and σ_v, then a activating condition may exist, and further actions may be warranted to protect the valve, the piping or both. Possible solutions associated with varying degrees of cavitation intensity are presented in section 8.

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Steps for Analyzing Cavitation

Steps for Analyzing Cavitation:

1. Gather the conditions.

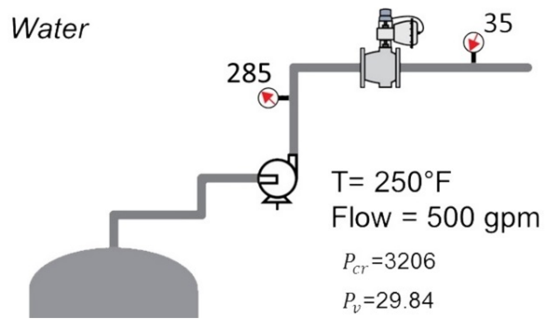

Figure 10, VPB application

Pipe	2" Sch. 40
Fluid	Water
Upstream P1	300 psia
Downstream P2	50 psia
ΔP	250 psia
Flow	500 gpm
Temp	250°F (SG = 0.9)
Pv (vapor pressure)	29.84 psia
P critical	3206
Valve Type	2" VPB (Cv = 210)

2. Is it flashing?

Compare the downstream P2 with 50 psia with the fluid's vapor pressure 29,84 psia.

P2 > Pv = therefore, it is not flashing

3. Calculate the % open (assuming non-choked flow)

$C_v = 500\sqrt{\frac{0.9}{250}}$ = 30 from the chart in section 4.6, f_l^2 is approx. 0.8

For steps 2 – 3, the following equations are used:

$$F_f = (0.96) - (0.28)\sqrt{\frac{P_V}{P_C}}$$

$$P_{VC} = F_f P_V$$

$$\Delta P_{choke} = F_L^2\left(P_1 - F_f P_{VC}\right)$$

4. Check for choked flow (see section 4.6 for F_l @ opening for VPB)
   a. ΔP_{valve} = 250 psia

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b. $F_f = (0.96) - (0.28)\sqrt{\frac{29.84}{3206}}$ = 0.93

a. P_{VC} = (0.93)*(30) = 27.75

b. $\Delta P_{choke} = 0.8(300 - 0.93 * 27.75)$ = 219

c. $\Delta P_{choke} < \Delta P_{valve}$ ***Valve is choked.***

For choked: $C_v = GPM\sqrt{\frac{SG}{\Delta P_{choked}}}$

5. Determine the new required process C_v and % opening of the VPB:

$C_v = 500\sqrt{\frac{0.9}{219}}$ = 32 *(compare with VPB response curve as shown to determine the % opening)*

