EXPERIMENTAL INVESTIGATION ON THE SOUND PRESSURE LEVEL FOR DIFFERENT ACOUSTIC TREATMENT OF BOILER ROOMS

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Abstract. Noise pollution is the cause of many health problems, and the inhabitants of the neighborhoods from crowded cities exposed to high noise is growing in Europe. Noise from thermal power plants represents the main factor of the acoustic discomfort in the residential buildings for the occupants, but also for the people who operate the equipment. The goal of this article is the experimental analysis of the efficiency of acoustic treatment solutions and their effect in reducing the noise level inside thermal power plants. Although the thermal performance and efficiency of the equipment in a boiler room have increased, the noise level produced by thermal power plants has not decreased considerably. Current measurements of the sound level in boiler plants have shown an increase in the noise level due to the fact that modern burners are noisier than old atmospheric burners, the quality of materials of the burner-boiler fixing system is poor and the volume of the boiler space becomes getting smaller. Covering the burner with a housing can reduce the noise at the source because it absorbs the noise at high frequencies. Instead, this measure is less effective in terms of low frequencies which are also the best transmitted by the structure of the building to the apartments. Regarding the chimney, the noise inside it comes from the combustion process and can be a problem in new buildings for which sound insulation or outdoor installation can be recommended. Another solution to reduce the noise level is to remove the noise source. The boiler rooms must be placed from the design stage as far as possible from the apartments, in another building, in the basement of the building or at least there should be a buffer space between the living rooms and bedrooms represented by common spaces, halls, closets, storage spaces, sheds. The results obtained by the experimental comparisons proved to be satisfactory. This article is expected to assist design engineers in improving compliance with legislation, analysis, and optimization of boiler rooms.

Keywords: Noise pollution, thermal power plant, acoustic treatment, sound level, experimental comparison
1. Introduction

The acoustic behavior of boilers is of major importance in the current context of the development of gas-based domestic heating installations.

On the one hand, modern boilers are equipped with high-performance burners that produce a high level of noise, on the other hand legal and regulatory regulations on noise emissions they become stricter [1]. In the context of these three issues, the topics are of interest: The first is the analysis of the noise from different types of boilers. The difference in noise produced by a modern boiler compared to the old generation boilers with blown air will be investigated [2]. The second subject is the difference in noise produced by the same boiler for different thermal loads [3]. The third topic is the study on the efficiency of noise reduction solutions and the comparison of these methods to reduce it.

Regarding the boilers, there are a lot of parameters that can be potentially influential in amplifying the noise emission [4,5,6,7]. Another purpose of this article is to determine which of these parameters actually have a negligible influence on noise emissions.

2. Analysis of noise protection solutions in boiler rooms

2.1 Scientific goals

Although the thermal performance and efficiency of the equipment in a boiler room have increased, however, noise from thermal power plants did not decrease considerably [13]. Current measurements of sound levels in boiler rooms show a dispersion of these values, dispersion due to:

- the fact that modern burners are noisier than atmospheric burner.
- the quality of the materials, i.e. the burner-boiler torque.
- the most important noise is combustion noise.
- the volume of the boiler room.

To reduce the noise from the source it is necessary to:

- choose the least noisy equipment possible at the same thermal power.
- have a space for the boiler room as large as possible.

This is a useful paper suggesting practical ways to improve well-being of people leaving near noisy thermal plants. This study can be made accessible to engineers and designers so that they can choose the best acoustic treatment solution for the boiler room in their project.

2.2 Measuring techniques

For each experiment, significant efforts were made. The experiments were made applying different class 2-methods for the measurement of the sound power level of the boilers, as there are the measurement in a reverberant room according to ISO 3743, parts...
1 and 2 [8,9], and the intensity method described in ISO 9614-1 [10], there were performed at night, during the week and in different cities (Brasov, Ploiesti, Bucharest). Also, approvals were required from the management of the institutions where the measurements were performed.

The measurements were performed by a team of at least three or four people: one person records the gas consumption, another person operates the boiler automation, and the third person performs the noise measurements. Fochists participated in the experiments, automatists, students, teachers, and others to whom I am grateful for their help and effort.

The experiment consisted in the experimental measurement of the noise level in the boiler room using a portable sound meter type 2250 with frequency of 4-22 kHz, software Pulse Lab shop ver 5.1.0 for automatic processing of experimental data, balloons for measuring reverberation time and laser rangefinder for architectural measurements.

