SOUND SUPPRESSION

Bill Flowers, Emerson, USA, explains the history behind the development of the modal suppression device for noise reduction.

High aerodynamic noise levels are a natural result of turbulent flow. As gas or steam flows through a control valve, velocity increases in the flow passages and then slows, creating pressure fluctuations and sound waves. These waves are emitted from the valve and piping, radiating in all directions.

At low velocities the sound is minor and barely noticeable, but at higher levels the noise becomes irritating to personnel in the immediate area. Very loud noise levels can permanently damage hearing and destroy valve internals due to excessive vibration. Lighthill's law states that aerodynamic noise varies as the eighth power of the gas velocity, so high flow and high pressure drop applications get very loud, very quickly.

Most plants address high control valve noise in one of two methods, either source control or path control. Each method has varying levels of cost and effectiveness.

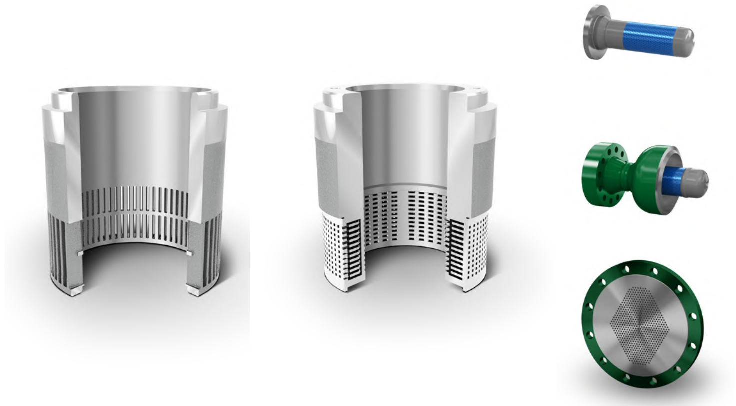

Figure 1. Source control often uses valve trims with small holes (left), multiple flow paths (middle), or downstream diffusers (right) to reduce aerodynamic noise. The methods spread the pressure drop and flow across multiple points to reduce vapour velocity and minimise noise.

Addressing the source

Source control attempts to diminish noise levels by eliminating or at least reducing the generated sound. This is often accomplished using pressure drop staging or flow division. Pressure drop staging reduces the overall sound by dividing the total pressure drop over a number of steps, rather than taking the full drop in at a single point.

The smaller pressure drops create smaller vena contractas with correspondingly smaller pressure variations, and thus less noise. This can be accomplished with a multistage low noise valve trim design, or it can include pressure reducing inline diffusers on the inlet and/or outlet to reduce the overall pressure drop through the valve itself (Figure 1).

An alternative source control method is flow division. Flow division breaks up the single flow path into multiple flow paths, thus reducing the overall velocity of each path. The reduced velocity results in lower levels of sound.

In either case, source control often requires a much more complex valve internal design, which is costly and prone to plugging. External diffusers also add cost and usually incorporate very small flow passages, which can plug as well.

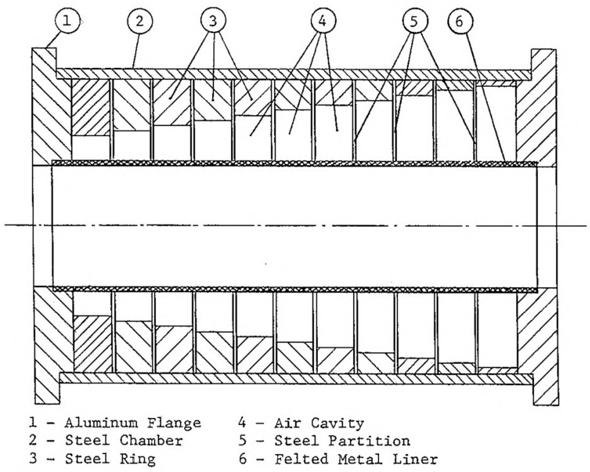

Figure 2. This diagram shows the original concept of a modal coincidence suppression device, designed to reduce the aerodynamic noise produced by a control valve. The series of chambers are each sized to produce destructive interference across a small range of frequencies.

Sound suppression

The second method of aerodynamic noise reduction is path control. This method attempts to muffle the sound and keep it from radiating to the surrounding area. The techniques can be as simple as thick walled pipe, pipe insulation, or encasing the pipe with acoustic blankets or materials designed to absorb the sound. Alternatively, one can employ specially designed silencers which either absorb the sound or use resonant chambers to cancel the noise through destructive interference. A car muffler is an example of a resonant chamber silencer that is common in everyday use.

Silencers work but often require a high pressure drop and tortuous path, and they may include sound absorbing materials which degrade or become saturated with process fluids. Acoustic blankets wear with exposure to the elements, and are often damaged or improperly installed after maintenance, so their performance declines over time.

Figure 3. The forged WhisperTube (6 in. model shown) undergoing noise testing at the Emerson Innovation Center Flow Laboratory.