For a 2" VPB $C_v = 210.$

Now compute the % of Maximum using the new required process C_v

: $\% = \frac{C_v\ Required}{C_v\ Max}$: $\frac{32}{210}$ = 15%

Using the VPB characteristic curve shown below, the % opening is approx. 47%

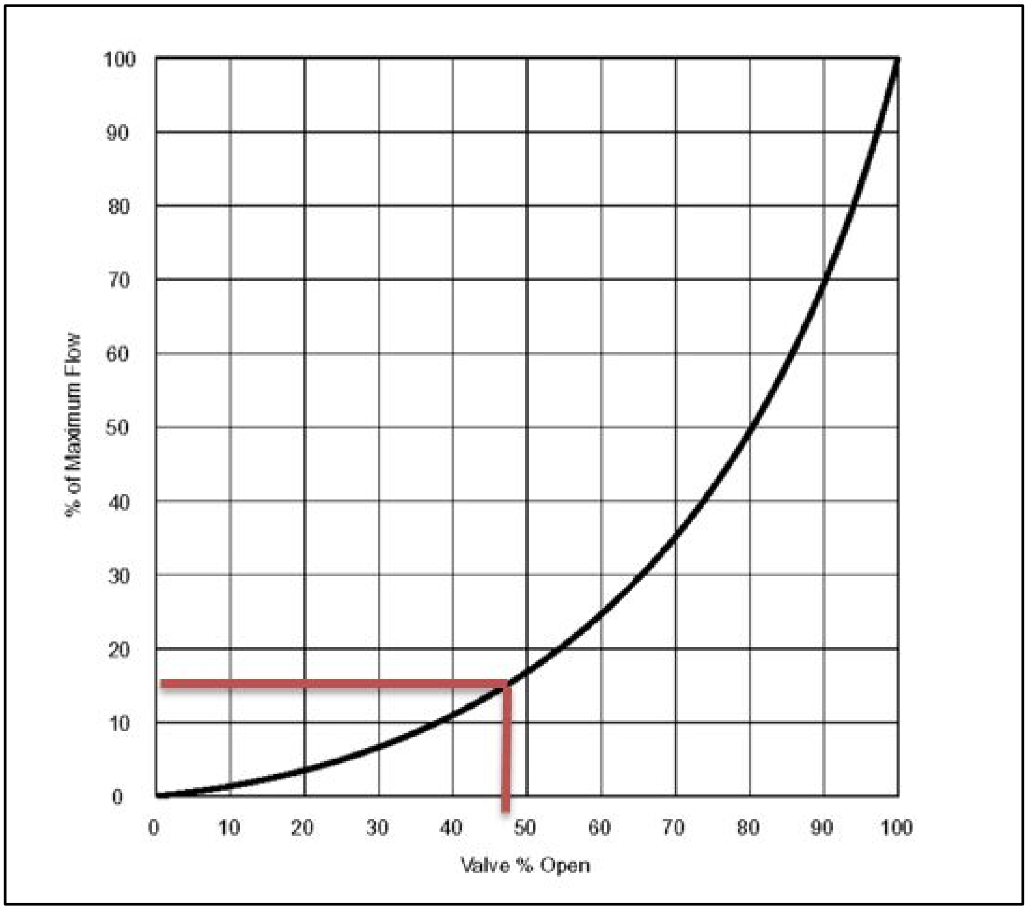

Figure 11, VPB Characteristic Curve

6. Calculate σ

$$\sigma = \frac{P_1 - P_v}{P_1 - P_2} \qquad \sigma = \frac{300 - 29.84}{300 - 50} = 1.08$$

7. Calculate Pressure Scale and Size Scale Effects from equations in section 6.1, and constants and variables found in Table 1

$$PSE = \left(\frac{300 - 29.84}{100}\right)^{0.3} = 1.347$$

$$b = 0.068\left(\frac{32}{1 * 2^2}\right)^{0.25} = 0.115$$

$$SSE = \left(\frac{2}{3}\right)^{0.115} = 0.954$$

8. Calculate σ_v using σ_{mr} based on % opening of the VPB from step 4 and curve found in Section 4.5

At 47% open σ_{mr} is approximately 1.6

$$\sigma_v = (1.6 * 0.954 - 1) * 1.347 + 1 = 1.71$$

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9. Calculate σ_p

Because there are no reducers before the VPB, or expanders after the VPB this step is not necessary. Essentially $\sigma_p = \sigma_v$

$$\sum K = K_{B1} + K_{B2} + K_1 + K_2 = 0$$

$$F_p = \left(1 + \frac{(\sum K) * C_v^2}{N_2 * d^4}\right) = 1$$

$$\sigma_P = 1^2 * \left(1.71 + \frac{(K_1 + K_{B1}) * 33^2}{890 * 2^4}\right) = 1.71$$

10. Compare $\sigma_p\ \sigma_v$ with the calculated σ from step 6

If $\boldsymbol{\sigma} \geq \boldsymbol{\sigma_V \sigma_P}$, no warnings are given, or cavitation does not exist. However, if $\boldsymbol{\sigma} < \boldsymbol{\sigma_V \sigma_P}$, then starting when $\boldsymbol{\sigma}$ is 90% of $\boldsymbol{\sigma_V \sigma_P}$ the **Onset** of cavitation exists. Please see Table 2 on the following page for further details.

