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Fluid Velocity Considerations

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Introduction

In the selection and specification of control valves, many process variables must be carefully considered. The composition and thermodynamic properties of the fluid being throttled is of paramount importance. Gases must be sized differently than liquids, and of course multi-phase streams require special consideration. Other properties may also place special demands on the control valve, including the fluid's corrosive nature, the presence of solids and any erosion that may result, or even if the liquid exhibits violent phase change and out-gassing during throttling. All or any one of these characteristics may require changes in the valve sizing and selection methodology as well as the use of specialty valve designs. One simple example is the effect a reduction in process temperature will have upon the well-understood mechanism of cavitation. Although 280° F water throttled from 200 psia to 75 psia may violently cavitate in a standard globe valve, the exact same process at 195° F will not exhibit any cavitation whatsoever! In fact, a simple change in just the valve style or flow direction will often sufficiently alter the pressure recovery characteristics and eliminate the possibility of damage entirely! This simple example demonstrates the need for a multi-variable approach to the selection and sizing of control valves, and should prove the futility of employing an overly simplified approach.

However, a number of end-users have approached Masoneilan and requested our input towards the development of some ***general*** guidelines for maximum valve trim, body and piping fluid velocities. These should not be misinterpreted as the sole criteria for selection or the prediction of actual performance. Masoneilan has always been at the forefront of developing physical models for the accurate prediction of flow induced effects, and will continue to do so.

Overview

Although fluid velocity in a control valve is an important parameter, it should not be the only criteria in proper valve selection for a particular application. High fluid velocity in and of itself does not cause erosion damage, trim wear, vibration, noise, or component failure, but the coincident effects of high velocity and a fluid's properties may lead to the development of these phenomena. Material selection and valve design may also play a key role in mitigating poor performance and should also be considered. One must employ sound engineering judgement with general guidelines in the management of any physical (temperature, pressure, noise, cavitation etc.) property, velocity being only one of these considerations.

Velocity limitations have not been set by any industry standards for several reasons. Variables exist that can effect the allowable limitations, such as:

- Type of fluid - compressible/incompressible
- Quality of the fluid - clean/dirty
- Valve material selections
- Frequency and duration service condition
- Valve style and flow pattern - varying geometries

I. Velocity limitation in a liquid application

For a clean liquid flowing through a control valve with carbon steel body material, the recommended maximum body inlet velocity should be limited to 25 feet per second. For the same carbon steel body, flowing a dirty liquid (containing particulate), the recommended maximum body inlet velocity should be less than 15 feet per second, in order to reduce erosion damage. For a clean liquid in a valve with a stainless steel or alloy body material velocity may reach 35 feet per second. Likewise, the velocity limit for a dirty fluid in the stainless steel or alloy body must not exceed 20 feet per second. Trim velocity limits are usually higher due to the fact that harder materials are applied to trim than to the valve body. The trim outlet velocity is measured by the following equation:

TrimVelocity=(560/density)*((DP*Gf)^0.5)

Velocity is expressed in feet per second

Density of liquid is expressed in lbs/ft^3

Gf is the liquid specific gravity

DP is expressed in psi.[1]

Technical Information Sheet

In general, it is recommended that the fluid velocity not exceed 200 feet per second across the trim for a liquid application. If the trim velocity exceeds 200 feet per second, special trim design, special body and trim material, as well as special body geometry may be considered.

Some valve manufacturers limit the trim velocity to a maximum of 75 feet per second. If we apply that limit to the equation for trim velocity, in a water application, the resulting pressure drop across the trim would be 70 psi. In many applications this 70 psi pressure drop across the trim or the last stage in the trim can be achieved only by using multi-stage trim. This limitation voices a very conservative approach, which is often unnecessary and very expensive. To prove our argument, let us consider this simple example. Consider a clean water application where the flow rate is 800 gpm; P1=500 psig; P2=200 psig; and T=70° F. If we select a 4" 41000, single stage cavitation containment, CV of 70, the valve outlet velocity is approximately 20 feet per second, the trim outlet velocity is approximately 155 feet per second. Applying the sigma methodology (See ISA-RP75.23-1995) for cavitation damage prediction, the indication is that the valve will not be damaged by cavitation in this particular application. Therefore our valve selection is acceptable despite the fact that the trim velocity exceeds 70 feet per second and the pressure drop across the trim exceeds 75 psi.

II. Velocity limitations in steam and gas applications

It has been the practice in Masoneilan to utilize the Mach number at the valve outlet to determine the velocity limitation in a compressible fluid application. The fluid Mach number is defined as the ratio of fluid velocity to the velocity of sound in this fluid. High outlet Mach numbers in control valves is an indication of high stream power and can generate high noise level, vibration, and erosion. Masoneilan recommends certain limitations for the valve outlet Mach number. These limitations are considered a safe approach to prevent the problems mentioned previously. As in liquid applications, these limitations also vary with the gas type, its cleanliness and the valve body material, the duration and frequency of operation at a given service condition etc. For example, for saturated steam the recommended maximum outlet Mach number is 0.3 for carbon steel body material and 0.4 for stainless steel or alloy body materials. For superheated steam and clean gas, the recommended maximum outlet Mach number is 0.4 for carbon steel body and 0.5 for stainless steel or alloy body materials. It is relevant to note that these limitations are overruled by noise performance specifications. One should be conservative with saturated steam due to its thermodynamic properties. A small decrease in temperature may lead to the formation of droplets of liquid in the flow and this will be extremely erosive at high velocities. Reducing the high outlet Mach number can be achieved by increasing the size of the valve or by backing up the outlet pressure at the valve via a Lo-dB® plate, a diffuser, or a silencer. Sometimes it is necessary to increase the size of the valve and provide a pressure back-up device downstream of the control valve in order to reduce its outlet Mach number and noise level to an acceptable limit. Quoting a valve that has high outlet Mach number should be avoided unless the customer can guarantee the duration of operation is very short (less than few minutes) and the frequency of operation is very rare (few times a year). Often, the actual process varies greatly from what is expected at the design and engineering stage and the valve specified must withstand both severity and frequency of operation. This is particularly true in steam vent applications. Such operation can result in damage to a valve by erosion or trim component failure due to vibration. It is always a good idea to know all the details of a given application in order to avoid such potential problems.

We have presented recommended limitations in liquid and gas applications as guidelines for control valve selection. However, it is very important to bear in mind that every application has its own peculiarities and engineering judgment should always be applied. Please contact applications engineering at the factory with problems or applications that involve high veolcity, vibration or potential erosion damage.

Note:
1. For multi-stage trims the DP should be considered at every stage in order to calculate the velocity at each stage.