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Experimental investigation on the sound pressure level for a high thermal capacity burner during a running cycle

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ABSTRACT

In many research or technical expertise studies the maximum noise level of a boiler is associated with the maximum thermal load of the burner. However, this type of air injected burners presents a complex running cycle with different functioning periods, where different parts (engine, fan, flame) of the burner are running separately or in the same time. In this study we are focused on the analysis, by experimental measurements, of the entire functioning cycle of a boiler by pointing out the noise differences and their importance when doing an experimental acoustical investigation. The entire 1/3 octave spectrum of the sound pressure level (SPL) was recorded during a complete running cycle by means of logging software associated to the sound meter. The sound equivalent level was calculated for each period of the running cycle and compared to the norms and with two theoretical prediction models that take into account the heating power and the boiler room volume. It was found that the most accurate data are obtained when the measurements are done in one-third octave. The maximum noise level was established to be not for the maximum thermal load period, but for the ventilation period of the boiler (before gas injection) with 82.1 dB at 125 Hz. A shut down delay was detected at the end of the cycle with 13 s for higher frequencies, due to the vibration of the boiler parts. Two 3D graphical representations point out the most important frequencies characterizing each running state of the burner. Compared to the noise curve (NC85) the minimum differences between the admissible values and the ones produced by the burner were found to be around 5.5 dB and therefore no acoustical treatment was needed. The results of the SPL prediction models matched the experimental data only for some of the boiler cycle periods and for only some of the frequencies. This type of detailed experiment investigation of the burner noise highlights the periods of the running cycle and the frequencies where the noise level requires acoustical treatment.

1. Introduction

Acoustic comfort is rapidly growing as a major factor that needs to be taken into consideration during the design stage for any new building that aims for high quality standards. The evaluation parameters of the acoustic comfort is based on both subjective criteria like: noise sensitivity [1,2], noise annoyance reactions [3], but also objective criteria like the standardized sound pressure, intensity or power levels [4].

In Romania many old buildings that use a gas boiler for the heating do not fulfill the acoustic comfort criteria because either the system is not functioning at the normal parameters or the new Romanian acoustical criteria are stricter than the ones from the year when the boiler was initially installed.

The Romanian Ministry of Regional Development and Tourism defines the technical expertise [5] as the investigation that aims to analyze the behavior of a specific installation system and eventually to point out the reasons for the malfunctioning. This research represents an acoustic expertise for a high thermal capacity gas burner aiming to understand the noise variation in accordance to the burner behavior.

This article tackles the analysis of noise variation for the entire sound spectrum during the full running cycle of a boiler. The research study presented in this paper provides interesting parts on the boiler function state and its application in field of acoustic expertise. In particular, the boilers with higher thermal power compared to smaller ones, generate the highest sound emissions and that can create an acoustic discomfort for the occupants. The burner is a major source of sound and it is caused by the combustion noise and ventilation. This noise is produced in the boiler room, but also in the gas evacuation system. Boilers with are not correctly designed in terms of flow rate and heating system are an important source of noise in the buildings.

The sound pressure level generated by a burner depends mainly on its type: atmospheric burners or air injected burners. The atmospheric burners have no control of the air flow needed in the burning process and the SPL depends on different parameters of the

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burner. The size of the burner nozzle proved to have a significant influence on the sound pressure level as an increase from 10 mm to 18 mm led to a 10 dB variation of sound pressure level [6]. In another study it was found that the shape of the nozzle (rectangular or circular) had a smaller influence, around 5 dB. Further on, the thermal power of the burner may explain another 15 dB variation [7]. Other parameters that may influence the noise of a gas burner are the temperature and the pressure of the gas [8], the turbulent flow [9] and combustion driven oscillation [10]. Various methods are known to decrease the combustion noise: the reduction of combustion intensity or the use of acoustic resonators [11]. These atmospheric burners present relatively acceptable noise levels but they have the inconvenience of small thermal efficiency. The air injected burners have a controlled air flow for the burning process by means of a fan and consequently the burner efficiency is much higher, over 90%. However, the sound level produced is about 12 dB(A) higher due to the other moving parts [12] and it may become completely unacceptable in domestic or educational environment [13].

There are some well-known issues about the noise propagation of noise from boiler rooms to indoor space. For high capacity boilers these problems may be even more difficult to control, so an accurate knowledge of each source of noise inside a boiler is necessary. The acoustic annoyance [14,15] on humans is very important in some cases and measures to avoid these situations are mandatory.

