



White Paper

Cavitation in Valves

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Cavitation in Valves

INTRODUCTION

Cavitation can occur in valves when used in throttling or modulating service. Cavitation is the sudden vaporization and violent condensation of a liquid downstream of the valve due to localized low pressure zones. When flow passes through a throttled valve, a localized low pressure zone forms immediately downstream of the valve. If the localized pressure falls below the vapor pressure of the fluid, the liquid vaporizes (boils) and forms a vapor pocket. As the vapor bubbles flow downstream, the pressure recovers, and the bubbles violently implode causing a popping or rumbling sound similar to tumbling rocks in a pipe. The sound of cavitation in a pipeline is unmistakable. The condensation of the bubbles not only produces a ringing sound, but also creates localized stresses in the pipe walls and valve body that can cause severe pitting.

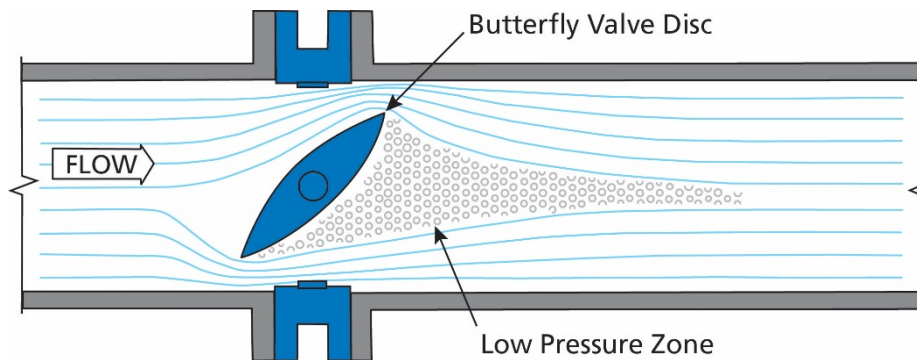


FIGURE 1. Cavitation

Cavitation is a common occurrence in shutoff valves during the last few degrees of closure when the supply pressure is greater than about 100 psig. Valves can withstand limited durations of cavitation, but when the valve must be throttled or modulated in cavitating conditions for long periods of time, the life of the valve can be drastically reduced. Therefore, an analysis of flow conditions is needed when a valve is used for flow or pressure control.

CAVITATION ANALYSIS

Three levels of cavitation have been defined:

- Incipient cavitation represents the beginning stage of cavitation where intermittent popping noises are heard.
- Constant cavitation is a steady rumbling sound associated with start of possible valve damage.
- Choked cavitation is the point where the vaporization of the fluid reaches sonic velocity in the valve port and limits the flow through the valve.

Val-Matic recommends that the constant cavitation data be used when judging the effects of cavitation on the life of the valve. If perfectly quiet operation is needed, then the factory should be consulted for incipient cavitation data. Only special control valves with cavitation trim (i.e. sleeve valves) should be used for choked conditions. A cavitation index can be calculated to predict whether cavitation will occur as follows:

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$$\sigma = (P_u - P_v) / (P_u - P_d)$$

where:

- σ = cavitation index, dimensionless
- P_d = downstream pressure, psig
- P_v = vapor pressure adjusted for temperature and atmospheric pressure, psig
= -14.4 psig for water at 60°F, sea level
- P_u = upstream pressure, psig

The lower the value for the cavitation index, the more likely cavitation will occur. As a rule of thumb, manufacturers typically suggest that when σ is less than 2.5, cavitation may occur.

CAVITATION DATA

Val-Matic conducted flow tests on quarter-turn valves and developed cavitation coefficients for the valves as shown in the graph below. To use the graph, the required valve angle must be calculated using the flow coefficient data for the subject valve. Next, the cavitation index is calculated and plotted on the graph. If the point is below the graphed line, then constant cavitation will occur and prolonged throttling at that angle would not be recommended. Also, prolonged throttling below 10 degrees open regardless of the cavitation index is not recommended because high localized velocities may scour and wear the valve seating surfaces.

