TRANSMISSION OF THE LOW FREQUENCY NOISE FROM BOILERS-ROOMS TO RESIDENCE

Stanislav Žiaran

Slovak University of Technology Faculty of Mechanical Engineering
Nam. slobody 17, 812 31 Bratislava, Slovakia
stanislav.ziaran@stuba.sk

Abstract: This article investigates the main noise sources of boiler-rooms (plants) as a whole located in residential areas, which are an important source of low frequency noise and the conditions for transmission of the sound energy. This article shows possibilities for reducing the energy of this type of noise as well. Measurements were made for different boilers and their operating conditions and some results are presented, and the effectiveness of boiler noise treatments discussed. Finally, the possibilities how to effectively assess low frequency noise are presented as well.

1 Introduction

Low frequency sound may be generally defined as having a frequency below 160 Hz. Sound enters buildings through their structure, through open windows from boiler plants (rooms) which are situated directly in the residential area, or can be generated by boilers inside the building. Sound with a very long wavelength may be heard as noise (primary noise), cause the rattling of windows, doors or furniture (secondary noise), and may be difficult to distinguish from structural vibration. Both of these forms of noise can cause disturbance, particularly in the evening and at night. Low frequency noise can be more noticeable indoors, which is why it is often associated with disturbed sleep and relaxation. The sound pressure increases too for some special conditions – standing waves [7].

2 Sources and transmission of vibro-acoustic energy

Boiler plants are usually located in living areas within a distance of up to 100 m and usually are even closer. Some of them are directly attached to the dwelling house by their chimneys. The main sources of the boiler rooms are boiler burners and ventilators. The air suctions, pumps, and gas regulators are less noisy technological equipment. All the sources have a larger or smaller influence on the ambient noise in residential and public buildings. The frequencies and levels of these sources have been correlated using some of the more obvious operational parameters, such as type, speed, power rating, and flow conditions.

2.1 Noise estimation of boilers

For determination of the total sound pressure level L (dB) in 1 m from the combustion chamber (burner) and for the total sound power level L_W (dB) generated by the flowing of the primary and secondary air can be used [6]

$$L = 44\,\lg v + 17\,\lg q_m - 146 \tag{1}$$

$$L_W = 44\,\lg v + 17\,\lg q_m - 135 \tag{2}$$

where v is speed of air flow ($m\cdot s^{-1}$);
q_m – mass flow rate ($kg\cdot s^{-1}$).

The data obtained by measuring permit the calculation of sound pressure levels in octave bands at the plants with installed noisy equipment [5]

$$L = 10\lg\left(\sum_{i=1}^{n}\frac{10^{0,1L_{Wi}}Q_i}{\Omega_i r_i^2} + \frac{4}{A}\sum_{i=1}^{m}10^{0,1L_{Wi}}\right) \quad (3)$$

where L_W is sound power level in octave for i^{th}-source (dB);
Q – factor of noise source direction;
Ω – spatial angle of source radiation (rad);
r – distance from acoustic centre of noise source up to rated point (m);
n – number of noise sources;
A – acoustic constant in the building (m^2);
m – total number of noise sources in the building.

The character of noise generated during the combustion process of gas is aerodynamic and can be defined as a continuous spectrum which changes amplitude in the low frequency domain. This phenomenon can be proved during the measurements, and changes in amplitude reach approximately 6 dB. By using a narrow band filter, a spectrum characterized by a slow drop of the sound pressure level with growing frequency can be measured. The results of acoustics measurements of boilers and boiler plants are in Fig. 1 and Fig. 2, respectively. The significant amplitude of noise for a boiler at the middle frequency 1/3 band is 112 Hz. This amplitude is increased in front of a protected dwelling house (Fig. 2), identified as a tonal frequency, and this frequency usually developed the standing waves in the protected area [6].

