

Control of Noise from a Fan in a Wall Gas Boiler

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Methods for reducing noise emissions from a fan in a wall gas boiler are investigated. Sound power and vibration measurements are conducted in order to identify the effect of noise reduction treatments. Numerical simulations and measurements of volume flow and temperature, before and after the installation of noise treatments, were conducted. A 3.5 dB reduction in the acoustic power and a 5.0 dB reduction in the vibration levels are achieved. The performance of the boiler was not affected by the noise control treatments. © Institute of Noise Control Engineering

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LIST OF SYMBOLS

ΔP	Boiler inlet-outlet pressure difference (mmH ₂ O)
ΔLa_f	Difference between MNCF acceleration levels before and after noise reduction (dB)
ΔLa_T	Difference between global acceleration levels before and after noise reduction (dB)
ΔLw_A	Difference between A-weighted sound power levels before and after noise reduction (dB)
ΔLw_f	Difference between MNCF power levels before and after noise reduction (dB)
f_f	main noise component due to the boiler exhaust fan (Hz)
La_f	MNCF acceleration level (dB)
La_T	Global acceleration level (dB)
Lw_A	A-weighted sound power level (dB)
Lw_f	MNCF power level (dB)
MNCF	Main Noise Component Frequency (acronym)
n	number of fan blades (non-dimensional)
rpm	fan blade passage frequency (revolutions per minutes)

1 INTRODUCTION

Wall gas boilers permit a single flat heating system to be independent from the other flat heating systems in a building. Wall gas boilers are usually characterized by high heating capacities and improved safety conditions. This kind of boiler is widely used in the heating systems of private homes. Wall gas boilers are often installed indoors. For these reason, wall gas boiler noise emissions may cause annoyance, especially during the night, when human sensitivity to noise is high¹. The

main elements of wall gas boilers which may cause noise are a circulating pump, the burner, the combustion chamber, a heat exchanger and the exhaust gas fan. Generally, the boiler main noise sources are the circulating pump and the exhaust fan.

Noise emissions reduction treatments applied to a custom wall gas boiler are discussed. The investigated boiler is the model "EOLO 27 Maior @", fabricated by Immergas, an Italian manufacturer. The research has been carried out by the Perugia University Acoustic Laboratory with funding provided by Immergas.

Sound power and vibration measurements were conducted in order to separate sources of wall gas boiler noise emissions. Measurements results show that the boiler fan is the main noise source. Thus, vibration and acoustic insulation noise treatments were proposed and installed in the pre-combustion chamber and exhaust fan surrounding area. Numerical simulations by means of a finite-volume computational fluid dynamics code (Fluent) and measurements show that the proposed noise reduction solutions do not affect the boiler performance.

Sound power and vibration measurements were conducted after the installation of the noise reduction treatments. Measurement results show a 3.5dB A-weighted power level reduction and a 5.0 dB vibration level reduction with the preferred noise treatments.

2 WALL GAS BOILER NOISE CHARACTERIZATION

Sound power measurements were used to separate sources of the noise emitted by the wall gas boiler. Measurement room characteristics are:

- approximately 65 metric Sabines of absorption;
- dimensions equal to 4.5m X 4.5m X 3m.

The wall to which the boiler was installed has an NRC absorption coefficient of approximately 0.7^{2,3}. Measurements were conducted for three boiler working conditions:

- only boiler pump is on;
- only boiler fan is on;
- all noise sources are on (i.e. the entire wall gas boiler is on).