For each experiment, the following steps were performed:
- photographs from different angles to analyze architecture
- find acoustic discomfort from external sources (street type, etc.)
- identify the type of absorbent material (type of wall, floor, ceiling)
- identification of boiler type (maximum boiler load, burner type
- gas meter
- identification of natural gas parameters (pressure, temperature)

Fig. 1 – Notations during the experiment.
• Analyzing the possibility of measuring gas flow.
• Identification of other noise generating equipment (pumps, heat exchangers, heat, chimneys, etc.);
• Identification of acoustic treatment solutions (noise attenuator, solid doors, insulated chimney, boiler detachment, etc.)
• Architectural measurements (room dimensions);
• B & K Type 2250 Portable Acoustic Analyzer (tripod mounting, mounting function, calibration, setting working parameters)
• Using the software Pulse Labshop ver 15.1.0, 25, measurements of noise was performed for 10 seconds at a total of 250 acoustics pressure levels.
• Using Pulse Labshop ver 15.1.0 software, time measurements and reverberation time were measured

Acoustic measurements were downloaded using the BZ5503 software on a workstation with Windows operating system, imported into Excel and added to the experimental database.

![Fig. 2 − Download measured data using BZ-5503 software from Brul & Kjaer](image)

After the experiment, the following database input values were obtained:
• input data: $P_{\text{burner}}$, log$(P_{\text{burner}})$, $L_w$, $V$, $\alpha_{125Hz}$, $\alpha_{250Hz}$, $\alpha_{500Hz}$, $\alpha_{1000Hz}$, $\alpha_{2000Hz}$, $\alpha_{4000Hz}$, $\alpha_{8000Hz}$,
• output data: $L_{Aeq}$, $L_p$ 63-8000 Hz, T20, T30, EDT.
The thermal power of the boiler is measured at the gas meter, so the thermal power at the connection level, not the useful thermal power (what comes out of the boiler). This thermal power depends on the normal state of the gas (normal pressure and normal temperature), the lower calorific value.

Through several mathematical processing, the following equation for calculating the thermal load produced by the burner was obtained:

\[
P_{\text{burner}} = \frac{(I_{1\text{min}} - I_{0\text{min}}) p_g + p_{\text{atm}}}{60} \cdot 273.15 \cdot \frac{273.15 + t_h}{35372}
\]

where: \(P_{\text{burner}}\) is the real thermal load for a duration of 60s [kW]; \(I_{1\text{min}}\), is the reading after 60 seconds of the gas index to the meter [m³]; \(I_{0\text{min}}\) is the initial index read from the gas meter [m³]; \(p_g\) is the methane gas pressure [bar]; \(p_{\text{atm}}\) is atmospheric pressure [bar]; \(t_g\) is methane gas temperature [°C];

2.3 Experimental setup

The actual work package dealing with the investigations on boilers began in autumn 2017. Twenty-nine different boilers were chosen for these testing to cover the most common products that are in use all over Romania. For each thermal power plant, a few 5-12 operating situations was simulated, so that the current database contains 162 real operating situations.

The list of inspected thermal power plants consists of technical spaces located in different cities (Ploiesti, Brasov, Bucharest), and includes from small power plants (wall power plant 40kW) to very high thermal load power plants (3500kW).

To avoid disturbing the experiments due to external noises, all the experiments took place, only at night, between 22:00 and 04:00. The experiments took place over three seasons and in different cities. The first experimental campaign was in the fall of 2017, in UTCB thermal power plants, the second in the spring of 2018, in Ploiesti and Brasov, the third in the summer of 2018 in Bucharest on RADET power plants, and the last one in winter 2019 on RADET power plants, in order to include a boiler operation in higher thermal loads.

2.4 First results

In the following we will graphically represent the limit of the database obtained from the experiments, and then to correctly interpret the physical phenomena that occur inside the thermal power plants during the experiments, we will represent the distributions of the database using MATLAB software and will create thermal power plant classes, which will be explained and represented graphically for a better understanding.
Thermal power plants from different cities with different thermal loads and architectures were selected in order to observe the influence that the thermal load has on the noise level, but also the comparison with the values imposed by the norms in force.

It can be seen from the graph above that the noise level for the situation in which no equipment works (yellow) is below 40dB at each frequency. When starting the pumps (blue, green and brown), the noise level increases up to 57dB at the frequency of
1000Hz.
After starting the burners, the noise level increases above 75dB at 1000Hz and depends to the thermal load. For frequencies between 500 and 4000Hz it exceeds the standard value in more than half of the operation scenarios.

As the first preliminary conclusion it is observed that at very low and very high frequencies, the noise level falls within the prescription imposed by the norm, the noise level exceeds the value from norm between 500 and 3000Hz.

Like the above comparison, an analysis of the equivalent noise level measured for each operating situation was followed, the one indicated in the regulations and the one given in the technical data sheets of the burner manufacturer.