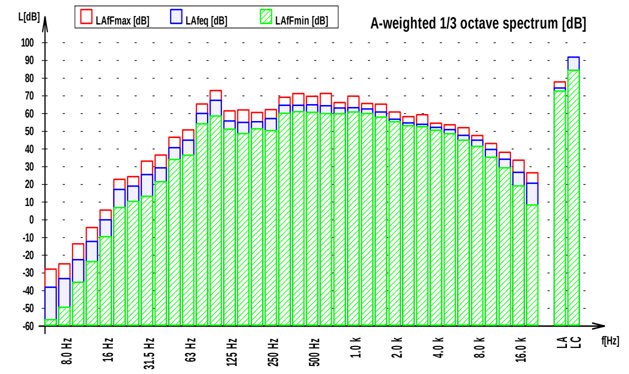

Figure 1. Spectrum of noise sources (boilers type VUP 1600) in boiler plant

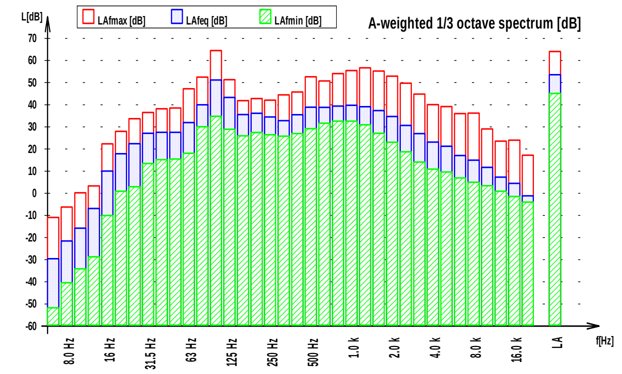

Figure 2. Spectrum of boiler plant noise measured in front of protected object

In most cases producers or suppliers of boiler products do not usually offer data about the noise emitted from the boiler to the boiler room and to the uptakes. Therefore, if the measurements for the boilers are not accessible, for determination of sound power level can be used diagrams in Fig. 3 and Fig. 4 respectively [2].

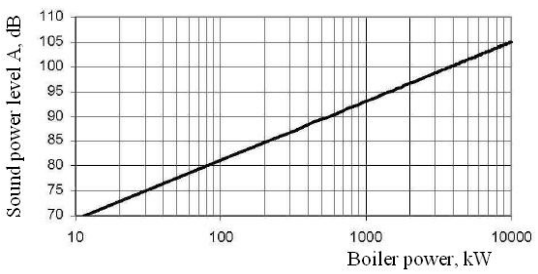

Figure 3. Propagation of noise from combustion equipment into the boiler room

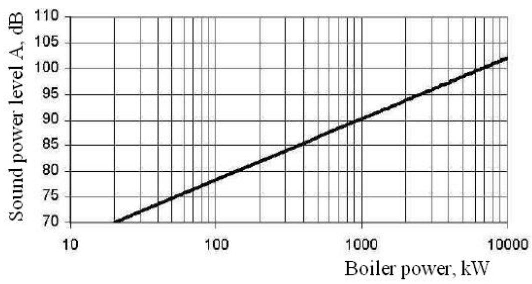

Figure 4. Propagation of noise from combustion equipment into the uptake

2.2 Transmission and reduction of sound energy

The classical material structures are very good conductors of vibro-acoustic energy. The frequency domain in which the human ear is most sensitive to any sounds is the most important domain for sound reduction [4, 7]. Any attenuation of vibration levels within this frequency domain has a positive impact on the reduction of sound intensity emitted into the environment and on the sound exposure of humans.

The transmission of sound power can be limited by reducing the amplitude of the vibration, reducing the emitting surface, reducing the time of emission, increasing the mechanical and acoustic impedance of the environment and increasing the loss coefficient and altering the Young's modulus of material [1, 5]. The reduction of the sound energy can be successfully solved by a dissipative silencer in combination with reflex principle [6].

Vibro-acoustic energy is transmitted from the source into the point of exposition of a protected space via fluids and structures. Noise from boiler plants situated outside a protected area is transmitted by air. Acoustic energy is emitted from the noise source by a chimney orifice, chimney structure, ventilation windows, the size of which is not negligible, service gates, and also by certain structural elements. Fig. 5 presents a model situation of a boiler plant, protected area and exposition places, together with structural elements which allow radiation of acoustic energy from the boiler plant. The radiation of acoustic energy is increased if partial standing waves are originated in the boiler house [5, 6].