For condition A), measurements were made at 12 locations,

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placed on a fictitious parallelepiped surface which surrounds the noise source⁴. Surface dimensions are $x=1.2\text{m}$, $y=1.2\text{m}$, $z=0.6\text{m}$ (x - y plane is the wall on which the boiler was installed). For conditions B) and C), measurements were made at 20 locations, placed on a fictitious parallelepiped surface which surrounds the noise source. Surface dimensions are $x=1.8\text{m}$, $y=1.8\text{m}$, $z=1.8\text{m}$. Measurement locations were chosen according to ISO 9614-1/93⁴. Measured sound intensity levels were processed by the data acquisition system in order to calculate one-third octave band sound power. Figure 1 shows the one-third octave band sound power levels for conditions A), B) and C). Measured sound power levels show that:

- for A) condition, main noise component frequency (MNCF) is 125 Hz;
- for B) condition, MNCF is 200 Hz;
- for C) condition, MNCF is 200 Hz.

The A-weighted sound power level produced by the "EOLO 27 Maior @" wall gas boiler is:

- 39.5 dB for A) condition;
- 55.0 dB for B) condition;
- 55.0 dB for C) condition.

Measurements results show that noise power spectra for B) and C) conditions are characterized by the same behavior and the same MNCF (200 Hz). Main noise component due to the fan may be estimated by the following relation⁵:

$$f_f = (n \cdot \text{rpm}) / 60 = 200 \text{ Hz} \quad (1)$$

where n is the number of fan blades ($n=24$) and rpm is the fan speed ($\text{rpm}=500$). Therefore, the exhaust gas fan in the boiler is the main noise source under nominal working conditions. A significant contributor to the global boiler noise may be due to structure-borne noise. Thus, vibration measurements were conducted in order to relate acceleration levels to the previously measured power levels. Measurements were conducted for C) condition (all noise sources are on). Ten measurements locations were chosen on the boiler external panels. Vibration levels have been measured in the 12.5-8000 Hz frequency range. The averages of the one-third octave band acceleration levels are reported in Fig. 2 (indicated as

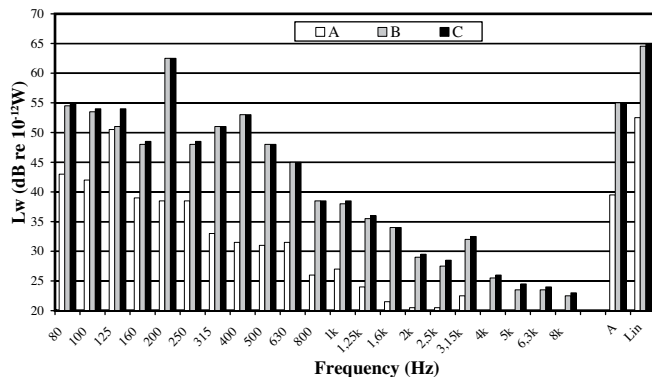


Fig. 1. Comparison among measured sound power levels for conditions A), B) and C) (untreated boiler).

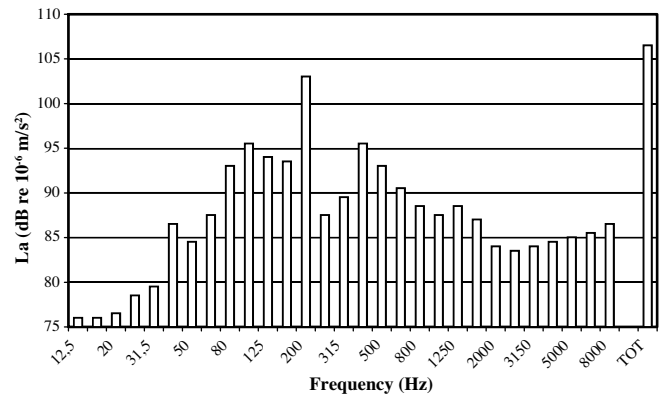


Fig. 2. Measured average acceleration levels before the noise treatments (C) boiler working condition)

BEFORE condition). Measurements results show that the highest vibration level occurs at 200 Hz, the same frequency at which the sound power level was highest. Therefore, the boiler vibration appears to be mainly due to the exhaust fan. Figure 3 shows the location of the fan in the investigated wall gas boiler.

