Ultrasonic Noise Acoustic Filters

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OVERVIEW

The increasing use of Multi-path ultrasonic meters for natural gas applications has lead the industry towards the challenge of resolving numerous installation hurdles. The installation challenges in question are not only piping induced disturbances that are not unique to MUSM applications but also noise induced disturbances such as those presented by Valves or Regulators.

This paper will discuss the design, development and application of a new product concept of Acoustic Filter.

NOISE - DEFINITIONS

Sound or noise is a longitudinal mechanical wave motion in an elastic medium and is classified according to its frequency - *infrasonic*, *audible* and *ultrasonic*. The infrasonic classification refers to frequencies below the detection level of the human ear (less than 20 Hz). The audible classification refers to frequencies that can be detected by the human ear (from 20 to 20,000 Hz). The ultrasonic classification refers to frequencies above the detection level of the human ear (above 20,000 Hz).

Classification	Frequency Range
Infrasonic	less than 20 Hz
Audible	20 to 20,000 Hz
Ultrasonic	greater than 20,000Hz

Sensory effects of sounds denoted by physiologists as loudness, pitch, and quality are correlated with the measurable parameters of sound denoted by physicists as intensity, frequency and wave shape.

Physiology		Physics
Loudness	corresponds to	*Intensity*
Pitch	corresponds to	*Frequency*
Quality	corresponds to	*Wave Shape*

NOISE – THE PRACTICAL CHALLENGE

The intensity of a sound wave is the amount of wave energy transmitted per unit time per unit area normal to the direction of sound propagation; that is, the intensity of sound is the power transmitted per unit area. In the *audible* classification of noise, the significant intensities for the human species are –

	Intensity (W/m2)	Level (dB)
Hearing threshold	1E-12	0
Whisper	1E-10	20
Conversation	1E-06	65
Street traffic	1E-05	75
Train in tunnel	1E-02	100
Pain threshold	1E+00	120

Acoustics is the systematic investigation of the nature, origin, and propagation of sound. Acoustic noise generation in a closed circular conduit can occur from a multitude of sources – protruding gaskets, misaligned pipe flanges, headers, line size changes, reducers, expanders, block valves, control valves, thermowells, transducer pockets, transducer probes, and so forth. The flowing velocity in the pipe is a major factor. When the pipe velocity is below 50 fps, then one would expect noise from only a control valve. When the pipe velocity is greater than 50 fps, noise generation can be initiated by a multitude of the aforementioned sources.

CONTROL VALVE NOISE

Current research indicates that control valves should be placed downstream of the meter runs to ensure that the acoustic noise generated by the valve does not "scramble" the acoustic signal of the ultrasonic meter.

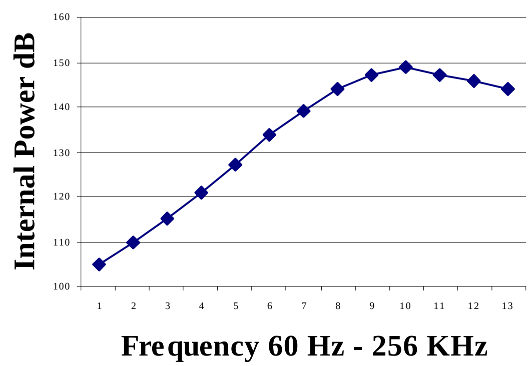
Various techniques are used by the MUSM manufacturers to minimize the impact of ultrasonic noise generated by the control valves; however, the near elimination of noise by devices such as acoustic filters offers significant advantages to the user.

In the case of a MUSM metering station, it is typical that either a control valve or regulator be located downstream of the meter. The noise emitted from these mechanical devices will normally cover a wide frequency range, part of which will include the operating range of the MUSM itself, 100-200KHz. The challenge becomes evident when the meter is operating and encounters noise levels in excess of the normal operating range of the meter.

A typical frequency response curve for a control valve is shown below. With this example the peak frequency being emitted is approximately 60 KHz. However it is important to illustrate that even at the higher frequencies, 100 – 200 KHz, it can be seen that the noise level may be in excess of 130dB.

The MUSM may operate effectively up to noise level of 90 dB; however above that level the noise may be too extreme for the meter to overcome using its traditional signal processing recognition techniques and gain control adjustments.

