Valve Noise Prediction vs. Velocity Head Limitations In Gas Applications

Author: Joseph Shahda - Principal Engineer
Masoneilan - Dresser, Inc.
February 2004

Abstract

In recent years, the control valve industry has seen an important debate about the validity of limiting the valve trim exit velocity head to a maximum of 480 kPa in gas and steam applications. This velocity limitation is assumed to provide an acceptable noise level and avoid problems that arise in control valve gas and steam applications. However, in a very large number of applications, adopting a velocity limiting approach may require the use of expensive multi-stage or multi-turn trim designs. The purpose of this article is to demonstrate that low noise levels can be achieved without following this overly conservative and expensive trim exit velocity head limitation. Also, this article will show that having a trim exit velocity head lower than 480 kPa will still generate a very high valve noise level if the valve outlet Mach number is high.

Noise Prediction in Control Valves

The IEC 534-8-3 aerodynamic noise standard is the most widely used in the valve industry for noise prediction in control valves. This standard calculates the stream power and the acoustical efficiency factors at various flow regimes. IEC 534-8-3 identifies five flow regimes that are determined by the relationship between various pressure parameters. This standard also provides methods to calculate the internal sound pressure, its corresponding peak frequency, the transmission loss, and the A-weighted noise level at 1m (3 ft) downstream of the valve and 1m (3 ft) away from the pipe wall. It is very important to note that this IEC standard does not recommend limiting the trim exit velocity head to 480 kPa in order to achieve a low noise level in the valve.

Valve Trim Exit Velocity Head

The valve trim exit velocity head is given by:

$$KE = \frac{1}{2} \cdot \rho \cdot V^2 \qquad \text{Equation 1}$$

Where KE Trim exit velocity head, **Pa**

ρ Fluid density, $\frac{kg}{m^3}$

V Fluid velocity at trim exit, $\frac{m}{s}$

The sonic velocity **C** is given by:

$$C = \sqrt{\gamma \cdot R \cdot T} \qquad \text{Equation 2}$$

Where C Sonic velocity $\frac{m}{s}$

γ Gas specific heat ratio

R Gas constant $R = \frac{8314}{MW}$ MW is Gas Molecular Weight

T Gas temperature, degree **Kelvin**

For regime II through V the trim exit velocity is sonic, hence from equation 1 and 2 the trim exit velocity head is given by:

$$KE_{regimeIIthruV} = \left(\frac{1}{2} \cdot \rho \cdot C^2\right) = \frac{1}{2} \cdot \rho \cdot \gamma \cdot R \cdot T \qquad \text{Equation 3}$$

Valve Outlet Mach Number

A very critical parameter in gas and steam applications is the valve outlet Mach number, which is defined as the ratio of the fluid velocity at the valve outlet, to the sonic velocity in the fluid at the given temperature. This is a very important parameter in determining not only the noise level in the valve, but also the potential for vibration in the valve/pipe system and potential for erosion damage to the body if the outlet Mach number is high. Typically a control valve body has a close resonance frequency to the pipe system. Therefore, a high outlet Mach number can generate a frequency that will match the valve/pipe system resonance frequency and this will lead to vibration. Unfortunately, the trim exit velocity head alone is not a good predictor of such an important phenomena. For superheated steam and clean gas, a valve outlet Mach number below 0.4 is recommended for continuous operation and below 0.5 for intermittent operation. Keeping the Mach number low will result in a low noise level and will eliminate the potential for vibration problems in the valve/pipe system. The maximum valve outlet velocity should be limited to Mach 0.3 for saturated steam, due to the thermodynamic properties of the fluid. A very small decrease in the temperature of saturated steam may lead to the formation of liquid droplets within the steam and this will be extremely erosive at high velocities.

Examples

Below are two examples that will illustrate the validity of the arguments made above. The first example will demonstrate that for some applications, when the trim exit velocity head exceeds 480 kPa, the valve can still generate a low noise level. The second example will show that for some other applications having a trim exit velocity head lower than 480 kPa but a high Mach number the valve will generate a very high noise level.

Example 1:

Consider an application with 30000 kg/hr of air at 100° C. The valve inlet pressure is 30 bar (a) and its outlet pressure is 12 bar (a). According to IEC 534-3-8, this application is represented by flow regime IV. Now consider a 4" globe style valve with single stage drilled hole cage. For the service conditions given above, the noise level generated by the 4" valve is approximately 85 dBA with an 8" outlet pipe schedule 40. The trim exit velocity is sonic and it is equal to 337 m/s from Equation 2. The air density at the trim outlet is 11.17 kg/m3. From Equation 3, the trim exit velocity head is equal to 836 kPa. The valve outlet Mach number is approximately 0.24.

(example 1 continued)

Thus, the example above demonstrates that a 4" globe valve with a single stage drilled hole cage can achieve a low noise level despite the fact that the trim exit velocity head is much greater than the 480 kPa limitations that some valve manufacturers advocate. The valve solution described above is technically excellent and very economical compared to a 4" valve with a torturous multi-stage trim.

Example 2:

Consider an application with 50000 kg/hr of air at 100° C. The valve inlet pressure is 50 bar (a) and its outlet pressure is 3 bar (a). From these service conditions the required Cv=62. Thus, consider a 6" globe style valve with a torturous path, with 24 stages, rated Cv=70. The outlet pipe is 8" schedule 40. For the given service conditions, the last turn in the trim has an exit velocity of 233 m/s and the fluid outlet density is 2.8 kg/m3. Thus per equation 1, the trim exit velocity head is 76 kPa, well below the maximum limitation of 480 kPa. However, despite this very low trim exit velocity head, the valve noise level is 98 dBA because the valve outlet Mach number is 0.78. Now, take the same exact trim and install it in an 8" globe style valve. In this case the valve outlet Mach number is 0.4 and the valve noise level is approximately 85 dBA.

This example demonstrates that a low trim exit velocity head does not result in a low noise level in the valve, unless the valve outlet Mach number is low. It is also noteworthy to mention that for the same application, an 8" globe style valve with two drilled holed cages is an excellent solution for the application above since it will generate a noise level of 80 dBA. These two drilled holed cages are much less expensive than the 24 turn torturous path trim.

Conclusion

Limiting the trim exit velocity head to a maximum of 480 kPa is not practical in a large number of steam and gas applications. As demonstrated above, this approach can be overly conservative in many gas applications and it can be insufficient to ensure low valve noise level in others. Low noise level can be achieved with trim that has an exit velocity head higher than 480 KPa. On the other hand, a valve trim exit velocity head lower than 480 kPa will have a very high noise level if the valve outlet Mach number is not low. When providing a control valve solution for gas applications, it is very important not to be bound by the trim exit velocity head limitation, but rather provide the valve that gives: low noise levels, a low outlet Mach number, and is the most economical solution available.