3 NOISE REDUCTION METHODS

Boiler fan sound power level characteristics are:

- A-weighted sound power levels higher than 30 dB for 80-1600 Hz frequency range;

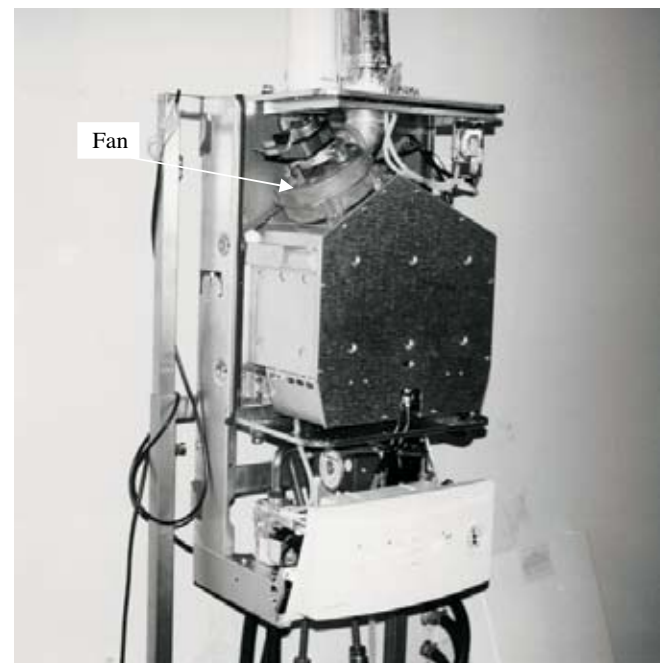


Fig. 3. Picture of the wall gas boiler before the noise treatments showing the location of the fan

- a tonal component whose frequency value (200 Hz) is proportional to the fan blade passage frequency.

Two kinds of noise reduction treatments were installed:

1) Airborne noise reduction. Two different treatments were proposed and compared:

1.a) 20mm thick noise insulation panels have been installed on the boiler internal walls and the combustion chamber external walls (see Fig. 4). The panels consisted of two polyurethane layers (35 Kg/m³ density, 0.018 W/m K thermal conductivity, 1400 J/Kg K specific heat at constant pressure) separated by a 1mm thick lead layer (11300 Kg/m³ density, 35.3 W/m K thermal conductivity, 130 J/Kg K specific heat at constant pressure). Material performances are guaranteed by the manufacturer for working temperatures less than 120°C⁶. This condition always occurs for the boiler nominal working conditions.

1.b) 40mm thick glass-wool insulation panels (22 Kg/m³ density, 0.034 W/m K thermal conductivity, 850 J/Kg K specific heat at constant pressure) were installed on the boiler internal walls and the combustion chamber external walls (see Fig. 5). Panels have been compressed in order to reduce their volume. Material performances are guaranteed by the manufacturer for boiler nominal working conditions⁷.

2) Vibration reduction: the exhaust fan was insulated from other boiler elements by means of a 3mm thick polyurethane gasket. The gasket has been placed on the contact surface between the fan and the combustion chamber (see Fig. 6). A polyurethane gasket was also installed where the boiler fan is connected to the exhaust duct. Combustion chamber

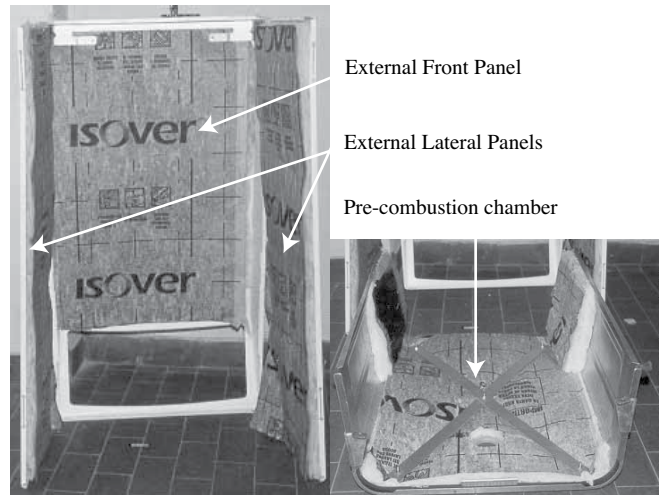


Fig. 5. Installation of glass-wool noise insulation panels

panels were insulated by means of 1mm thick Flexoid gaskets. Two 2mm thick steel stirrups were installed over the pre-combustion chamber internal walls in order to make them more rigid.

