potential for the cavitation to transfer from the valve to the orifice plate.

Noise Prediction

Aerodynamic

Industry leaders use the International Electrotechnical Commission standard *IEC 534-8-3: Industrial-process control valves—Part 8: Noise Considerations—Section 3: Control valve aerodynamic noise prediction* method. This method consists of a mix of thermodynamic and aerodynamic theory and some empirical information. The design of the method allows a noise prediction for a valve based only on the measurable geometry of the valve and the service conditions applied to the valve. There is no need for specific empirical data for each valve design and size. Because of this pure analytical approach to valve noise prediction the IEC method allows an objective evaluation of alternatives.

The method defines five basic steps to a noise prediction:

1—Calculate the total stream power in the process at the vena contracta. The noise of interest is generated by the valve in and downstream of the vena contracta. If the total power dissipated by throttling at the vena contracta can be calculated, then the fraction that is noise power can be determined. Since power is the time rate of energy, a form of the familiar equation for calculating kinetic energy can be used. The kinetic energy equation is $1/2\ mv^2$ where m is mass and v is velocity. If the mass flow rate is substituted for the mass term, then the equation calculates the power. The velocity is the vena contracta velocity and is calculated with the energy equation of the First Law of Thermodynamics.

2—Determine the fraction of total power that is acoustic power. The method considers the process conditions applied across the valve to determine the particular noise generating mechanism in the valve. There are five defined regimes dependent on the relationship of the vena contracta pressure and the downstream pressure. For each of these regimes an acoustic efficiency is defined and calculated. This acoustic efficiency establishes the fraction of the total stream power, as calculated in Step 1, which is noise power. In designing a quiet valve, lower acoustic efficiency is one of the goals.

3—Convert acoustic power to sound pressure. The final goal of the IEC prediction method is determination of the sound pressure level at a reference point outside the valve where human hearing is a concern. Step 2 delivers acoustic power, which is not directly measurable. Acoustic or sound pressure is measurable and therefore has become the default expression for noise in most situations. Converting from acoustic power to the sound pressure uses basic acoustic theory.

4—Account for the transmission loss of the pipewall and restate the sound pressure at the outside surface of the pipe. Steps 1 through 3 are involved with the noise generation process inside the pipe. There are times when this is the area of interest, but the noise levels on the outside of the pipe are the prime requirement. The method must account for the change in the noise as the reference location moves from inside the pipe to outside the pipe. The pipe wall has physical characteristics, due to its material, size, and shape, that define how well the noise will transmit through the pipe. The fluid-borne noise inside the pipe must interact with the inside pipe wall to cause the pipe wall to vibrate, then the vibration must transmit through the pipe wall to the outside pipe wall, and there the outside pipe wall must interact with the atmosphere to generate sound waves. These three steps of noise transmission are dependent on the noise frequency. The method represents the frequency of the valve noise by determining the peak frequency of the valve noise spectrum. The method also determines the pipe transmission loss as a function of frequency. The method then compares the internal noise spectrum and the transmission-loss spectrum to determine how much the external sound pressure will be attenuated by the pipe wall.

5—Account for distance and calculate the sound pressure level at the observer's location. Step 4 delivers the external sound pressure level at the outside surface of the pipe wall. Again, basic acoustic theory is applied to calculate the sound pressure level at the observer's location. Sound power is constant for any given situation, but the associated sound pressure level varies with the area the power is spread over. As the observer moves farther away from the pipe wall, the total area the sound power is spread over increases. This causes the sound pressure level to decrease.

Hydrodynamic

Noticeable hydrodynamic noise is usually associated with cavitation. The traditional description of the sound is as rocks flowing inside the pipe. This association of hydrodynamic noise with cavitation is reflected in the various prediction methods available today. The methods account for one noise characteristic for liquids in non-choked flow situations and another characteristic in choked, cavitating flow situations.

There are a variety of situations where the fluid is a two-phase mixture. These include liquid-gas two-phase fluids at the inlet of the valve, flashing fluids, and fluids that demonstrate out-gassing due to throttling. Noise prediction methods for these cases are not yet well established. Test results and field surveys of installed multi-phase systems indicate these noise levels do not contribute to overall plant noise levels or exceed worker exposure levels.

