Verification of a Duct Resonator Array for Larger Pipe Diameters

Michael James NEWMAN[1]; Maria Garrido[1]; Zheji LIU[2]; André-Pierre RYLISKIS[3]; Julien COLETTE[3]; Inigo EUGUI[4]; Ole Georg HAAHEIM[5]

[1] Lifetec, Norway

[2] Dresser-Rand, USA

[3] Dresser-Rand, France

[4] Aibel, Norway

[5] Statoil, Norway

ABSTRACT

A reactive silencer for gas compressors and associated pipework has been investigated for use in pipes of larger diameter. This complements the investigation carried out previously on a silencer for smaller diameter pipes. The acoustic performance of the two sizes of Duct Resonator Arrays are compared. The silencer is applied to the inlet and discharge pipes as spool pieces. The evaluation was carried out as sound insertion loss measurements. The arrays can be custom tuned to deliver maximum attenuation at the predominant tonal noise component (commonly at the blade passing frequency) of the corresponding compressor or be tuned to a frequency range with broadband high levels of noise. Workshop verification measurements demonstrated that the duct resonator array reduces narrow band noise by 14dB or more for the designed bandwidth (2-3 kHz) and broadband noise by up to 8dB (1-2kHz). This technology provides a flexible solution for the implementation of noise control measures to compressor piping systems.

Keywords: Compressor, Noise control, Reactive silencer I-INCE Classification of Subjects Number(s): 11.6.2, 34.2

1. INTRODUCTION

In recent years, awareness has been raised on the consequences of noise exposure on offshore installations. Both the regulating authorities and the oil and gas industry are working on finding the means to reduce noise exposure and thus, prevent hearing damage. Excessive noise is also a safety concern as it can interfere with verbal communication and the audibility of the PA system. Often measures that treat the sound transmission path have been used. It is always better to prioritize the use of low noise equipment, technical measures, which act directly on the source or as close to the noise source as possible.

Compressors are a major contributor to noise on offshore installations; hence targeting the noise emitted by turbo-machinery is a very effective way to reduce noise exposure. Since 2000, a centrifugal-compressor noise reducing technology, called Duct Resonator Array (DRA), has been commissioned in over 220 compressors. DRAs were first designed to attenuate blade passage frequency (BPF) noise and its harmonics, as some compressors are variable speed the DRA is designed to cover a limited bandwidth covering these frequencies. The BPF of an industrial turbo-compressor typically lies within 1200-4500Hz, a frequency range where the human ear is most sensitive. Later the DRA has been modified to cover a larger frequency range to attenuate broadband noise.

The initial DRA device was installed in the diffuser region of the compressor. This paper covers its application in spool pieces applied to the inlet/discharge pipes of compressors. For new compressor

[1] mike.newman@lifetec.no, maria.garrido@lifetec.no
[2] ZLiu@Dresser-Rand.com
[3] ARyliskis@Dresser-Rand.com, JColette@Dresser-Rand.com
[4] inigo.eugui@aibel.com
[5] olgh@statoil.com

designs, installing a resonator array inside the compressor is the preferred choice [1] as it is a highly effective and easy to implement solution. The external application is more suitable when retrofitting existing compressors (unless the compressor is to be re-bundled) or the compressor is too small to install a DRA.

2. Pipe Resonator Array Design

The pipe resonator array (PRA) sits inside a pipe spool rated for the pressure in the system. It consists of a one-piece solid steel tube with acoustic chambers machined from the outside, which are connected to the flow path by a series of perforations, Figure 1.