Afterwards, sound power levels and boiler performances were evaluated in the following conditions:

- before the noise treatments were installed (BEFORE condition);
- after 1.a) and 2) noise treatments were installed (AFTER I condition);
- after 1.b) and 2) noise treatments were installed (AFTER II condition);

4 NOISE REDUCTION METHODS COMPATIBILITY WITH BOILER PERFORMANCE

The proposed noise reduction methods (additional gaskets and noise insulation panels) may decrease the boiler aspiration

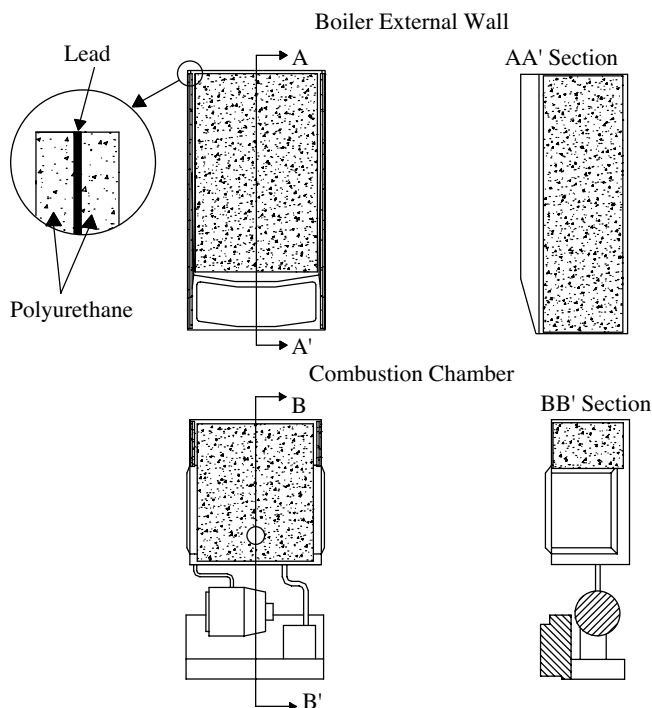


Fig. 4. Installation scheme of sound insulation multilayer panels

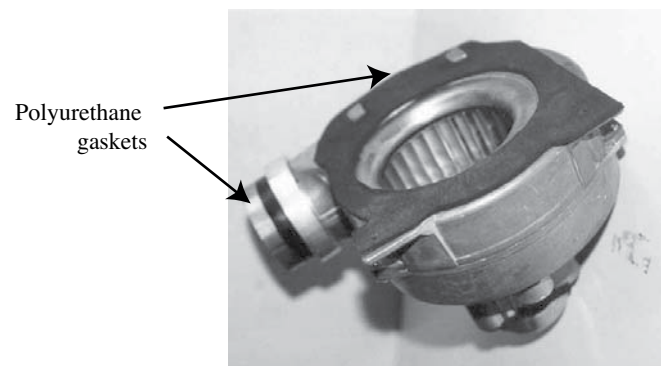


Fig. 6. Vibration treatments by means of polyurethane gaskets

air flow rate. This fact may reduce the boiler performance: the exhaust gas flow rate may decrease and the internal temperature may increase. Measurements of the gas flow rate and temperature were conducted in order to evaluate the boiler performance with and without noise treatments. In particular, the characteristics of the system consisting of aspiration circuit, combustion chamber and exhaust gas duct were determined by varying the pressure difference (ΔP) between boiler inlet and outlet. An air flow was induced by an industrial fan placed at the system inlet. The industrial fan blade passage frequency was varied in order to control ΔP by a differential manometer. Air flow rate was measured by an anemometer installed into the system.