Noise Control

In closed systems (not vented to atmosphere), any noise produced in the process becomes airborne only by transmission through the valves and adjacent piping that contain the flowstream. The sound field in the flowstream forces these solid boundaries to vibrate. The vibrations cause disturbances in the ambient atmosphere that are propagated as sound waves.

Noise control employs either source treatment, path treatment, or both. Source treatment, preventing or attenuating noise at its source, is the most desirable approach, if economically and physically feasible.

Recommended cage-style source treatment approaches are depicted in figure 5-8. The upper view shows a cage with many narrow parallel slots designed to minimize turbulence and provide a favorable velocity distribution in the expansion area. This economical approach to quiet valve design can provide 15 to 20 dBA noise reduction with little or no decrease in flow capacity.

The lower view in figure 5-8 shows a two-stage, cage-style trim designed for optimum noise attenuation where pressure drop ratios ($\Delta P/P_1$) are high.

To obtain the desired results, restrictions must be sized and spaced in the primary cage wall so that the noise generated by jet interaction is not greater than the summation of the noise generated by the individual jets.

This trim design can reduce the valve noise by as much as 30 dBA. The final design shown uses a combination of several noise reduction strategies to reduce valve noise up to 40 dBA. Those strategies are:

- Unique passage shape reduces the conversion of total stream power generated by the valve into noise power.


W1257/IL


W6980/IL

Figure 5-8. Valve Trim Design for Reducing Aerodynamic Noise

- Multistage pressure reduction divides the stream power between stages and further reduces the acoustic conversion efficiency.

- Frequency spectrum shifting reduces acoustic energy in the audible range by capitalizing on the transmission loss of the piping.

- Exit jet independence is maintained to avoid noise regeneration due to jet coalescence.

- Velocity management is accomplished with expanding areas to accommodate the expanding gas.

- Complementary body designs prevent flow impingement on the body wall and secondary noise sources.

For control valve applications operating at high pressure ratios ($\Delta P/P_1 > 0.8$) the series restriction approach, splitting the total pressure drop between the control valve and a fixed restriction (diffuser) downstream of the valve can be effective in minimizing noise. To optimize the effectiveness of a diffuser, it must be designed (special shape and sizing) for each given installation so that the noise levels generated by the valve and diffuser are equal. Figure 5-9 shows a typical installation.

Control systems venting to atmosphere are generally very noisy because of the high pressure ratios and high exit velocities involved. Dividing the total pressure drop between the actual vent and an upstream control valve, by means of a vent diffuser, quiets both the valve and the vent. A properly sized vent diffuser and valve combination, such as that shown in figure 5-10, can reduce the overall system noise level as much as 40 dBA.

Source treatment for noise problems associated with control valves handling liquid is directed primarily at eliminating or minimizing cavitation. Because flow conditions that will produce cavitation can be accurately predicted, valve noise resulting from cavitation can be eliminated by application of appropriate limits to the service conditions at the valve by use of break-down orifices, valves in series, etc. Another approach to source treatment is using special valve trim that uses the series restriction concept to eliminate cavitation as shown in figure 5-11.

A second approach to noise control is that of path treatment. The fluid stream is an excellent noise transmission path. Path treatment consists of increasing the impedance of the transmission path to reduce the acoustic energy communicated to the receiver.

Dissipation of acoustic energy by use of acoustical absorbent materials is one of the most effective methods of path treatment. Whenever possible the acoustical material should be lo-

