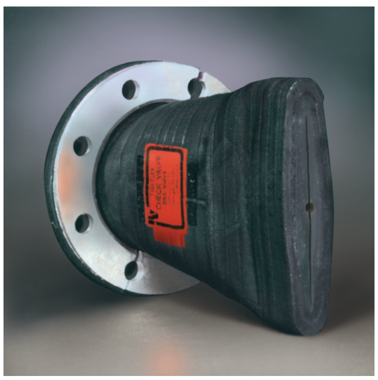
Control Valve Technical Information

Sizing TFO Flow Restrictors

When sizing control valves, many times the actual pressure drop (DP actual) across the valve will exceed the allowable pressure drop (DP allow), indicating that damaging cavitation may occur. Under severe operating conditions, this can happen even though one of Red Valve's advanced, patented anti-cavitation sleeves, such as the Cone or the Variable Orifice Sleeve, is selected.



When this occurs, a properly sized and selected Red Valve TFO flow restrictor can be of significant value in minimizing or even completely eliminating cavitation damage.

In the past, various methods have been used to reduce the actual pressure drop across a control valve, such as using a manual valve or a fixed orifice plate down stream to absorb some of the pressure drop. While these approaches have achieved some measure of success, they suffer from a common deficiency. The pressure drop through a fixed restriction (manual valve or orifice plate) increases exponentially as a function of the flow rate, e.g. doubling the flow rate increases the pressure drop by a factor of four (see Figure 1).

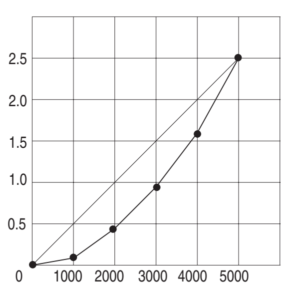


Figure 1 - Typical Orifice Plate Characteristic

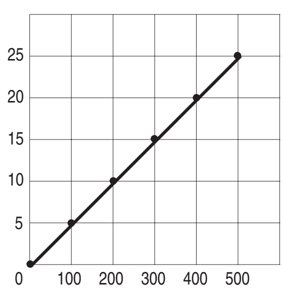


Figure 2 - Typical TFO Characteristic

Since in virtually all control valve applications the maximum pressure drop occurs at minimum flow rate, this type of characteristic is of limited usefulness. It provides a very high pressure drop at high flow rates and a very low pressure drop at low flow rates. For example, the pressure drop at 200 gpm would be 4 psi, and at 500 gpm the pressure drop would be 25 psi.

The Series TFO Flow Restrictor is a device with a linear pressure drop versus flow rate characteristic (see Figure 2). In this case, the pressure drops are 10psi at 200 gpm and 25 psi at 500 gpm. This characteristic is better, since it provides greater pressure drop at 200 gpm (10 psi versus 4 psi) with the same pressure drop at 500 gpm (25 psi).

The TFO Flow Restrictor is designed and built to generate a precise and linear pressure drop (headloss) in the normal (forward) flow direction. Referring to Figure 3, note that the

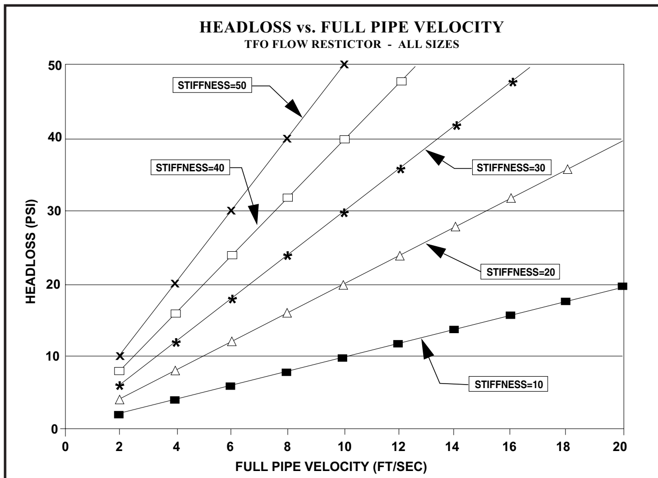


Figure 3 - Actual TFO Characteristics

TFO's are characterized by a "stiffness" factor (s), which is simply the pressure drop generated at a flow velocity of 10 feet/second.

Let's look at a simple example of how a TFO can eliminate the damage associated with cavitation. Consider a system consisting of a pump generating 50 psig, with the flow throttled by a Red Valve Series 5200 Control Pinch Valve, discharging to atmosphere to supply a mixing tank as shown in Figure 4.

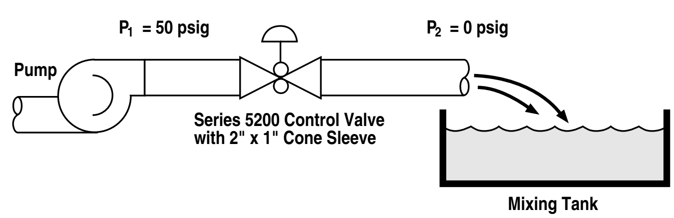


Figure 4 – Simple Control System

The flow rate to be controlled is between 50 gpm and 100 gpm. The fluid is lime slurry with a specific gravity of 1.21. The temperature is 68 F.