Thus, the system characteristic curve (ΔP vs. flow rate) has been evaluated (see Fig. 7, BEFORE condition). In addition, the air temperature was measured at boiler inlet by means of a sensor placed at the aspiration duct outlet and the exhaust gas temperature was measured at boiler outlet by means of a sensor placed at the exhaust duct inlet. The boiler fan working point was obtained as the intersection between the system characteristic curve (ΔP -flow rate) and the fan characteristic curve⁸ (see Fig. 7). Air and exhaust gases flow rates are equal to 115.5m³/h; this value corresponds to an air aspiration velocity equal to 4.7 m/s (aspiration duct diameter = 0.093 m) and an exhaust gases velocity equal to 5.2 m/s. Inlet temperature is the environmental temperature; exhaust gases temperature is about 125°C.

Boiler performance was also studied by means of a finite-volume computational fluid dynamics code⁹. In the numerical simulations the boiler internal volume was divided into about 500,000 tetrahedral elements. Boiler internal pressure, velocity and temperature were simulated in BEFORE, AFTER I and AFTER II conditions.

Simulations were carried out by applying the following boundary conditions:

- boiler inlet pressure equal to the boiler outlet pressure (equal to 101,325 Pa);
- pressure difference between exhaust fan inlet and outlet equal to the pressure difference determined during the performance measurements;

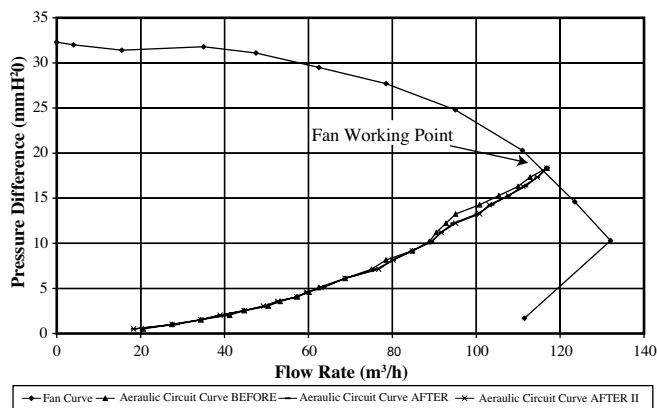


Fig. 7. Boiler fan operating point after the installation of the proposed treatments.

- the boiler inlet and outlet temperatures equal to the measured temperatures (respectively 27°C and 125°C);
- 31.5kW heat flux generated by the boiler burner (this assumption is determined by the burner characteristics given by the manufacturer);
- 28.5kW heat flux absorbed by the boiler heat exchanger, at the combustion chamber upper side (also this assumption is obtained by the heat exchanger characteristics given by the manufacturer).

Simulation results have shown no significant changes in the boiler performance properties due to the installation of noise treatments (both AFTER I and AFTER II). Therefore, boiler performances are not affected by the proposed noise treatments. Thus, the proposed noise treatments were installed in the boiler and performance measurements were conducted for AFTER I and AFTER II conditions. Fig. 7 shows the comparison among the boiler system characteristics curves relative to BEFORE, AFTER I and AFTER II conditions. The fan flow performance curve is also presented. These curves show a negligible displacement in the operating point after the installation of the noise treatments. The fan operating point is not modified: thus, exhaust gases flow rate is 115.5m³/h for BEFORE, AFTER I and AFTER II conditions. Also aspirated air and exhaust gases temperatures are not modified by the proposed noise treatments.

5 EFFECTIVENESS OF THE NOISE TREATMENTS

The sound power measurements were repeated after the installation of the noise treatments. The measurements were conducted in according with ISO 9614-1/93⁴. Figures 8 and 9 show the comparison between the measured power level spectra for condition C) relative to:

- BEFORE and AFTER I conditions (Fig. 8);
- BEFORE and AFTER II conditions (Fig. 9).

