Efficient Mitigation for Low-frequency Noise (LFN)

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The effects of Low-frequency noise (LFN) from some mechanic equipments, such as compressors and engines have been realized for many years. Noise between 20 Hz and 250 Hz can be annoying to people even at relatively low levels, which is why it has become a very strong component of the AEUB's revised noise directive. Because low frequency noise is difficult to stop or absorb, well-designed acoustic materials and structures must be used to get an optimized control.

In this paper, the characteristics of generation and propagation of LFN were analyzed; the feasible mitigation measures were briefly investigated; and some important conclusions have been acquired. The potential noise mitigation measures include: sound absorptive material and structures; isolation structures and enclosures; broadband frequency silencers; and active noise control technology.

For the effective low frequency absorption, acoustic absorbers can be used in the building based on its low frequency design and space settings. A higher performance silencer comes from the optimised design of absorptive or reactive silencer, or the combination of both of them based on the low frequency consideration. In order to improve the insertion loss of an enclosure, both the transmission loss and sound absorption of wall assembly should be sufficient. All the aspects involved with stiffness, mass, damping and sound absorptive properties have to be considered. Based on our research for the effective containment of LFN, appropriate measures and designs according to the frequency characteristics of the sound sources are very important for the mitigation of low frequency noise.

Complaint Investigation and Assessment of Noise and Infrasound of the Pubnico Point Wind-Energy Facility, Nova Scotia

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The presentation highlights the results of extensive sound and infrasound measurements conducted near the Pubnico Point Wind Farm in Nova Scotia and demonstrates the key technical concepts and descriptors in an understandable fashion; provides insight and a good technical basis for assessing noise and infrasound impacts – through measurements and modeling – against quantitative regulatory guidelines and internationally accepted references; and points out that, even when a situation is acceptable on an average basis, certain wind, atmospheric and operational conditions can lead to significant variations in impact. The presentation will provide insights into the handling of a complaint situation and associated pitfalls of not adequately addressing the situation in advance of a wind farm start-up. The presentation will use clear graphics and describe the results in technical and layman's terms, along with interesting anecdotes.

Practical considerations for the prediction of low frequency noise

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Low frequency noise (LFN) generated by industrial and oilfield applications is generally recognized as having the potential to cause annoyance, particularly in rural residential locations. The recent revision of EUB directive 38 quantifies sound levels which may be symptomatic of an LFN annoyance condition and recommends that the dBC-dBA level be determined through modeling of new plants and expansions. This paper examines the reliability and limitations of current noise propagation modeling methods with respect to low frequency noise predictions. Topics of discussion include the importance and prospective availability of noise emission levels in the 16 Hz Octave Band, limitations imposed by the prediction accuracy of LFN in software modeling tools and standards, and potential supplementary analysis of noise sources which may help to anticipate a LFN problem. A case study involving dBC-dBA level predictions is presented as practical example.

Low Frequency Noise Case Study – Identification and Mitigation of a Severe Infrasonic Tone from a Mine Shaft Ventilation Fan

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At homes near a large mine shaft ventilation fan in Dallas, West Virginia, windows were rattling and lightweight furnishings were falling off shelves. Preliminary work by a silencer supplier had indicated strong low frequency acoustic pulsations as far as 200 metres from the fan. HGC Engineering was retained by the coal mine company to investigate the source of the problem and find solutions. Sound level measurements readily identified acoustic pulsations on the order of 75 dB at 15 Hz outside the residences. Vibration was perceptible on the walls and windows of the dwellings, and had a high measured coherence with the air-borne pulsations. 15 Hz was found to correspond to the rotational speed of the fan. Sound level measurements of an identical fan at another location showed a similar tone, suggesting that the fan was operating normally, and that the low frequency pulsations were typical of this particular fan model. Work began to develop a silencing solution. Controlling acoustic emissions at 15 Hz is a significant challenge because of the long wavelengths of sound. Quick calculations indicated that, if a conventional silencer were to be used, its pressure drop and length would have been prohibitive. HGC Engineering assisted by developing a design for a custom tuned acoustical plenum chamber (approximately 10 x 10 x 6 metres in size). Numerical Boundary Element Analysis was used to optimize the acoustical design, and a 1/10 scale model was built and tested to verify the performance of the acoustical plenum.

SUMMARY OF LOW FREQUENCY NOISE RESEARCH AND POLICY DEVELOPMENT CONDUCTED BY THE ENERGY & UTILITIES BOARD

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Environmental noise from energy industry facilities in Alberta is regulated by the Alberta Energy and Utilities Board (EUB) as cited in the *Noise Control Directive. T*he fifth edition of the directive is comprised of a comprehensive policy and guide that has adopted A-weighted energy equivalent sound levels ($L_A$eq) as the primary measurement system with sound pressure level criterion for a receptor location. With the receptor being some distance from the energy industry noise source, the high and mid frequency components can dissipate or be absorbed by air and ground conditions leaving mostly low frequency noise. Consequently, A-weighted measurements do not reflect the full annoyance potential of the remaining industrial noise. Complaints related to low frequency noise (LFN) are often described, by the affected party, as a deep, heavy sound, like humming, sometimes with an accompanying vibration. In some cases the direction of the source of the LFN will be unknown to the receptor. However, it is the complainant that is most able to detect the presence of the LFN signifying a particular sensitivity of the individual to the sound while others in the same family may not be able to detect the sound at all. To make a proper determination for the presence of LFN, the data must be collected during a time when environmental conditions are representative of when the sound is annoying. Residents who are impacted by LFN may suffer from sleep disturbances, headaches and in some cases chronic fatigue. This paper examines the work undertaken by the EUB to understand the issue, the various metrics tested in attempting to easily identify LFN, and finally the approach that would be incorporated into the new legislation *Noise Control Directive 038* to address the problem.