In this example $\frac{\sigma}{\sigma_V}$ = 0.63 or 63%

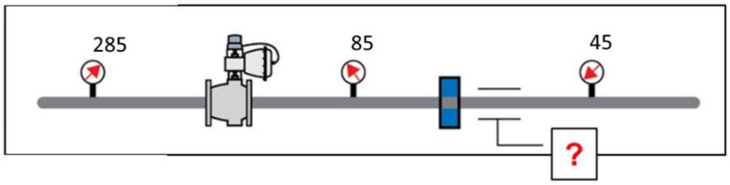
Cavitation Guidelines

Alpha-I V20 reports cavitation and severity as shown in the left column in Table 2. If such a condition is present, one of these warnings will appear for each condition in: the cavitation report, on the sizing page and the ISA Data Sheet. For all the valves listed in the following tables, Onset Cav through Severe Cav are pre-choked conditions.

Table 2, Cavitation guidelines for VPB

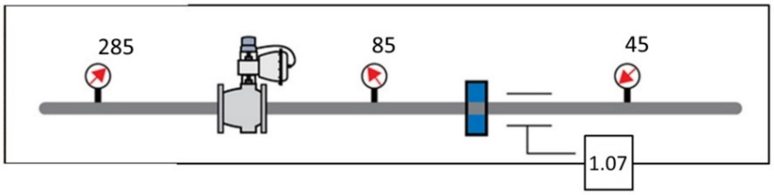
$\sigma < \sigma_V \sigma_P$ **Regime (Alpha 1 Reporting)**	**VPB Trim**
90% **Onset Cav**	317/316 Trim
85% **Mild Cav**	317/316 Trim Hardened Trim (Option)
80% **Mod Cav**	Hardened Trim *Cobalt-chromium alloy (overlay)* *Consider plate or KGV*
75% **Severe Cav**	Hardened Trim *Cobalt-chromium alloy (overlay)* *plate or KGV required*
75% (& choked condition) **Critical Cav**	Hardened Trim *Cobalt-chromium alloy (overlay)* *plate or KGV required*
Flashing **(Cond: P2 <= Pvap)**	Tungsten Carbide Trim S3S Hardened internal body overlay 5% or < less Also consider expanding the downstream pipe size

For the RCV, VPB and PEC a downstream restrictive orifice or a throttling KGV could be an economical and effective solution to supply back pressure to alleviate cavitation. Please note that these solutions may not be sufficient for providing back pressure for the full range of a throttling control valve. See factory for assistance.



Restriction orifices can be easily sized starting with Alpha-I V20, and making a few assumptions:

- The plate is sharp edged,
- straight through bore
- produces a Reynolds number that is fully turbulent



For example, with conditions given: P1 = 285 psig, P2 = 45 psig, 2” Sch. 40 pipe, T= 100°F, and flow = 100 gpm. Sizing an RCV with Alpha 1 V20 reports **Critical Cav.** Adjusting P2 = 85 psig with Alpha1 V20 reduces the cavitation severity. Using this as the ΔP for a restriction orifice, and using the RCV example in the following formulas:

$$C_{coeff}=\frac{GPM}{\sqrt{\frac{\Delta P}{S_g}}} = 15.811$$

$$D = \frac{7}{8}\sqrt{\frac{C_{coeff}}{14.0}} = 0.93$$

$$L_{thick} = 0.25$$

$$D_{corr} = D\sqrt[5]{\frac{L_{thick}}{.125}} = 1.068$$

Nomenclature *(Equations and method: Chemical Engineering Magazine, August 17, 1987)*

C_{coeff}	*Restrictive orifice coefficient*	S_g	*Specific gravity of water at temperature*
D_{corr}	*Corrected bore, in. for 0.25 in. thick plate*	*14.0*	*The number 14.0 is a valve coefficient equivalent for a straight-thru bore*

This same method can be used with the VPB, BAW, BHP, BOS US and PEC.