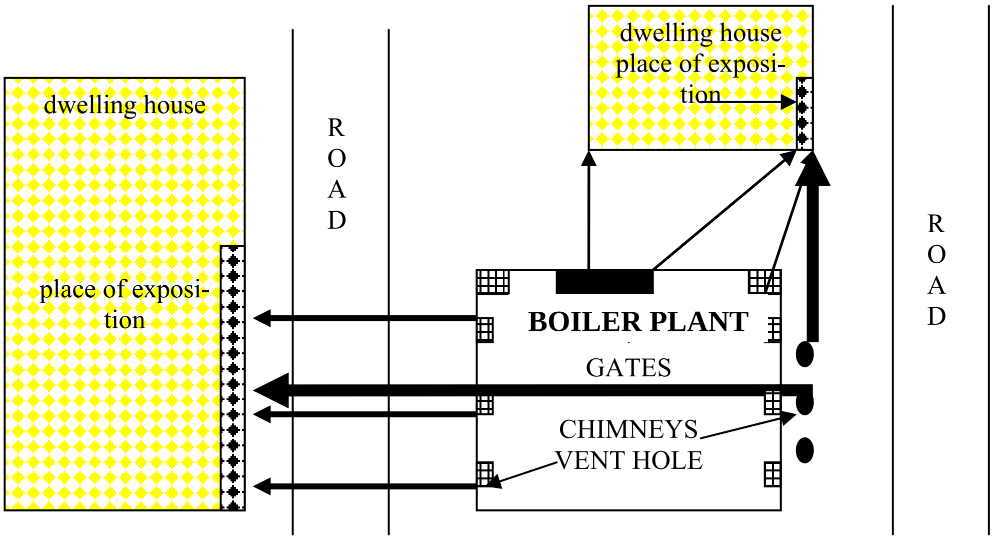

Figure 3. Model situation of radiation sound energy from boiler room to projected objects

Under certain circumstances acoustic energy excites vibration (rattling) in structural elements within a protected area. This phenomenon is an important element of the disturbance caused by a low frequency sound; rattling, as a factor related to strong low frequency and impulse noise, can be observed in structural elements located in dwelling houses as well [6].

3 Assessment of low frequency noise – conclusion

There are a large number of ways to measure and evaluate noise, each normally resulting in different noise measures, descriptors, or scales [1, 3, 7]. The different measures and descriptors result mainly from the different sources and the different researches involved in producing them. From these measures and descriptors, criteria have been developed to decide on the acceptability of the noise levels for different activities. These criteria are useful in determining whether noise control efforts are warranted in order to improve speech communication, reduce annoyance, and lessen sleep interference.

The sound spectrum of boilers is perceived to have a "rumbly" quality with low-frequency sound energy. A rumbly spectrum is characterized as one with octave band sound levels that exceed the determined RC curve [1, 7] by more than 5 dB at and below 500 Hz. Acoustically induced perceptible vibration indicates sound pressure levels in the 16 Hz to 63 Hz octave bands at which perceptible vibration in building walls and ceilings can occur.

Investigations have shown that the perception and effects of sounds differ considerably at low frequencies as compared to mid or high frequencies [8]. The main reasons for these differences are as follows: a weakening of pitch sensation as the frequency of the sound decreases below 60 Hz; perception of sounds as pulsations and fluctuations; a much more rapid increase in loudness and annoyance with increasing sound pressure levels at low frequencies than at mid or high frequencies; complaints about feelings of ear pressure; annoyance caused by secondary effects like rattling of buildings elements, windows, and doors; less building sound transmission loss at low frequencies than at mid or high frequencies.

Therefore for the assessment of sounds with strong low-frequency content, the rating procedures should be modified. The measurement location may be changed and the frequency weighting affected, since sounds with strong low-frequency content engender greater annoyance than is predicted by the A-weighted sound pressure level. In the assessment of low-frequency noise the main factors are as follows:

- the frequency range of interest appears to be about 5 Hz to about 160 Hz;
- one of the issues in low-frequency noise assessment is that room resonances at low frequencies can create situations that may be hard to predict from outdoor measurements. This can be especially important in evaluating specific residences. However, for the purposes of estimating the prevalence of high annoyance in a large community population, outdoor measurements may be sufficient;
- sound-induced rattles in building elements are important determinants of the annoyance caused by low-frequency sound.

Acknowledgements

The article is published with the support of the Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences (VEGA) 1/4091/07.

References

[1] M. J. Crocker, *Encyclopedia of Acoustics*, (JOHN WILEY & SONS, New York 1997).

[2] M. Kucera and R. Novy, *Sources of Noise in Heating Systems* (Webside 2004).

[3] S. Ziaran, *Measurements and Criteria of the Evaluation for Noise Environment in New Millennium*, (Proceedings "Heating 2000", Stará Lubovňa 2000).

[4] S. Ziaran, *Acoustics and Acoustic Measurements*, in Physical Methods, Instruments and Measurements, [Ed. Yuri M. Tsipenyuk], in *Encyclopedia of Life Support Systems (EOLSS),* Developed under the Auspices of UNESCO, Eolss Publishers, Oxford, UK, [http://www.eolss.net] (2005).

[5] S. Ziaran, V*ibration and Acoustic. Noise and Vibration Control in Industry,* Monograph (STU Bratislava 2006).

[6] S. Ziaran, *Acoustic Solution of Boiler Room* (Research report Bratislava 2007).

[7] S. Ziaran, *Protection of Human Beings Against Noise and Mechanical Vibration,* Monograph (STU Bratislava 2008).

[8] ISO 1996-1, *Acoustics. Description, measurement and assessment of environmental noise. Part 1: Basic quantities and assessment procedures* (2003)