The bar graph for CT Bucov shows an exceeding of the noise level for all burner operating situations, with one exception at 902kW. The burner prospects indicates a value, above the norms, but close to the actual measured value.

2.5 Outlook

These graphs also highlight the conclusions reached by Hamayon[11,12] as the main noise generating equipment in a technical space such as a boiler room is the burner (noise produced during combustion)[1].
Another important conclusion is that thermal load depends to the noise level, and for high thermal loads it is necessary to obtain a lower value of the noise level to comply with regulations.

### 3. Noise analysis of acoustic treatment

Boilers equipped with atmospheric air burners are rarely used in new buildings due to their very low efficiency. Modern boilers are equipped with blowers with blown air to ensure the best possible efficiency of the transformation from methane gas to thermal energy.

There is a major difference, up to 23dB, between noise from a modern blower with blown air and that produced by the classic burners with natural draft. This difference is given by noise from the flue gas fan provided in the construction of modern burners.

![Comparison between noise from blower with blown air / atmospheric Dorobanti (blown air) - CT Barbu Vacarescu 167kW (natural draft)](image)

Fig. 6 – Comparison between noise from blower with blown air / atmospheric Dorobanti (blown air) - CT Barbu Vacarescu 167kW (natural draft)
Several comparisons were made between the two different construction types for an operation at the same thermal load and the following table was obtained:

### Table 1

**Comparisons between boiler burner at same thermal load for different construction type**

| Nr.crt | Plant1       | Plant2        | $P_{burner}$ [kW] | $L_{AeqAI}$ [dBA] | $L_{AeqAA}$ [dBA] | $\Delta L_{Aeq}$ [dBA] |
|--------|--------------|---------------|-------------------|-------------------|-------------------|------------------------|
| 1      | AI DOROBANTI | AA BARBU VACARESCU | 167               | 86.1              | 66.05             | 20.05                  |
| 2      | AI DOROBANTI | AA FLOREASCA  | 71                | 82.45             | 57.48             | 24.97                  |
| 3      | AI TURTURELE | AA FLOREASCA  | 294               | 79.93             | 75.83             | 4.1                    |
| 4      | AI MOZART    | AA FLOREASCA  | 637               | 76.81             | 76.8              | 0.01                   |
| 5      | AI DOROBANTI | CM STOIAN     | 180               | 83.62             | 49.61             | 34.01                  |

\[ \mu \Delta L_{AeqAA - AI} [\text{dBA}] = 12.28 \]

\[ \mu \Delta L_{AeqAA - CM} [\text{dBA}] = 34.01 \]

Boilers with modern burners (AI) produce up to 12dBA more noise than boiler with atmospheric burners (AA), but are preferable in modern boilers due to much higher efficiency. There is a difference of up to 34dB in addition for the boiler compared to the wall boiler (CM). It is thus highlighted the possibility of reducing noise in technical spaces by using a wall boiler, when it is not necessary to provide high thermal loads.

![Graph of the weighted global equivalent noise level, depending on the thermal load for modern boiler with case (AI CC) and modern boiler without case (AI FC)](image)

Fig. 7 – Graph of the weighted global equivalent noise level, depending on the thermal load for modern boiler with case (AI CC) and modern boiler without case (AI FC)

Covering the burner with a housing can reduce the noise at the source because it absorbs the noise at high frequencies. Instead, this measure is less effective in terms of low frequencies which are also the best transmitted by the structure of the building to the
apartments. The housing can attenuate noises at low frequencies only if its walls are heavy, which has the disadvantage of making it difficult to move, so difficult to maintain the burner.

The graph above shows that the noise level for burners without housing is higher than for those provided with housing. There is a higher dispersion of the points corresponding to the measurements of the modern burners with blown air with case - AAI CC.

Since the predominant source of noise is the burner, those without the housing are less sensitive to other noise sources, for example pumps, the blue dot cloud is more grouped than those with the housing.

In the following, one of the analyzed solutions will be presented to highlight the effect of the sound-absorbing casing, thus comparing the noise level with / without the sound-absorbing casing for CT Republicii with a real thermal load of 204Kw.

Fig. 8 – Noise level with / without sound-absorbing housing for Republic Republic CT 204kW
A noise level reduction of 14dB is observed for frequencies higher than 500Hz. This acoustic treatment solution is feasible, but attention must be paid to how the housing is sealed to the boiler.

For all sound-absorbing housings, a reduction in noise level of up to 20dB was observed. This reduction had different values because the equipment was operated at different thermal loads, and for the same thermal load the sealing mode of the housings was different (some plants had a very well-sealed housing, others did not have it sealed).