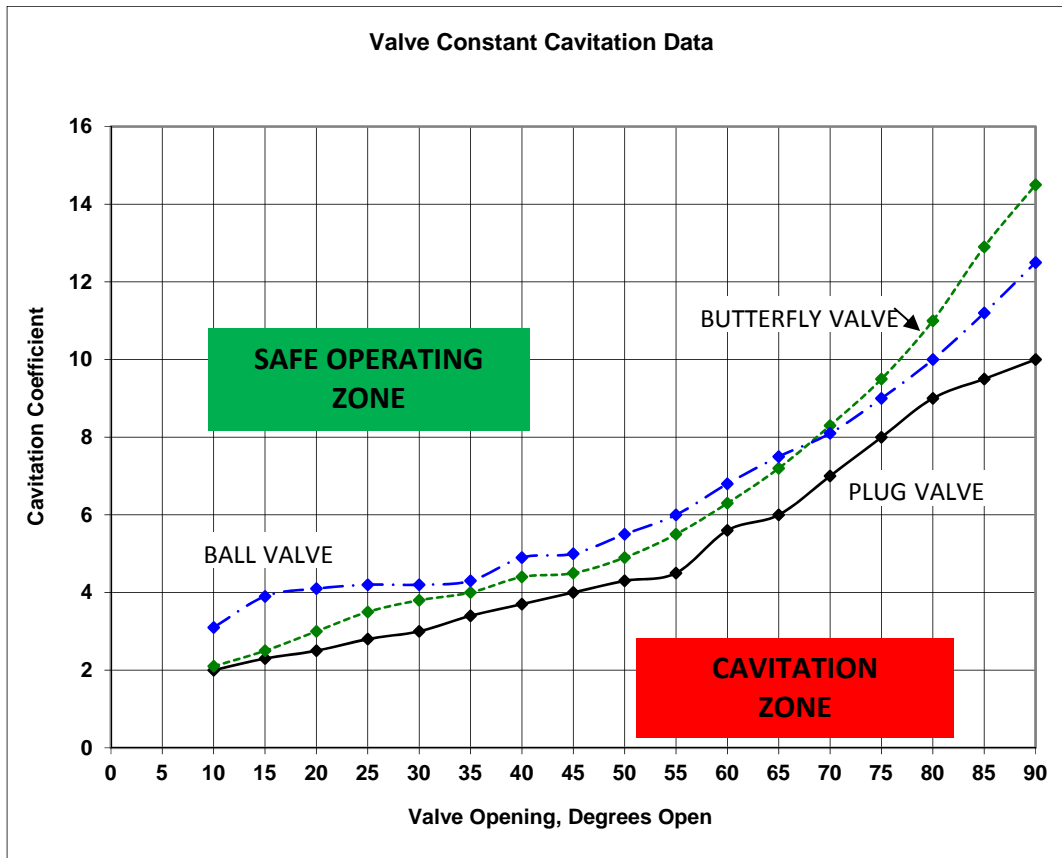


FIGURE 2. Cavitation Characteristics of Valves

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VALVE COEFFICIENT DATA

To determine the required valve angle for a particular flow application, calculate the required valve Cv from the following equation:

$$\text{Required Cv} = Q / \sqrt{\Delta P}$$

where:

ΔP = valve differential pressure, psi

Q = desired flow rate, gpm

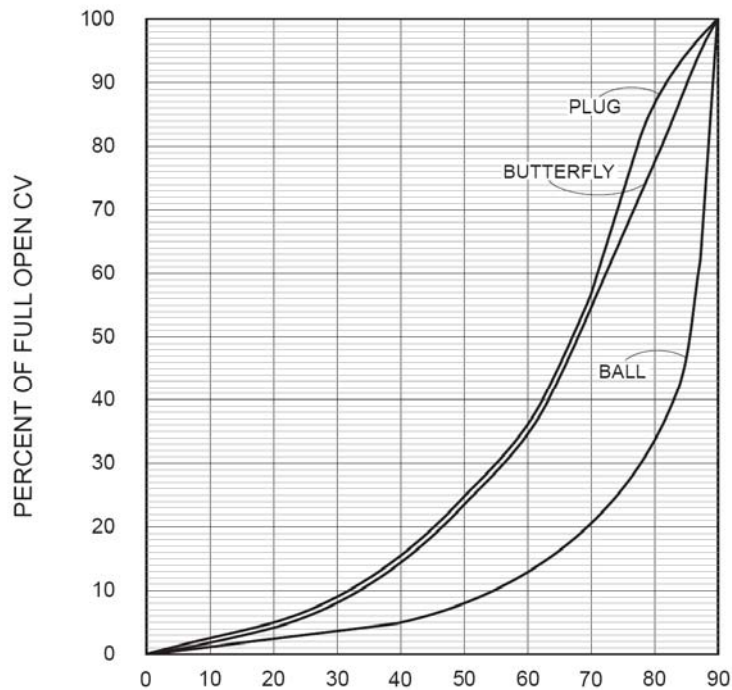
Given the required Cv, the angle of throttling can be found by dividing this required Cv by the full open Cv shown in the table below. This is the percent of full open Cv.

