# Assessment of noise with low frequency line spectra – practical cases

**Michael Friis Sørensen**

*Ødegaard & Danneskiold-Samsoe, Jylland ApS, Beder Landevej 29, 8330 Beder, Denmark*

***Many small power plants have been built in Denmark in recent years. These plants are often situated near dwellings giving rise to complaints about annoyance of low frequency noise and vibration indoors. Normally the annoying low frequency noise is in the frequency range 10-200 Hz. Since it is created by combustion engines the noise has a line spectrum. In Denmark the A-weighted total level in the frequency range 10-160 Hz $L_{pA,LF}$ is used for assessment and legislation about low frequency noise exposure in dwellings. From our experience solving practical low frequency noise and vibration problems $L_{pA,LF}$ seems to overestimate the annoyance of very low frequency noise whereas noise with the major spectral content near 160 Hz seems to be underestimated. This problem is discussed based on our experience.***

## Introduction

In recent years many small thermal power plants have been built in Denmark replacing larger central power plants. This decentralisation has caused many power plants to be situated close to dwellings. The short distance to the neighbours calls for very strict engineering in the design of the power plants in order to avoid low frequency noise and vibration disturbance. As consulting engineers in noise and vibration control our company has solved several problems where one or more factors in the design of the power plant caused low frequency noise and vibration annoyance to the neighbours.

In cases where neighbours are annoyed by low frequency noise, the problem is normally only experienced indoors. Sometimes the neighbours can be annoyed indoors even if the power plant complies with the normal external A-weighted noise exposure demands. This is due to the fact that low frequency noise can be transmitted to the neighbouring houses as structure-borne sound via the ground or the heating pipe connection. The noise is then radiated from the floor, walls and ceiling of the house. Differences in natural frequencies of the building elements can cause quite different indoor noise levels in two different houses even at the same distance from the power plant.

In order to handle the above-mentioned problem the Danish Environmental Protection Agency (DEPA) has in Miljøstyrelsen[1] specified techniques for indoor measurements of low frequency noise and vibration together with a set of recommended limit values. The parameters to measure and the recommended limits are seen in Table I.

Based on the experience of our company noise and vibration from power plants most often give problems complying with the low frequency noise level $L_{pA,LF}$. Therefore, the present paper discusses $L_{pA,LF}$ and its correlation with the subjective evaluation of the noise.

## Typical indoor noise spectra

Often the power plants are powered by one or more diesel or natural gas 12-20 cylinder engines running at 500-1500 rpm. The noise and vibration "finger prints" from such engines are characterised by a line spectrum. The basic frequency of this harmonic line spectrum is determined by the engine rotational speed. In addition, large

*Table 1. Parameters and recommended limits for indoor noise and vibration levels stated by the Danish Environmental Protection Agency*

| Parameter | Technical description | Recommended limit |
|---|---|---|
| Low frequency sound $L_{pA,LF}$ | A-weighted sound pressure level, 10-160 Hz | 20 dB re. 20 μPa |
| Infra sound, $L_{pG}$ | G-weighted sound pressure level, 1–20 Hz | 85 dB re. 20 μPa |
| Low frequency vibration, $L_{aw}$ | KB-weighted acceleration level, 1-80 Hz | 75 dB re. 1 μm/s$^2$ |

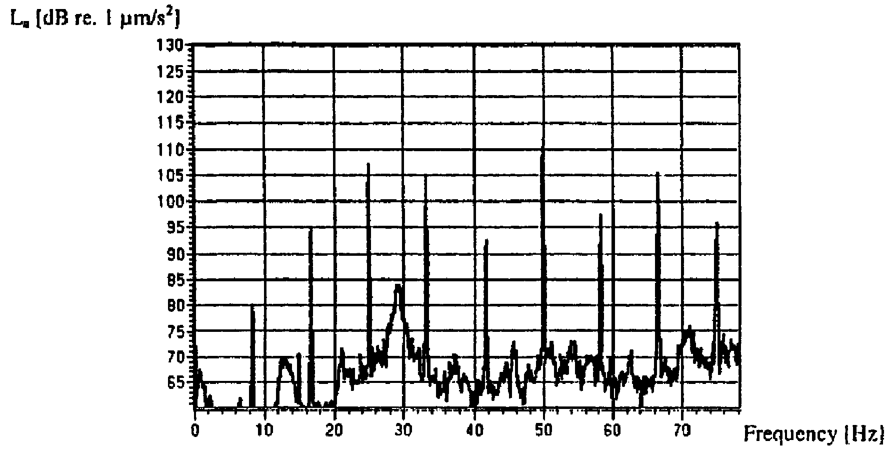


*Figure 1. Narrow band spectrum of vibration level measured on a V18 gas engine running at 1000 rpm.*