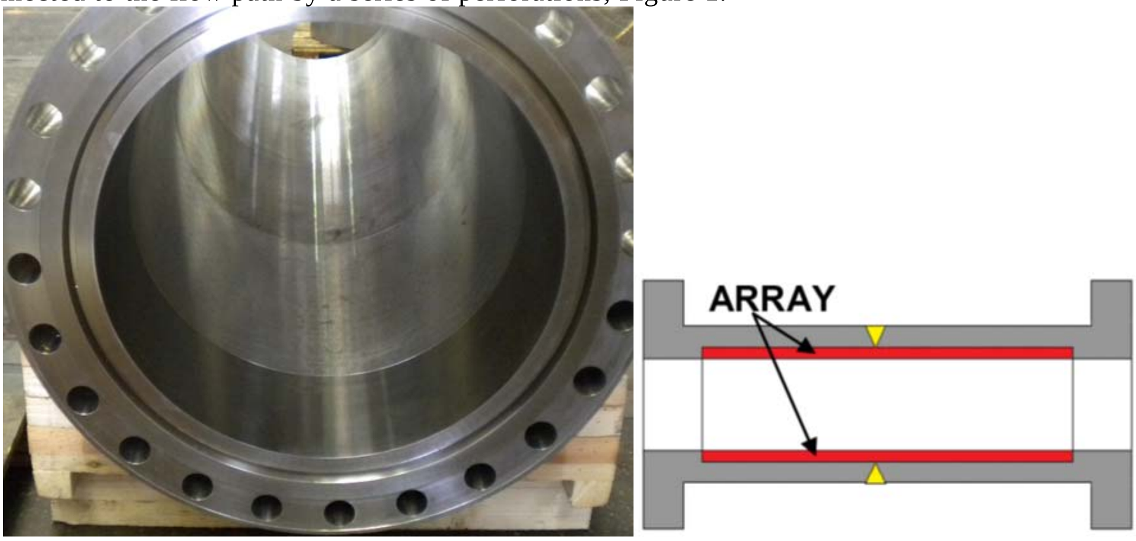

Figure 1 – Photo of the perforations inside the array and cross sectional sketch of array in spool piece

The PRA changes the pipe wall impedance from hard, for a solid pipe, to reactive/absorptive within a frequency bandwidth. The bandwidth is dependent on the size of the volumes machined into the rear of the PRA, number of perforations and their diameter and length. Tuning of the volume, hole size and number of, allows the PRA to be adjusted for particular installations, either to attenuate BPF noise or broader band noise. The PRA both reflects sound energy in the gas medium back towards the source and dissipates some of the energy in viscous losses in the oscillating flow through the perforations. Again tuning will affect the proportion of the sound energy that is absorbed and/or reflected.

3. Acoustic measurements

Airborne sound insertion loss measurements were carried out on the smaller PRAs and reported in [2 & 3]. Equivalent measurements have now been carried out on a 30" diameter PRA. This was only tested in 4 x diameter (4D) with a straight pipe configuration, as the PRA was just over 3m in length and the test pipe over 9m in length. As with the previous tests, the pipe was filled with air at atmospheric pressure, as opposed to its conditions when installed in the gas pipework under much higher pressure and with hydrocarbon gas as the medium. The increase in pressure and change of media causes the PRA to give attenuation at higher frequencies than in air.

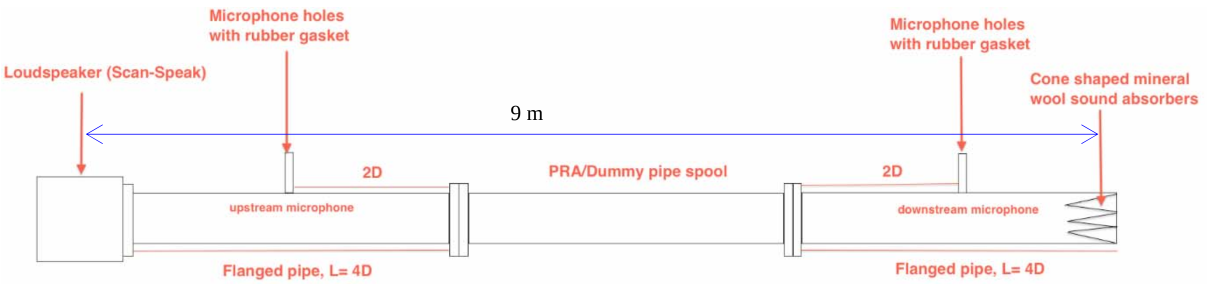

Figure 2 – Sketch of test equipment

4. Results

Typical measured sound pressure FFT spectra upstream and downstream of the PRA are shown in Figure 3. The sound pressure was also measured in 1/12 octave bands, these insertion losses were then averaged to gain the expected insertion loss for the PRA, see Figure 4.

