Understanding Choked Flow in Fisher™ Valves

Choked flow is often a subject of concern among our customers due to misunderstandings and association with potentially damaging conditions. The following guidelines are to help in the understanding of choked flow and how it affects control valves. It will also dispel any misconceptions associated with it.

What is Choked Flow?

Choked flow is defined as the point at which increasing the pressure drop (ΔP), while maintaining a constant inlet pressure (P_1), yields no further increase in flow rate.

Note: It is important to note that this definition assumes a fixed flow area. It is also important to note that increasing P_1 will also increase the flow rate.

Common Questions and Misconceptions

Q: The valve is choked in a liquid application. Does this mean damage will occur?

A: Choked flow by itself is not a cause for damage. While it is true that choked flow in a liquid application indicates the presence of cavitation or flashing, it does not necessarily mean damage will occur. There are many different characteristics of the operating conditions and valve construction that must be considered when trying to determine if damage will occur due to the cavitation present in any given application. For more information on these factors, contact your Emerson sales office or Local Business Partner.

Q: The valve is choked, does this mean there will be excessive noise produced?

A: Choked flow by itself is not an indicator of elevated noise. In liquid applications, noise is associated with cavitation; the more severe the cavitation, the higher the noise levels. The same thing can be said about choked flow in gas applications. In gas applications, choked flow occurs when the velocity at the vena contracta reaches sonic velocity (a.k.a critical flow condition). At this point, any increase in ΔP does not increase flow, but instead additional energy takes the form of increased noise levels. Common solutions to noise in gas applications are noise attenuating trim technology and/or enlarging the valve outlet area.

Q: If the valve is choked, will it pass the required flow rate?

A: The IEC liquid sizing equation includes the recovery coefficient (F_L), which is used to calculate the choke point of the valve. It is important to confirm you are using the correct F_L value, as it directly impacts the calculated C_V. If these values are properly accounted for, the sizing will be accurate for the considered flow rate.

In gas sizing, due to the compressible nature of the fluid, it is important to pay close attention to the pressure drop ratio factor (X_T). This value is used to calculate the choke point (similar to F_L in liquid sizing). Simply put, the higher the X_T value, the lower the required C_V to pass a given flow rate through a given orifice (the converse is true as well).

Q: The valve is choked in a liquid application, does this mean it will be flashing?

A: Choked flow does not cause flashing, but may indicate a flashing situation. Flashing is a system dependent phenomena, where the downstream pressure (P_2) is below the liquid's vapor pressure (Pv). For more information on solutions for flashing applications, please contact your Emerson sales office or Local Business Partner.

Q: Is it true that liquids don't choke, because they can't reach sonic velocity?

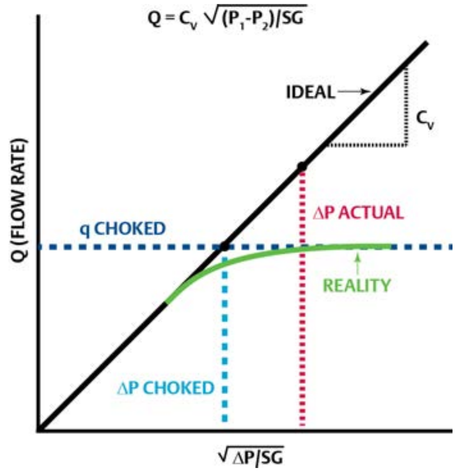
A: No, liquids can also choke. Choked flow in liquids occurs as the velocity at the vena contracta increases, causing the local pressure to drop below the liquid's vapor pressure. At this point, the liquid will start to form vapor which takes up additional space, leading to the choked condition. This point is determined experimentally, and denoted by the value, F_L. High recovery devices will have numerically lower F_L values with more energy being released as cavitation or flashing. Conversely, low recovery devices have numerically higher F_L values with less energy available in these conditions. When sizing for liquids, pay close attention to the F_L values, and make sure the values used match the trim and valve selected.

The Physics of Choked Flow

In an ideal world, there is a linear relationship between the differential pressure (ΔP) and flow Rate (Q) as depicted by the "ideal" linear line in the graph below. In this case, as the ΔP increases (as a function of decreasing P_2), so does the flow rate.

In reality, this in only true to an extent. After a certain point, the line begins to level off as the flow becomes choked. This point is determined experimentally, by modeling the actual flow through a specific device, and is depicted by the bold curved line in the graph in figure 1.

Figure 1.



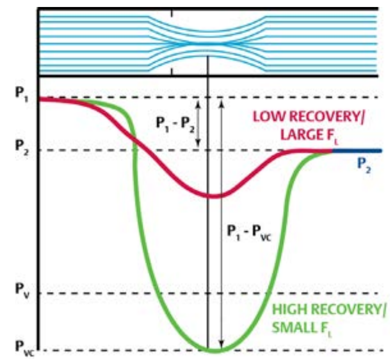
The point at which the flow becomes choked is determined by the F_L value for liquid sizing, and the X_T value for gas sizing. In liquid flows, this is due to the formation of vapor. In gas flows, it is due to the gas reaching sonic velocity at the vena contracta. The equations below show how these values are obtained, and how they relate to the sizing.

$\Delta P_{choked} = F_L^2 [P_1-(F_F)(P_v)]$
F_L = pressure recovery factor
F_F = liquid critical pressure ratio factor
$F_F = 0.96-0.28(P_V/P_C)^{½}$
P_V = vapor pressure of fluid
(Per IEC 60534-2-1)

In gas sizing, make sure to use the correct X_T value as it will have an impact on the required C_V for a given condition. Whisper trims generally have a different X_T value than a standard trim design.

Additionally, if a valve is choked, it does not necessarily mean unfavorable performance will occur. For example, in liquid sizing, a globe valve may choke, but it might not experience damaging cavitation. However, with a rotary product, the valve may experience damaging cavitation before it chokes. This is because of the F_L values and the flow geometry of the valve. Globe valves generally have a numerically high F_L, which results in a lower recovery factor. Rotary products generally have a smaller F_L, which results in higher recovery. The following diagram in figure 2 shows the difference between the two. The point here is that choked flow is not always a cause for concern. Contact your Emerson Sales office or Local Business Partner for additional information.

Figure 2.



Choked flow, when considered by itself, is not a cause for concern. The confusion stems from the potential association with many negative phenomena that affect control valves. This leads to misunderstandings amongst our users who correlate negative thoughts about choked flow by its association with these undesirable situations. It is our mission to fully understand and help educate our customers on important valve sizing and selection considerations that must be made when dealing with conditions of choked flow. If you encounter conditions of choked flow and have concerns/questions on how to proceed with valve selection, please contact your local Emerson sales office for additional technical support.

If you have any further questions, please contact your Emerson sales office or Local Business Partner.

Emerson Automation Solutions
Marshalltown, Iowa 50158 USA
Sorocaba, 18087 Brazil
Cernay, 68700 France
Dubai, United Arab Emirates
Singapore 128461 Singapore

www.Fisher.com