A typical sizing calculation sequence would be -

1. Velocity Check:

$$V_{MAX} = \frac{Q_{MAX}}{312 \times A} = \frac{100}{312 \times \pi \left(\frac{2.067}{2}\right)^2} = 9.56 \text{ ft./sec.}$$

2. Flow Coefficients (Cv) Required:

$$C_{V\,MIN} = Q_{MIN}\sqrt{\frac{S.G.}{\Delta P}} \qquad C_{V\,MAX} = Q_{MAX}\sqrt{\frac{S.G.}{\Delta P}}$$

$$= 50\sqrt{\frac{1.21}{50}} \qquad = 100\sqrt{\frac{1.21}{50}}$$

$$= 7.8_{MIN} \qquad = 15.6_{MAX}$$

3. Select Sleeve Size & Configuration:

A 2" X 1" Cone Sleeve is a good choice. It has a C_V of 7.8 @ 29% open, and a C_V of 15.6 @ 44% open.

4. Determine Maximum Allowable Pressure Drop (ΔP)

ΔP allow = FL^2 (P1 + 14.7 - rc x Pv)

@ Q min = 50 gpm	**@ Q max = 100 gpm**
FL @ 29% open = 0.84 (See FL tables)	FL @ 44% open = 0.78 (See FL tables)
P_1 = 50 psig	P_1 = 50 psig
rc = critical pressure ratio = 0.94	rc = critical pressure ratio = 0.94
Pv = Vapor pressure = 0.339 @ 68°F (See Vapor Pressure table)	Pv = Vapor pressure = 0.339 @ 68°F (See Vapor Pressure table)

Min. ΔP allow = 0.84^2 x (50 + 14.7 - (0.94 x 0.339))
Max. ΔP allow = $.078^2$ x (50 + 14.7 - (0.94 x 0.339))
ΔP allow = 45.4 psi ΔP allow = 39.2 psi

In this situation, with the control valve discharging to atmosphere, the actual pressure drop (DP actual) is 50 psi at both 50 gpm and 100 gpm. Since the maximum allowable pressure drops (DP allow) are only 45 psi at 50 gpm and 39 psi at 100 gpm the valve can be expected to excessively cavitate at both minimum and maximum flow rates. This is clearly not a desirable situation, even though rubber pinch valve sleeves are more tolerant of cavitation than metal or ceramic valve trims.

Now, let us add a TFO at the discharge end of the pipe as shown in Figure 5 and repeat the sizing calculation sequence.

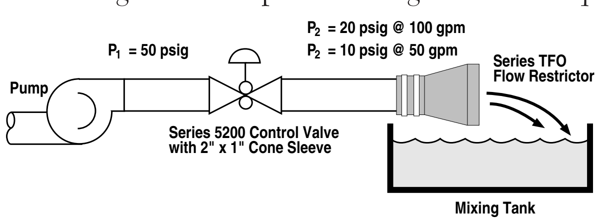


Figure 5 – Simple Control System With TFO

A TFO with a stiffness (s) of 20.9 will have a pressure drop across the TFO of 20.9 psi @ a pipe line velocity of 10 ft./ sec. At 9.56 ft./sec. (100 gpm), the pressure drop will be 20 psi, and at 4.78 ft/.sec. (50 gpm), the pressure drop will be 10 psi.

Therefore, by selecting a TFO with a stiffness of 20.9, the system pressures will be as follows -

Q min = 50 gpm	Q max = 100 gpm
P_1 = 50 psig	P_1 = 50 psig
P_2 = 10 psig	P_2 = 20 psig
ΔP = 40 psi	ΔP = 30 psi

Since the maximum flow velocity is still 9.56 ft./sec., the sizing sequence then becomes -

1. Flow Coefficients (C_V) Required -

$$C_{V\,MIN} = Q_{MIN}\sqrt{\frac{S.G.}{\Delta P}} \qquad C_{V\,MAX} = Q_{MAX}\sqrt{\frac{S.G.}{\Delta P}}$$

$$= 50\sqrt{\frac{1.21}{40}} \qquad = 100\sqrt{\frac{1.21}{30}}$$

$C_{V\,MIN}$ = 8.7 or 31% open **$C_{V\,MAX}$ = 20.1 or 54% open**

Notice that ΔP across the valve is no longer 50 psi but is reduced by the pressure drop across the TFO and the required C_V values and percentage of valve's opening have shifted because the pressure drop across the valve has changed.

2. Sleeve size -

Sleeve size & configuration are still acceptable with 54% open and 31% open at the max. & min. flow conditions.

3. Determine maximum allowable pressure drop

ΔP allow = FL_2 (P_1 + 14.7 - rc x P_V)

@ Q max = 50 gpm	**@ Q max = 100 gpm**
FL @ 31% open = 0.84 (See FL tables)	FL @ 54% open = 0.73 (See FL tables)
P_1 = 50 psig	P_1 = 50 psig
rc = 0.94	rc = 0.94
Pv - 0.339 @ 68°F	Pv = 0.339 @ 68°F

Min. ΔP allow = 0.84^2 (50 + 14.7 - (0.94 x 0.339))
Max. ΔP allow = 0.73^2 (50 + 14.7 - (0.94 x 0.339))

With an actual ΔP of 30 psi @ 100 gpm and 40 psi @ 50 gpm, the actual ΔP's are less than allowable ΔP's.

By the simple addition of TFO's we have reduced the actual pressure drops (DP) across the control valve to below the calculated allowable pressure drops (DP allow) and have eliminated cavitation damage.

The TFO Flow Restrictor is easy to install, requires no maintenance and no source of power. When used in conjunction with control valves, the TFO Flow Restrictor is effective in reducing or eliminating the wear caused by cavitation.