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Table 3, Cavitation Guidelines for RCV

$\sigma < \sigma_V \sigma_P$ **Regime (Alpha 1 Reporting)**	**RCV Trim**
90% **Onset Cav**	317/316 Trim
85% **Mild Cav**	317/316 Trim Hardened Trim (Option)
80% **Mod Cav**	Hardened Trim *Cobalt-chromium alloy (overlay)* *Consider plate or KGV*
75% **Severe Cav**	Hardened Trim *Cobalt-chromium alloy (overlay)* *plate or KGV required*
75% (& choked condition) **Critical Cav**	Hardened Trim *Cobalt-chromium alloy (overlay)* *plate or KGV required*
Flashing **(Cond: P2 <= Pvap)**	Tungsten Carbide Trim S3S Hardened internal body overlay 5% or < less Also consider expanding the downstream pipe size

Table 4, Cavitation Guidelines for the PEC

$\sigma < \sigma_V \sigma_P$ **Regime (Alpha 1 Reporting)**	**PEC Trim**
90% **Onset Cav**	Standard Valve Elastomer Seat, CI Body
85% **Mild Cav**	CS or SS Body Elastomer Seat
80% **Mod Cav**	Metal Plug (316 SST) CS SS Body Flow into the back of the plug *Option plate or KGV*
75% **Severe Cav**	Metal Plug (316 SST) CS or SS Body Flow into the back of the plug *Plate or KGV required*
75% (& choked condition) **Critical Cav**	Metal Plug (316 SST) CS or SS Body Flow into the back of the plug *Plate or KGV required*
Flashing **(Cond: P2 <= Pvap)**	Not recommended

Table 5 is for DeZURIK's butterfly valves (BHP, BOS US & BAW)

Butterfly valves are often used because they are lower in cost compared to other valve styles of the same size, especially in larger sizes. Torque, head-loss (ΔP) and cavitation are all important factors when sizing and selecting a DeZURIK butterfly valve for a water system.

The vena contracta or low pressure zone develops downstream from a butterfly valve. Depending on where the pressure recovery occurs, the imploding bubbles can form close to the disk or further downstream in the piping. Regardless of where this occurs, the energy still has to be absorbed and often the piping takes all of it. Vibration and noise produced from cavitation are also a concern, especially when a large butterfly valve is used. When considering a butterfly valve in cavitating service, the following guidelines should be followed:

1. Consider the butterfly valve's location and orientation in the system
2. Consider the % opening of the disk. Butterfly valves that throttle near the closed position can produce cavitation because the ΔP is highest at that point
3. Consider using two valves in series
4. A bypass line to handle the low flow or cavitating condition
5. For cavitation that develops to **Mod Cav** with a DeZURIK butterfly valve, a downstream restriction orifice that lowers the ΔP is recommended; for **Severe Cav** it is required.
6. For 24" and larger, consult with the factory for **Mild Cav** and beyond

Table 5, Cavitation guidelines for BHP, BOS-US and BAW Butterfly Valves

$\sigma < \sigma_V \sigma_P$ **Regime (Alpha-I Reporting)**	**Butterfly Valve Trim**
90% **Onset Cav**	OK
85% **Mild Cav**	*OK*
80% **Mod Cav**	*Consult DeZURIK* *Recommend: Downstream Restriction Orifice**
75% **Severe Cav**	*Consult DeZURIK* *Required: Downstream Restriction Orifice**
75% (& choked condition) **Critical Cav**	*Consult DeZURIK* *Required: Downstream Restriction Orifice**
Flashing **(Cond: P2 <= Pvap)**	*Consult DeZURIK*

**** A restriction orifice is a good method for cavitation prevention provided the valve has a narrow throttling range. (See method described on page 18 – 19)***