Usually the research or technical expertise studies are well focused on the noise generated by the burner during its maximum thermal load [16,17]. However, the air injected burners present a complex running cycle with different functioning periods, according to the control process designed by the HVAC engineer in order to maintain the indoor thermal comfort.

The inherent source of noise in boilers rooms designed at present is the combustion process inside the boiler. In most of the cases, the flame noise is the most difficult problem. Despite that, we have to make a difference between the noise produced by the fan supplying air into the combustion chamber and the one produced by the combustion inside the boiler.

The indoor thermal comfort is achieved by means of controlling the hot water flow and its temperature. This control may lead to many small running cycles of a burner during 1 day. The other functioning states, besides the maximum thermal load, must not be systematically ignored, as one might find that the maximum noise can be generated in one of the other functioning steps of the running cycle and the time weight might be considerable. Very few studies analyzed the time variation of the sound pressure level during running states, and most of them were focused on the analysis of wall mounted heating boilers [18,19]. The new indoor environmental quality standards [20] give a considerable weight to the acoustic comfort criteria. Thus, a complex analysis should be performed for the entire running cycle of a burner. The originality of this article is due to a detailed analysis on the acoustic behavior of a high thermal capacity gas burner during the entire running cycle in accordance with the different functioning states.

2. Experimental campaign

2.1. System description

The experimental work was carried out on an existing thermal station so the analysis would be relevant to a real acoustic expertise study. It was chosen the boiler room of the Faculty of Building Services and Equipment of the Technical University of Civil Engineering of Bucharest which is placed at the semi-basement of the building and with an air inlet above ground. This boiler room has the following dimensions: length 9.4 m, width 7 m and height 3.5 m, and the walls are covered with cement–sand plaster (see Fig. 1). Inside the boiler rooms there are two gas boilers of 770 kW thermal power each which are used for the heating of the entire building while the warm sanitary water is prepared with other two gas boilers. The two heating boilers are equipped with gas burners with two-stage operation (S_1 – burner stage 1, S_2 – burner stage 2), with aluminum frame, high power engine for higher combustion efficiency and flame stability. The hot water is circulated between the boilers and the hydraulic separation cylinder by means of individual water pumps installed on each boiler circuit (pump 1 in Fig. 1). Further, the hot water passes through the distribution system and is pumped towards five different branches of the heating installations.

The hot water recirculation pipe of the boiler (from the hot water output to the hot water input), has a small recirculation pump placed on the backside of the boiler that generates a low noise level (pump 2 in Fig. 1). The boilers are secured to high pressure by means of expansion vessels and safety valves. During the experimental tests only the first boiler was analyzed, the second one being a spare boiler in case of a malfunction of the first one.

The adjacent spaces of the analyzed thermal station are: on the left – the corridor of the semi-basement, on the right the underground sanitary cold water pumping station and two more storage rooms.

2.2. Measurements

During in situ experiments the background noise might disturb the sound pressure level measurements, thus one should assure a low background noise during the experimental sequence [21,22]. To carry out the experimentation several measures were adopted:

- The hot water circulation was restricted. This measure ensured that the five circulation pumps from the distribution system were shut off as well as the boiler circulation pump 1. The only pump remaining running was the pump 2, which is a small pump, placed behind the boiler.
- Other equipment (e.g. cold water pumping station) in the thermal station that might disturb our measurements was shut off.
- The thermal station door was insulated so that the indoor corridor noise would not perturb the experimental campaign.
- The automatic light switches were shut off.
- The time chosen for the measurements was 06:00 am, when the road traffic is low and consequently the street noise is consistently low. No noise attenuator was needed for the thermal station air inlet.

The sound pressure level was recorded by means of sound meter "2250 Investigator" from Bruel and Kjaer, which is a class 1 precision device. This study focuses on the acoustical behavior of burner 1 during the entire running cycle. The measurements were performed at 1 m distance from burner 1 by placing the sound meter on the same horizontal plane of the burner (around 1 m height from the floor). The signals data were collected on a computer storage card and analyzed using a specialized data analysis software.

The "logging enhanced" software [31] was used in order to record the time variation of sound pressure level for different frequencies. Usually, for practical building studies it is used the frequency spectrum 125–4000 Hz, but we have considered it inadequate for this acoustic analysis of the burner. The low frequencies proved to be very important for understanding the noise annoyance rating [23–25] and the effects of sound insulation on the acoustic comfort [26–28] and therefore the studied spectrum includes also these frequencies. Moreover, the influence of various components of the burner on sound pressure level will behave