$$\% \text{ Cv} = 100 \times \text{Required Cv} / \text{Full Open Cv}$$

PLUG, BUTTERFLY, AND BALL VALVE FULL OPEN Cv FLOW COEFFICIENTS														
VALVE SIZE, in	1	2	2.5	3	4	6	8	10	12	14	16	18	20	24
Plug	37	150	240	320	570	1,200	2,070	3,250	4,750	6,150	8,050	10,200	12,600	18,100
Butterfly				380	590	1,430	2,750	4,300	6,550	8,350	11,800	15,000	18,600	27,000
Ball						4,310	8,520	14,700	22,800	30,500	42,700	56,100	70,500	106,000

VALVE SIZE, in	30	36	42	48	54	60	66	72
Plug	28,300	40,700	55,400	91,650	91,650			
Butterfly	42,000	61,900	87,100	114,000	144,000	180,000	221,000	266,500
Ball	172,000	257,000	369,000	480,000				

Finally, by finding the percent of full open Cv on the vertical axis of the flow characteristic graph, the valve position in degrees open can be read off of the horizontal axis in Figure 3.



VALVE POSITION (DEGREES FROM CLOSED POSITION)

FIGURE 3. Flow Characteristics of Valves

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The valve position in degrees obtained from Figure 3 and the cavitation index calculated above are then plotted on the graph in Figure 2. If the resultant point falls below the applicable valve curve, then serious cavitation may occur.

EXAMPLE APPLICATION

An 8" plug valve equipped with a modulating motor will be used in a backwash system to limit the flow rate to a sand filter. The upstream pressure is a constant 25 psig because the supply source is an elevated tank. The valve is mounted near the sand filter and will see a downstream pressure of 5 psig while controlling the flow rate to 300 gpm. At this flow rate, it was calculated that the valve must drop 6 psig. Therefore, P_u equals 5 + 6 or 11 psig.

1. Calculate the cavitation index:

$$\begin{aligned}\sigma &= (P_u - P_v) / (P_u - P_d) \\ \sigma &= (11 - (-14.4)) / (11 - 5) \\ \sigma &= 4.2\end{aligned}$$

2. Calculate the required Cv:

$$\begin{aligned}Cv &= Q / \sqrt{\Delta P} \\ Cv &= 300 / \sqrt{6} \\ Cv &= 122\end{aligned}$$

3. Determine the valve angle:
The full-open Cv for the 8" valve is 2070.
The percent of full open Cv is found by:

$$\% Cv = 100 \times 122 / 2070 \text{ or } 5.9\%$$

Referring to the plug valve characteristic curve in Figure 3, the throttling angle will be 22 degrees open.

4. Plot the cavitation index of 4.2 on the cavitation graph (Figure 2) with 22 degrees on the x axis. The point is above the cavitation line and is in the "Safe Operating Zone", so cavitation will not be a problem.

CONCLUSION AND RECOMMENDATIONS

Valve manufacturers can perform an analysis to predict when cavitation will occur based on flow test data. When cavitation is predicted, some available remedies include:

1. Increase the downstream pressure by throttling a downstream valve or installing an orifice.
2. Decrease the differential pressure by using two valves in series.
3. Use a small bypass line for low flow rates.

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4. Install air inlet ports equipped with vacuum breakers immediately downstream of the valve to reduce the vacuum pocket.
5. Some valves can be furnished with cavitation reducing trim.

REFERENCES

1. AWWA Manual M49, *Quarter-Turn Valves: Head Loss, Torque, and Cavitation Analysis*, 3rd ed. pp. 77-84.
2. Rahmeyer, William J., *Journal AWWA*, November 1986. "Test Procedures for Determining Cavitation Limits in Control Valves," pp 55-58.

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