PRESSURE FIELDS NEAR COMPLEX SOURCES EMITTING LOW FREQUENCY NOISE

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Recently, Richarz (2006 CAA Mtg.) reported on a low frequency bias in the pressure field of compact sources above a reflecting plane. The phenomenon is driven by the interference of the direct and reflected waves. The analysis has now been extended to deal with realistic sources. To this end the sound fields of hemispherical radiators with arbitrary surface velocities have been studied. The framework was selected because closed form solutions are readily available. The novelty introduced herein is that instead of the customary focus on individual higher order radiators, patches of the surface are treated individually. Each element is modelled by a suitably weighted and phased collection of equivalent spherical radiators. Each patch may vibrate at a different frequency, which is similar to that of a multi-side enclosure. The analysis provides detailed information on the extend of the so-called acoustic near-field. The implications with regards to the measurement of sound power via acoustic intensity or other means are illustrated.

Title: Acoustic Performance Considerations for a `Once Through Steam Generator'/OTSG

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Once-Through heat recovery Steam Generators (OTSGs) are used by electricity power plants and a host of other Industrial and/or commercial centers to recover the heat from a gas turbine exhaust stream. The OTSG is capable of dry operation; therefore a bypass stack is not required, resulting in reduced leakage and more efficient operation from a construction standpoint. This makes an OTSG very attractive as a fundamental part of a heat recovery system in a cogeneration power plant. An important property of an OTSG is its acoustical characteristics and primarily its ability to reduce gas turbine exhaust noise emissions (sound power in the range of 140-150 dB re: 1pW) with respect to casing or wall radiated sound of the exhaust breaching and emissions attributable to the exhaust stack outlet.

This paper examines the various parameters that govern the acoustic performance of an OTSG under both steam generating and dry running conditions. In particular, the paper deals with the effects of elevated gas temperature on properties such as speed of sound, viscosity, gas flow conditions and how this affects the acoustic performance of an OTSG.

Development and application of a procedure for the assessment of low-frequency noise complaints

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The paper describes work carried out at the University of Salford to develop and field trial a procedure for the assessment of LFN complaints. The procedure includes guidance notes and a pro-forma report with step-by-step instructions. It does not provide a prescriptive indicator of nuisance but rather gives a set procedure to help Environmental Health practitioners to form their own opinion. The development of the assessment method included laboratory tests and field measurements, complimented with interview-based questionnaires. Volunteers from Environmental Health departments then conducted a series of six trials with genuine 'live' LFN complaints to test the workability and usefulness of the procedure. Examples of field measurements and application of the procedure are presented. The procedure and examples are likely to be of particular interest to Environmental Health officers involved in the assessment of low-frequency noise complaints. [Work funded by the Department for Environment, Farming and Rural Affairs (DEFRA) UK].

LARGE REFINERY AND PETROCHEMICAL PLANT FURNACES AND HEATERS: LOW FREQUENCY NOISE MEASUREMENT AND SOUND POWER LEVEL PREDICTION

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One of the major plant process equipment noise sources at refineries and petrochemical plants are large industrial furnaces and gas fired heaters. At the stack-top level, these furnaces and heaters produce a low-frequency tonal noise from "combustion roar"; as well they can produce a mid-frequency broadband noise from induced draft fans. The prime noise generating mechanisms are due to turbulent mixing of fuel gas and air and combustion generated oscillations. Although some degree of noise reduction can be achieved through burner design, largely noise control engineering occurs at the furnace and heater manufacturing or plant retrofit level.

This paper presents two methods of accurately measuring stack-top radiated noise, which are firstly using a microphone in the near-field attached to a crane hook, and secondly using a high-temperature microphone probe inserted into the stack via an air sampling port. After sound power level results are calculated, and directivity corrections are applied, results from eleven facilities are compared.

Some of these facilities have multiple furnaces and heaters, making the order-ranking of results imperative. Results of one plant with 19 furnaces and heaters are presented order-ranked, to isolate which furnace and heater stacks are the most predominant noise contributors.

Some of these facilities have utilized acoustical silencers to reduce the stack-top radiated noise. Silencer performance measurements were conducted, and compared with the silencer manufacturer's predicted Insertion Loss data, to verify design predictions.

Finally, the results of all furnaces and heaters from the eleven projects are correlated, showing noise generated versus combustion characteristics.

Challenges and Limitations in Retrofitting Facilities for Low Frequency Noise

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Equipment associated with Oil & Gas and Power Generation facilities emits high levels of low frequency noise. As these facilities become more and more distributed, their proximity to the residential areas increases, and so do their noise contribution levels. The low frequency noise is gradually being recognized as one of the main issues negatively affecting the relationship between the energy facilities and neighboring communities. Excessive levels of low frequency noise can have a significant impact at the residential locations ranging from annoyance to sleep depravation. Generally, there is little awareness in the energy industry in regard to low frequency noise and its effect on communities. Frequently, insufficient attention is paid to low frequency noise during the facility design stage. This often leads to costly retrofits. This paper discusses the challenges and limitations of field retrofits of the facilities aimed at reducing low frequency noise and discusses actual field cases.