The price of silence

Both source and path controls do work, but they come with significant costs and limitations. Low noise valve trims usually require a more expensive globe valve, and its intricate internals raise the valve price considerably. Silencers and diffusers add pressure drop by design and their peak performance can be limited to certain ranges of flow. None of these options are capable of passing a pipeline pig, so a pig capture and bypass chamber are required.

An alternative emerges

In the early 1980s, a graduate student named Ali Broukhiyan published his honors thesis on a new method of control valve aerodynamic noise reduction called 'A Modal Coincidence Suppression Device' (Figure 2).

The design consisted of a series of carefully sized concentric rings and partitions around a pipe, with the device to be installed downstream of a noise producing control valve. The different sized rings were specifically designed to resonate at a particular range of frequencies. When put together, it was theorised that the set of concentric rings would produce destructive interference across a broad range of frequencies, effectively reducing the total sound emitted by the valve.

Early trials of the core technology were encouraging, but there was no feasible way to economically construct such a device capable of handling the pressures and temperatures encountered in typical processes. After several attempts, the concept was abandoned and shelved for decades.

Resurrection through additive manufacturing

The advent of additive manufacturing and 3D metal printing enabled Emerson to create complicated metal components that could not have been economically fabricated in the past. New and innovative anti-cavitation and low noise trims were the focus of early additive manufacturing efforts, but attention eventually turned to the modal coincidence suppression device.

A series of preliminary trials proved the modal suppression device held promise, and suggested the new manufacturing techniques might be employed to fabricate the device at an affordable price. After several years, Emerson engineers developed and patented a method that allows the sound suppression device to be produced as a casting.

Emerson's WhisperTube will be released for sale in late 2021 and will be offered in sizes from 2 in. to 12 in. with flange ratings of 150, 300, and 600lb (Figure 3). Its pressure ratings generally match the flange rating sizes, and the maximum temperature is 650˚F.

The new modal suppressor utilises a similar construction to the original design but incorporates several improvements (Figure 4). The inner pipe is a full bore perforated liner which allows a pipeline pig to pass through it with no restriction. The new design also includes a larger number of concentric cavities to provide an average 10dB noise reduction across a broader range of frequencies.

In addition, the rings have been modified to allow the device to be self-draining so process liquids do not collect in the rings and negatively impact noise reduction performance.

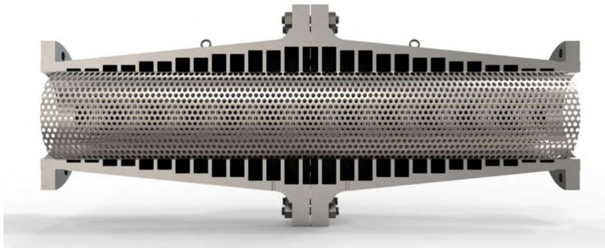

Figure 4. The modal suppressor consists of cylindrical chambers of varying sizes surrounding a full bore perforated tube. Each chamber generates destructive interference over a small range of frequencies to provide significant noise reduction across a broad spectrum.

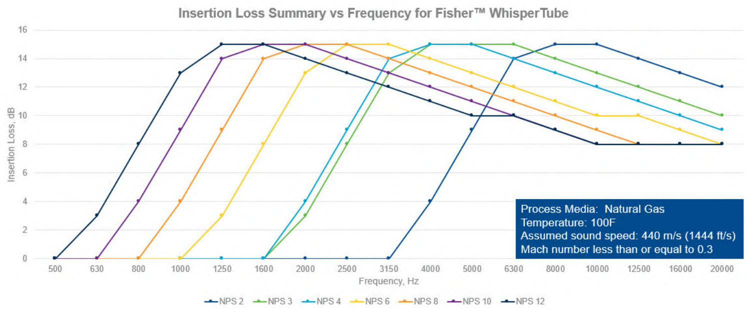

Figure 5. Concentric rings of various sizes create broadband noise reduction as shown in this chart. Generated noise and rejected frequencies tend to shift higher as pipe size is reduced, so the suppressor is well matched to the typical application.

A new option for noise reduction

The modal suppression WhisperTube is a simple, passive device offering a 10 dB average noise reduction across a broad range of frequencies (Figure 5).

This new design is full bore and generates no pressure drop. When combined with a full ported ball valve, the device can provide a noise suppressed pipeline control system that can be pigged without additional pig catching and bypass equipment.

Less expensive butterfly valves can also be paired with this device to provide a lower cost option as compared to a typical globe control valve with low noise trim. Finally, the self-draining version can be utilised for steam and two-phase flow applications where liquid accumulation would adversely affect many other noise abatement designs.

Conclusion

It may have been nearly 40 years in the making, but additive manufacturing and some diligent engineering have finally brought full bore noise reduction to reality. Applicable to either gas or steam, the new product offers new possibilities for pipeline applications, as well as high noise control valve applications in a variety of services.