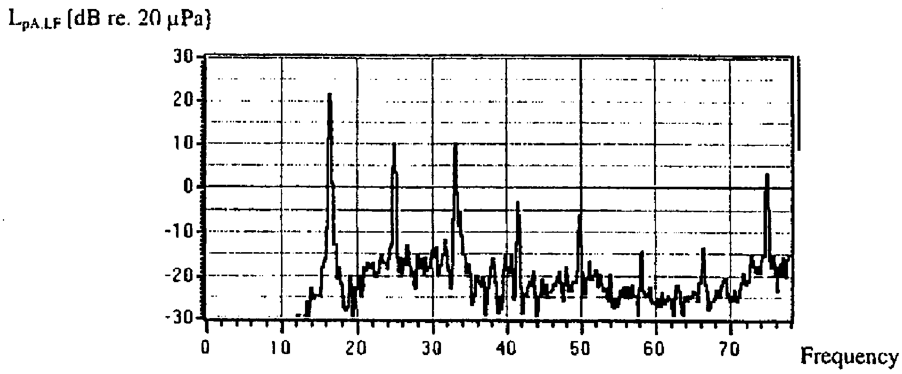


*Figure 2. A-weighted low frequency noise spectrum measured in the living room of a power plant neighbour.*

noise levels can be expected at the engine firing frequency which is determined also from the number of cylinders.

Figure 1 shows an example of the vibration spectrum measured on a V18 gas engine running at 1000 rpm. As seen the basic frequency in the harmonic spectrum is 8.3 Hz.

Low frequency noise can be transmitted from the power plant as air-borne or structure-borne sound. The typical air-borne transmission paths are from the exhaust gas outlet, the engine cell ventilation or radiation from the walls and roof of the power plant. Structure-borne noise can be transmitted either via the ground or via the heating pipe connection to the power plant.

Figure 2 shows the low frequency noise measured in the dwelling near the power plant with the engine from Figure 1 running. The characteristic pure tones from Figure 1 are easily recognised and the resulting $L_{pA,LF}$ value of 23 dB is above the recommended limit. Please note that the fundamental frequency 8.3 Hz is not seen since the A,LF-weighting is not specified below 10 Hz.

The subjective response to the noise in Figure 2 with a $L_{pA,LF}$ level of 23 dB is that it is a very deep noise, clearly audible, but still at a very low level. However, one person living in the house felt highly annoyed. Reduction of the transmitted vibration by improving the flexible suspension of the engine resulted in the spectrum seen in Figure 3.

As seen especially the dominating 16.7 Hz tone was considerably reduced. The $L_{pA,LF}$ value was reduced to 15 dB. The subjective response to the resulting noise is that it is hardly audible and the annoyed person was satisfied.

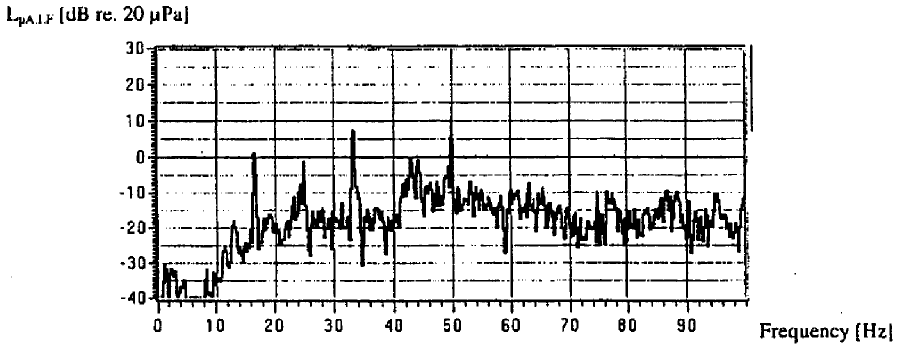


*Figure 3. Noise spectrum measured in the same position as in Figure 2 but after improvement of the flexible engine suspension.*

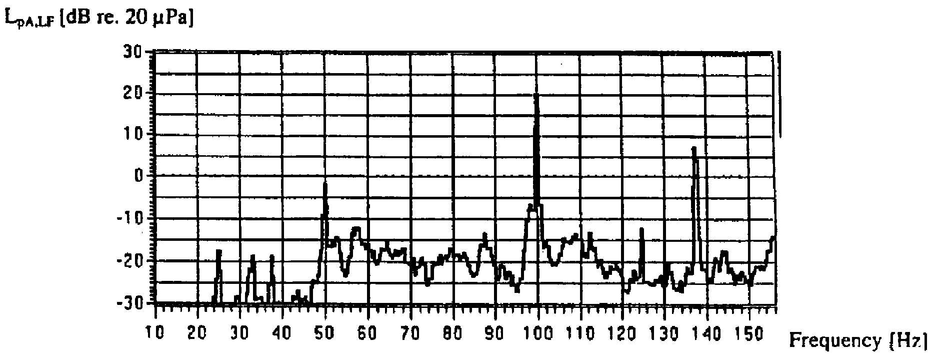


*Figure 4. A-weighted low frequency noise spectrum measured in the basement of a power plant neighbours house.*