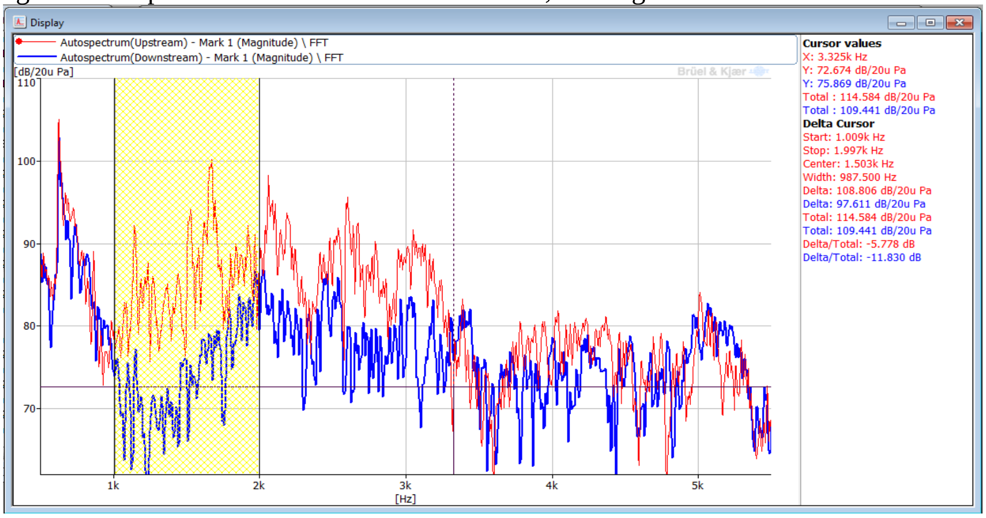

Figure 3 – FFT sound pressure upstream (red) and downstream of the PRA

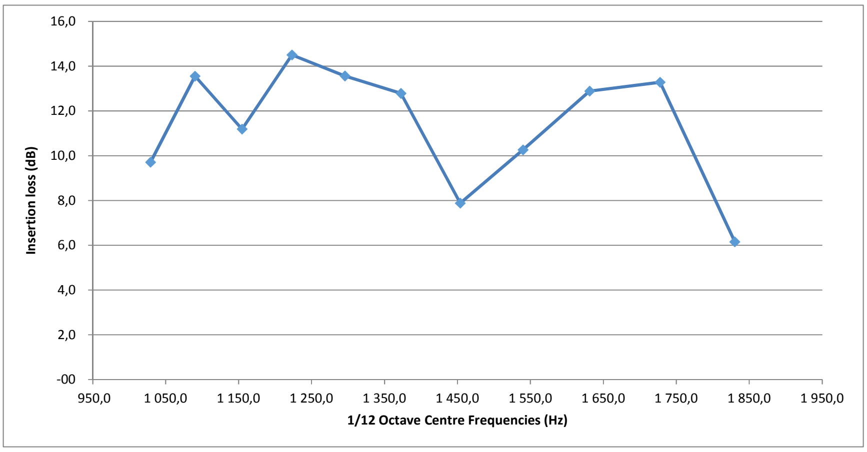

Figure 4 – Averaged 1/12 octave insertion loss for the 30" PRA

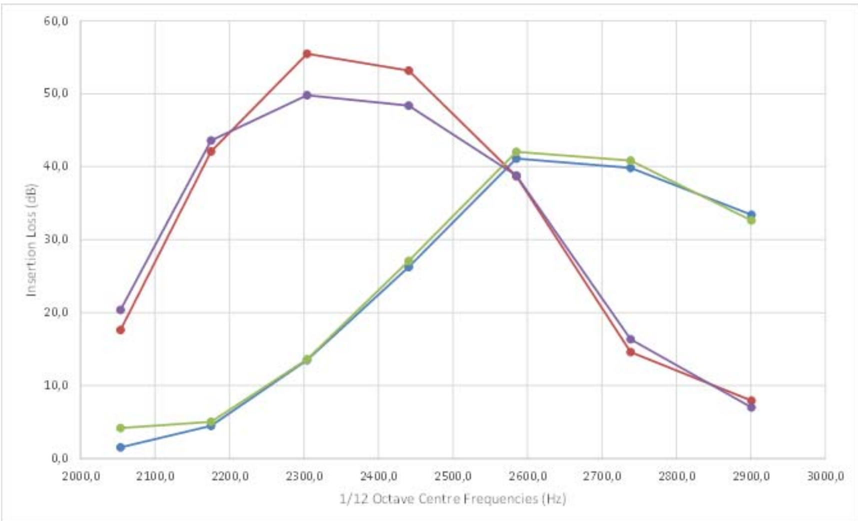

Figure 5 – Averaged 1/12 octave insertion loss for the 4" PRA

Sound attenuation measured in the frequency band 1-2 kHz, i.e. the frequency range at which the compressor produces strong broadband noise, was 8.6 dB for the 30" pipe. This compares with the

15.5dB average achieved by the 4" PRA that was tuned to the frequency band 2-3kHz, see Figure 5. The difference between the two sets of results is due to both the size and the tuning.

The 4" PRA was tuned to cover a bandwidth of 40% of the centre frequency, whereas the 30" was tuned to cover 67% of the centre frequency. This shows the usual tradeoff between bandwidth and attenuation.

The results indicate a typical reduction for the noise emitted by the pipework of around 5dB for the total A-weighted level when a broadband tuning is applied and 7-8dB when applied to a smaller bandwidth containing the BPF. This is accounting for the fact that the measured PRA attenuations are for the gas-borne noise. The structure-borne noise in the pipe wall is only attenuated by the mechanical impedance change at the flanges/change in cross-section at either end of the PRA. In addition the PRA only attenuates the noise within the bandwidth that the PRA is tuned to.

5. Conclusion