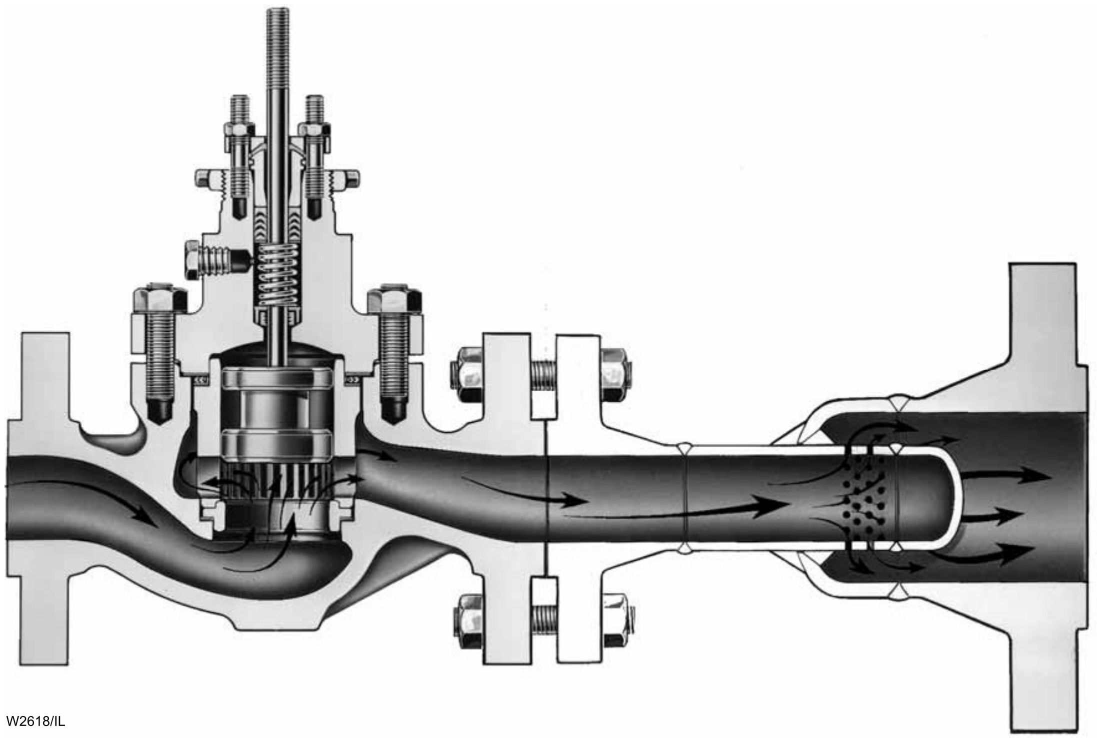

Figure 5-9. Valve and Inline Diffuser Combination

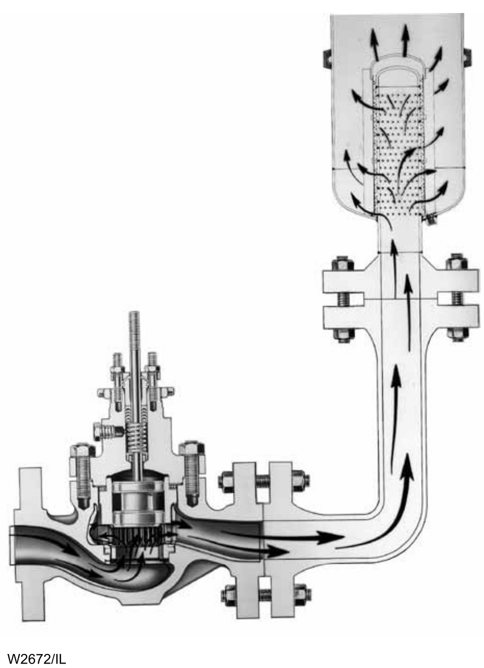

Figure 5-10. Valve and Vent Diffuser Combination

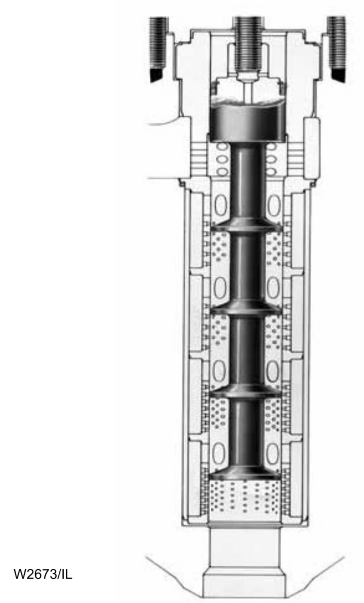

Figure 5-11. Special Valve Design to Eliminate Cavitation

cated in the flow stream either at or immediately downstream of the noise source. In gas systems, inline silencers effectively dissipate the noise within the fluid stream and attenuate the noise level transmitted to the solid boundaries. Where high mass flow rates and/or high pressure ratios across the valve exist, inline silencers, such as that shown in figure 5-12, are often the most realistic and economical approach to noise control. Use of