At this point it becomes clear that the meter will start losing pulses during the transmission and reception cycle and become inoperable or marginally functional depending upon the noise levels being experienced.



The level of noise being generated will be dependant on:

- Flow Rate
- Pressure Drop across the valve or restriction
- Valve or restriction type

The challenge becomes therefore, the design of the Acoustic Filter has to accommodate the extreme noise reduction scenario of high velocity with high-pressure drop through an ultrasonically noisy restriction.

CURRENT REMEDIES

As mentioned earlier, the MUSM manufacturers employ different noise mitigation techniques in the meter itself, ranging from increasing the amplitude of the pulse being transmitted sometimes coupled with complex Digital Signal Processing techniques. However, while the amplitude of the noise remains above that which the meter can effectively operate, it will be difficult to establish a working environment for the meter.

Most MUSM manufacturers will now consult with the end-user to ensure that the meter has a better chance at successful operation by establishing installation criteria for the meter. These may include:

- Deployment of higher frequency transducers
- Installation of multiple blind tees and elbows between the source of the noise and the MUSM

Both of these options are worth discussing. Higher frequency operation of the transducers cannot be guaranteed to eliminate the noise problem entirely as it can be seen from the frequency response curve that the noise levels at the higher frequencies, while being less than the lower frequencies, are not significantly reduced.

With regards to the deployment of multiple "Blind" or dead ended tees and elbows, this creates a number of challenges for the piping designer with regards not only minimization of station foot-print but also potential erosion challenges at the higher velocities typically experienced in MUSM applications.

Therefore the development and use of effective in-line acoustic filters will provide the user with another tool to ensure the successful operation of the MUSM even in close coupled, ultrasonically noisy installations.

DIRECT AND INDIRECT NOISE

Two new acoustic filters have been developed over the last two years that address two distinctly different noise attributes of control valve and regulator installations.

The first was a unique plate and helix configuration referred to as the Destroyer®. With respect to *the Destroyer*®, attenuation of the pressure wave is achieved by conversion of the systematic motion of the fluid into uncoordinated random motions. As the fluid passes through the Destroyer®, the device 'isolates' the piping system since the design is a 'flow-through' and not a 'see-through' design, thus reducing the **Line of Sight** noise issues that form part of the Ultrasonic noise challenge.

Both laboratory experiments on acoustic filtering and field trials, have indicated that the Destroyer® has the ability to reduce acoustic noise and reduce the effects of ultrasonic noise from control valves, regulators or other restrictions on ultrasonic flowmeters.

Research into the design of the Destroyer® indicated that while it provides a conversion from direct to indirect noise, it might not necessarily provide the complete solution to the problem of ultrasonic noise abatement. Therefore research was initiated into a more absorptive technique to work in conjunction with the Destroyer®.

It was determined that to effectively reduce noise levels in these typical MUSM installations it is necessary to ABSORB the noise at some point during the transition from noise source to the meter itself.

During the testing and development of the SAFE®, it was determined that ultrasonic noise has the ability to travel in many modes including both direct and in-direct, i.e., it may travel in a straight line or reflectively as the energy is reflected within the piping. Indirect or reflective noise has been demonstrated to be easier to absorb as it is presenting itself obliquely to the absorbing material as opposed to traveling perpendicular to the absorbing material.

This will be referenced later in the paper during practical application of the technology.

R&D RESULTS-DESTROYER\SAFE®

The challenge in the development of the ultimate acoustic filter has been the understanding of the impact of both line of sight noise elimination in addition to the gross absorption elimination of the ultrasonic noise. **Commonly used blind tee combinations work to satisfy the elimination of noise through the use of multiple elements.** Typical blind tee configurations provide a practical solution of typically 7-10dB per blind tee, thus requiring the use of multiple blind tees for total noise reduction requirements that may be in excess of 30-40dB. The SAFE® design, when used in conjunction with some element of Line of Sight elimination, either a Destroyer or single blind tee, provides the user with as much as 40-50dB noise reduction in the Ultrasonic Frequency range.

The design of the SAFE® was accomplished using empirical testing of numerous materials, porosities, sizes, and surface area combinations to determine the most effective noise elimination solution.

Over 250 tests were carried out over a **wide frequency spectrum** to analyze the material and mechanical design effectiveness. The ultimate goal of the design program was to satisfy the requirement for upwards of 40dB reduction using a single element.