Workshop verification measurements demonstrated that the PRA significantly reduces the noise level over the designed frequency bandwidth, this can either be the frequency at which the compressor produces a strong tonal noise (BPF) or a chosen bandwidth. Overall A-weighted sound pressure level attenuation in the range of 5-8 dB reduction of the sound power from the pipework can be expected, with 9dB or more reduction in the frequency band that the PRA is tuned to. The BPF noise is often of such a high level that it can be assessed as tonal noise and then attracts a 5dB penalty for noise exposure assessment. The PRA is very effective at reducing this tonal noise such that it no longer attracts to the tonal noise penalty.

6. Acknowledgements

The authors thank Dresser-Rand, Lifetec and Statoil for allowing them to publish this paper. Thanks to the sponsors of this work, Troll A.

7. References

1. Liu, Z., Kuzdzal, M., Kenneth, E., Atkins, P., & Rials, R. (2010). Diagnosis and Solution of High Noise and Vibration Issues After a Propylene Refrigeration Compressor Re-rate - Proceedings of ASME Turbo Expo 2010: Power for Land, Sea and Air.
2. Palacios S.R., Liu Z., Melvær A., Peikli V., Skorping R., Syverud E., Haaheim O.G., Enger J., Newman M.J., Qualification of Duct Resonator Array for Noise Reduction in Offshore Installations - Procedings BNAM 2012.06.18-20, Odense, Denmark.
3. Palacios S.R., Liu Z., Peikli V., Skorping R., Melvær A., , Haaheim O.G., Enger J., Newman M.J., Syverud E. Qualification of Duct Resonator Array for Noise Reduction In Offshore Installations - Proceedings ASME Turbo Expo 2012.06.11-13, Copenhagen, Denmark.