Figure 5-12. Typical In-Line Silencer

absorption-type inline silencers can provide almost any degree of attenuation desired. However, economic considerations generally limit the insertion loss to approximately 25 dBA.

Noise that cannot be eliminated within the boundaries of the flow stream must be eliminated by external treatment. This approach to the abatement of control valve noise suggests the use of heavy walled piping, acoustical insulation of the exposed solid boundaries of the fluid stream, use of insulated boxes, buildings, etc., to isolate the noise source.

Path treatment such as heavy wall pipe or external acoustical insulation can be an economical and effective technique for localized noise abatement. However, noise is propagated for long distances via the fluid stream and the effectiveness of the heavy wall pipe or external insulation ends where the treatment ends.

Noise Summary

The amount of noise that will be generated by a proposed control valve installation can be quickly and reasonably predicted by use of industry standard methods. These methods are available in computer software for ease of use. Such sizing and noise prediction tools help in the proper selection of noise reduction equipment such as shown in figures 5-13 and 5-14. Process facility requirements for low environmental impact will continue to drive the need for quieter control valves. The prediction technologies and valve designs that deliver this are always being improved. For the latest in either equipment or prediction technology, contact the valve manufacturer's representative.

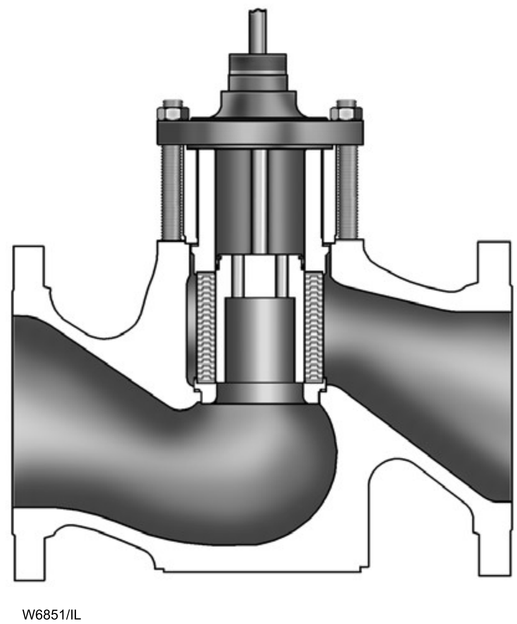

Figure 5-13. Globe Style Valve with Noise Abatement Cage for Aerodynamic Flow

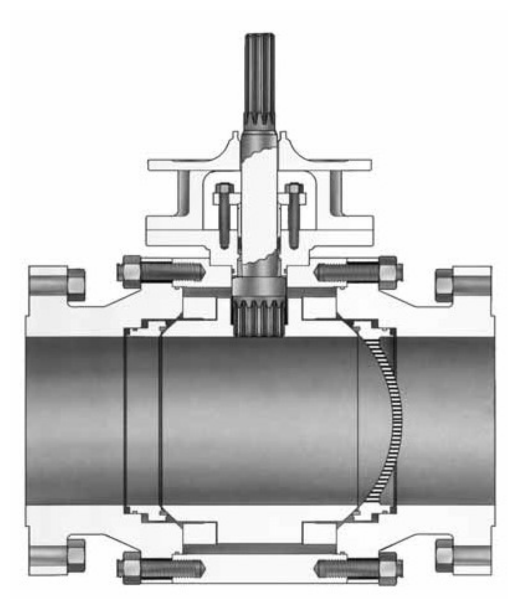

Figure 5-14. Ball Style Valve with Attenuator to Reduce Hydrodynamic Noise