Table 2

Comparisons between boiler equipped with blown air burner, of the same thermal load with and without CASE

| Nr.cr | Plant                | Phunter [kW] | LAeqAI FC [dBA] | LAeqAI CC [dBA] | Δ LAeq [dBA] |
|-------|----------------------|--------------|-----------------|-----------------|-------------|
| 1     | AI - REPUBLICII      | 276          | 78.59           | 64.92           | 13.67       |
| 2     | AI - MOZART          | 609          | 82.02           | 76.81           | 5.21        |
| 3     | AI - TURTURELE       | 290          | 79.93           | 61.97           | 17.96       |
| 4     | AI – DIMITROV A1     | 399          | 80.24           | 76.82           | 3.42        |
| 5     | AI – EROILOR 1       | 216          | 76.18           | 63.67           | 12.51       |

μ Δ LAeq[dBA] 10.55

Another acoustic treatment solution identified in 4 measuring points, made in two thermal power plants is represented by acoustic treated walls from an acoustic point of view with sound-absorbing material.

Fig. 9 – Graphical representation of the weighted global equivalent noise level, depending on the thermal load for boiler room with treated and untreated walls
It seems that the trend of these points is above the general trend of the point cloud - for air blowers without AI FC case, but not with a significant influence. Given the insufficient number of measurements, no exact conclusion can be drawn regarding the influence of this parameter on the model.

It seems that the trend of these points is above the general trend of the point cloud - for air blowers without AI FC housing, but not with a significant influence. Given the insufficient number of measurements, no exact conclusion can be drawn regarding the influence of this parameter on the model.

Another acoustic treatment to noisy boiler rooms is the detachment. The high-power boilers required to heat a collective building are large generators of vibration and noise. They must be mounted on their own foundation, a solid concrete, different from the boiler foundation and placed on the support in order to limit the propagation of the vibration of the boiler and its foundation to the rest of the building structure. These supports can be made based on rubber, elastomers, metal springs, etc. Anti-vibration supports must be framed in an equal manner, which ensures that the boiler vibrates properly. The boiler mounted on the anti-vibration supports must not be rigidly connected to the pipes by means of the drums.

![Graphical representation of the weighted global equivalent noise level, depending on the thermal load for boiler with/without detachment](image)

**Fig. 10** – Graphical representation of the weighted global equivalent noise level, depending on the thermal load for boiler with/without detachment

The measuring points for blown air burners without housing and without detachment - AAI FC FD are in the norore stage of the points of blown air burners without housing with detachment - AAI FC CD.
The graph above shows that solid decoupling solutions do not provide significant prediction information of LAeq [dBA].

After removing the outliers, the cloud of points shows or reduced variation.

Another detachment solution for thermal power plants is the boiler foundation. Normally this element must be separated from the concrete slab of the building by a rubber buffer. Detachment through the foundation is used to limit the vibrations transmitted after combustion to the boiler and then to the structure of the building.

![Graphical representation of the weighted global equivalent noise level, depending on the thermal load for boiler with/without boiler foundation](image)

It seems that this solution reduces the noise level inside boiler room, so for equal thermal loads, higher noise levels were recorded for measuring points in other thermal power plants. Due to the lack of a larger number of points (minimum 10 measuring points) it is not possible to conclude on the benefits brought by such a positioning of the pumps inside the thermal power plants.

There are other acoustic treatment solutions, less effective for reducing the weighted equivalent global noise level, but useful in reducing the noise level for certain frequencies, for example flexible connection for the burner gas supply pipe (low frequencies) or moving the pumps in rooms adjacent to the space of the thermal power plant (high frequencies).
4. Conclusions

After achieving the experiments, it was found that that the equipment that produces a high noise level in a thermal plant is fan of the modern burners, and not pumps or other components of the heating system.

From the analysis made in comparison with the datasheet, there were revealed overtaking of the values given by the producer of the burner, which indicate differences due to faulty equipment settings. Also, in this study were highlighted that the measurements of the noise levels exceeding the maximum value indicated in the norm [1].

According to the results of theoretical studies [5,6], a boiler case near the burner can be used. In addition to this recommendation, other studies have been conducted in this article on the influence of acoustic treatments on noise reduction.

We also demonstrate that it is possible to decrease noise from boiler plant by using other acoustic treatment solutions when it is not possible to mount a burner housing, but in this case the results will be less effective.

The purpose of this paper was to carry out such measurements in different boiler plants to choose the optimal solution for the acoustic treatment of the boiler room. Engineers involved in the design and construction of the installations can use this information for noise reduction when the designed solution or the existing boiler room exceeds the values of acoustic comfort parameters from local regulations.

This study can be made accessible to the wider community, not just scientific community, because it is of pressing importance with the political push to leave a better planet for the future generation.

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