Testing was carried out at ambient pressures in an air lab. Velocities tested were initially set at a maximum of 60 ft\sec.

Ultrasonic noise was generated throughout a frequency range of 20KHz – 100KHz, the piping used for the majority of the tests used the noise source located upstream of the acoustic filter and receiver. However, other configurations were used to establish the effectiveness of various piping methods and other designs.

Line sizes tested were both 4” and 10” nominal diameters.

The following is a small example of the test results:

4" Tests	Pt.A	Pt. B	dB Reduction	dB imp.
BARE	80	67	13	
SAFE®	80	37	43	30
SAFE® (WET)	78	35	43	30

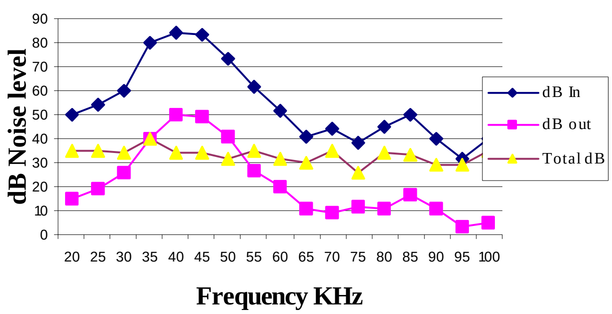
10" Tests	Pt.A	Pt. B	dB Reduction	dB imp.
BARE	80	71	9	
SAFE® (Indirect Noise)	80	26	54	45
SAFE® (Direct Noise)	79	34	45	36

The material selected as the noise absorbing element had to be both mechanically sound in addition to being able to withstand both water and hydro-carbon saturation. It was found that with the final material choice these factors were accomplished by using a hard, man-made fiber formed into cylindrical configurations. This design enabled the porosity to be maximized while establishing enough surface area for the noise absorption to take place.

The material selection satisfied the requirement for noise absorption as it established a direct conversion from ultrasonic noise energy into very low levels of thermal energy, the conversion of the energy being the core to the absorption.

As can be seen from the test data, direct noise, wherein the noise was being beamed directly at the SAFE®, created a slightly reduced performance factor, as part of the noise energy was being successfully transmitted through the absorbing tubes of the device. However, with indirect noise, such as that seen using a single blind tee or Destroyer® downstream of the SAFE®, provides the optimal performance of up to 50+ Db Noise reduction.

The SAFE® was tested at frequencies from 20KHz to 100KHz and the following response curve was noted.



The above response indicates compatibility with earlier testing as the frequency response curve was established using DIRECT noise upstream of the SAFE®.

PHYSICAL CONFIGURATION

The final configuration employs a flange-mounted assembly that is typically mounted directly in the meter run between the noise source and the meter. A pin is required on the down-stream side of the canister to ensure mechanical rigidity. The absorptive material is held in place mechanically from end to end using a compression system and is mechanically coupled to the containment vessel, which forms the absorption canister.

The design is configured for bi-directional flow should it be required and may be placed either upstream or downstream of the MUSM, depending on the source of the noise.

To ensure that the location of the SAFE® does not negatively impact the performance of the meter or associated flow conditioners, the recommended location of the SAFE® is to be no closer than 5D from the MUSM, flow conditioner, or disturbance (Noise).

S.A.F.E.® Acoustic Filter

As previously discussed the noise intensity will be a function of dynamic flow factors, however it is considered that a SAFE with a single blind tee or Destroyer should be able to satisfy most of the high noise applications.

The following are the typical installations:

- MUSM with noise source (Indirect) downstream
- MUSM with noise source (Indirect) upstream
- MUSM Bi-Dir. Noise source (Indirect) upstream
- MUSM Uni\Bi-Dir Noise source direct upstream\ downstream

PERFORMANCE MONITORING

The ongoing performance of the SAFE® can be monitored by analyzing the Noise or Signal to noise ratio diagnostics in the MUSM data log. Upon installation a benchmark of noise should be measured using the diagnostics and this should be analyzed periodically to determine any detrimental changes, indicating a deterioration of the acoustic filter performance.

High velocity testing for the SAFE® has been completed; however additional testing remains to be done and will be complete and the data published for the AGA conference.

CONCLUSIONS

The use of acoustic filters will enable the industry to take better advantage of the MUSM technology as it moves closer to regulated pressure environments without the negative impacts of costly and bulky alternative solutions.