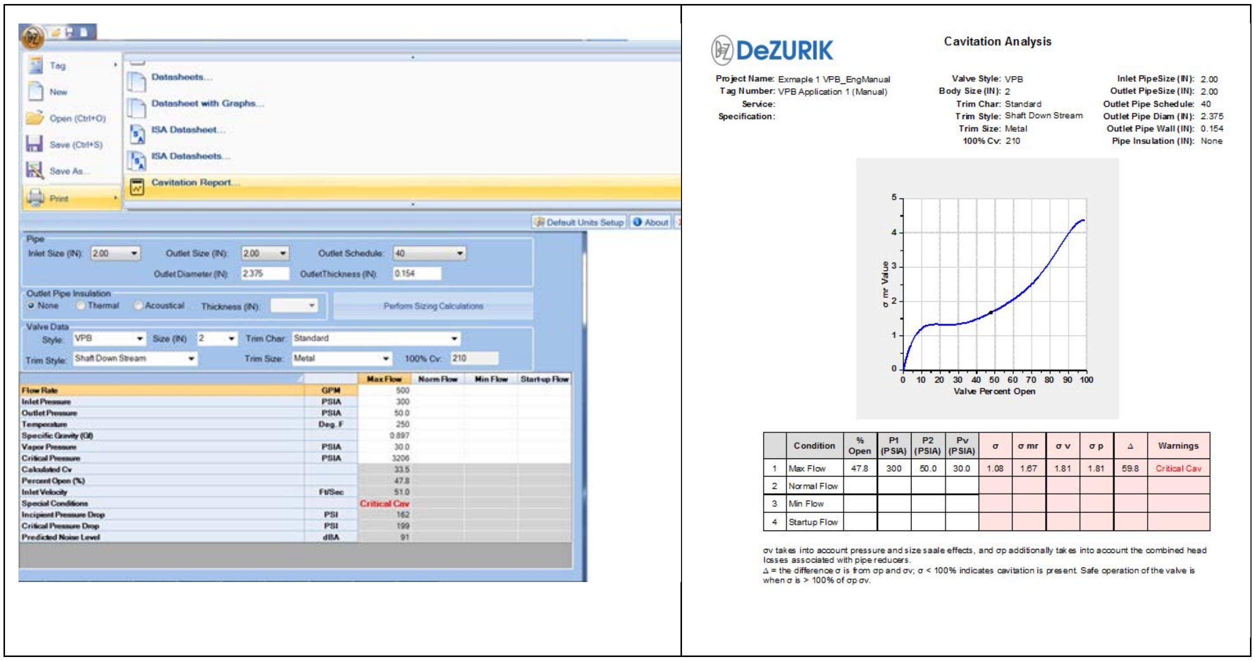
Market solutions for cavitating butterfly valves that have a broad throttling range are available. Consult with DeZURIK application engineering to determine if such an approach is a viable solution.

Alpha-I V20 for Cavitation Reporting

DeZURIK's Alpha-I valve sizing program will calculate and report cavitation in accordance with ISA 75.23 which the method outlined in section 4.9, and report levels of cavitation as shown in section 4.10 for the following DeZURIK Products:

1. VPB
2. RCV
3. BHP
4. BOS US
5. PEC
6. BAW

From the additional features menu in the program – under "Print" selection cavitation report as shown:



The program will print the cavitation as shown on the right, which includes:

- Project Name, Tag, Service, Specification
- Valve information and Pipe information
- $\boldsymbol{\sigma_{mr}}$ graph for the valve, and the point on the graph where the valve is operating per the condition.
- Summary of the conditions and data, and resulting $\boldsymbol{\sigma}_s$ that the program used and calculated to arrive at the cavitation warning.

In addition to ΔP Alpha1 V20 now has the option to select P2 as a downstream condition on the sizing screen. Under the <u>Size Valve Tab</u> , select outlet pressure for P2.