Another example of indoor noise is seen in Figure 4. The A-weighted noise spectrum was measured in the position in the basement with the highest level. As seen the noise is clearly dominated by a 100 Hz tone and the $L_{pA,LF}$ value is 21 dB. However, since the average value of all measurement positions in the room was below 20 dB the $L_{pA,LF}$ limit was not exceeded.

The subjective response to the noise in Figure 4 was a clearly audible, irritating humming noise which also caused complaints from the occupier of the house. The problem was structure-borne noise from the power plant transmitted to the neighbour via the heating pipe connection in the basement. Careful vibration isolation of the piping at the power plant solved the problem and the neighbour was satisfied.

## Conclusion

The two examples described above with noise measured according to the guidelines given by the DEPA in Miljøstyrelsen1 illustrate our experience with the $L_{pA,LF}$ and the 20 dB limit. Due to the nature of the noise from power plants neighbours are often exposed to noise dominated by one or a few pure tones. If the noise is dominated by very low frequency components in the range 10-30 Hz we evaluate that the 20 dB limit is strict. However, if the dominating frequency components are

in the range 100-160 Hz we evaluate that the 20 dB is vague.

This can be explained by the fact that at 20 Hz the $L_{pA,LF}$ value of 20 dB corresponds to a level 3 dB below the hearing threshold described in ISO 389-7[2]. At 160 Hz the 20 dB $L_{pA,LF}$ corresponds to a level 20 dB above the ISO 389 7[2] threshold.

Our evaluation is that the $Lp_{A,LF}$ limit of 20 dB may be an acceptable compromise with low frequency noise distributed in the whole frequency range 10160 Hz. However, if the noise is dominated by pure tones or very narrow band noise, $L_{pA,LF}$ does not give a satisfactory correlation with the subjective effect of the noise. Therefore, more knowledge should be collected for creation of an additional quantification method for indoor low frequency noise.

## References


1. *Miljøsbrelsen (The Danish Environmental Protection Agency) (1997). Orientering fra Miljøstyrelsen Nr. 9 1997 "Lavfrekvent stoj, infralyd og vibrationer i eksternt miljø". (English translation of the title: Low Frequency noise, infra sound and vibrations in the external environment").*

2. *ISO 389-7 (1996). "Reference zero for the calibration of audiometric equipment – Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions", International Organization for Standardization, Geneve.*


noise notes

## OSHA and construction noise

Hoping to protect construction workers from job-related hearing loss, the US's federal Occupational Safety and Health Administration (OSHA) is considering stricter noise control standards – a move that two construction industry trade groups are questioning. OSHA currently has a hearing conservation program for general industry workers, but the construction industry is not covered by those rules. Under current OSHA standards for construction, employers are required to provide hearing protection devices for workers who face high noise levels. Workers may not be exposed to noise that exceeds 90 decibels for eight-hour day. A hearing conservation program would impose additional requirements, including hearing tests and noise exposure monitors, and would be similar to the general industry program. OSHA's general industry program requires employers to provide, among other things, audiometric testing, audiogram evaluation, noise monitoring, training and education for employees who are exposed to high noise levels. OSHA spokesman Bill Wright said the agency wants to get the construction industry's input regarding the proposed change and how they would work. "There are some major hearing problems (associated with) construction sites, and that's what this is all about," Wright said. Rock drilling, blasting, demolition, and heavy equipment operation are examples of construction-related noise hazards, according to OSHA. Not everyone agrees, however, that stricter regulations are necessary. Justin Crandol, director of safety and health services for the Associated General Contractors of America, said the current standard provides enough protection. If OSHA wants to protect workers, he added, it would be better to focus on improved compliance with existing rules. "AGC feels that there's a low percentage of hearing injuries within the construction industry," Crandol said. "We don't understand why OSHA wants to add additional standards to a program that already works. We feel that they should move that effort to outreach instead of more regulations. Crandol added that construction should not be lumped in with general industry because noise levels are much more constant in a factory setting. "In a factory you have the same static noise all day," he said. "In construction, you have a changing environment as well as a changing workforce. It would be a program that doesn't fit into construction that the contractor would have to adapt to the construction environment." Anita Drummond, director of legal and regulatory affairs for the Associated Builders and Contractors in Washington, D.C., questioned whether OSHA has sufficient data to warrant a change in the noise standard for construction.