Reduction in the A-weighted power level (L_{wA}) are reported in Table 1. Reduction in the A-weighted power level relative to the MNCF (125Hz for A) condition, 200Hz for B) and C) conditions) are reported in Table 2.

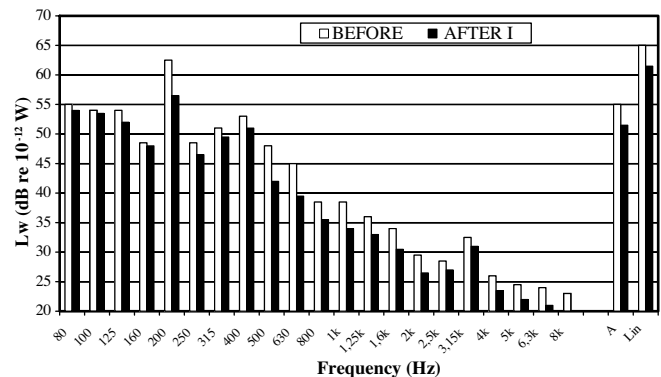


Fig. 8. Comparison between power levels relative to BEFORE and AFTER I conditions (C) boiler working condition)

Table 1 - Measured power levels relative to BEFORE, AFTER I and AFTER II conditions and obtained power level reductions by means of the proposed noise treatments.

Measurement Condition	L_{w_A} (dB) BEFORE	L_{w_A} (dB) AFTER I	L_{w_A} (dB) AFTER II	ΔL_{w_A} (dB) AFTER I	ΔL_{w_A} (dB) AFTER II
A	39.5	37.0	38.0	2.5	1.5
B	55.0	51.5	52.5	3.5	2.5
C	55.0	51.5	52.5	3.5	2.5

Table 2 - Measured MNCF levels relative to BEFORE, AFTER I and AFTER II conditions and obtained MNCF level reductions by means of the proposed noise treatments.

Measurement Condition	L_{w_f} (dB) BEFORE	L_{w_f} (dB) AFTER I	L_{w_f} (dB) AFTER II	ΔL_{w_f} (dB) AFTER I	ΔL_{w_f} (dB) AFTER II
A	50.5	46.0	47.5	4.5	3.0
B	62.5	56.5	58.5	6.0	4.0
C	62.5	56.5	58.5	6.0	4.0

Measurements results show that the AFTER I treatment results in a higher sound power level reduction than the AFTER II treatment. In particular, for boiler nominal working conditions C) the reduction in the MNCF is 6.0dB for AFTER I treatment and 4.0dB for AFTER II treatment. Thus, AFTER I is the preferred solution for airborne noise reduction. The reduction in the AFTER I A-weighted power levels is:

- 2.5 dB for A) condition;
- 3.5 dB for B) condition;

- 3.5 dB for C) condition (boiler nominal working conditions).

Vibration measurements were repeated after the installation of the noise treatments. Reductions in the vibration are mainly due to the second noise reduction method. Thus, it has been verified in that reductions with AFTER I treatments are very similar to the reductions with AFTER II. The AFTER I treatments are preferred for airborne noise reduction; thus, vibration measurement results are reported only for AFTER I condition.

In Table 3 La_T global acceleration levels and main component (200Hz) La_f acceleration levels are reported for the various measurement points. Fig. 10 shows the comparison between acceleration levels for the BEFORE and AFTER I conditions. The average acceleration level reduction is 5.0dB. Moreover, acceleration level reduction is higher than 4.5dB for each measurement point. Average main vibration component (200 Hz) reduction is 8.0 dB; maximum main vibration component reduction is 9.0 dB. Maximum reductions correspond to the points near the boiler fan, where the vibration treatment is concentrated.

6 CONCLUSIONS

A custom wall gas boiler has been studied in order to identify its main noise sources. Sound power and vibration measurements results show that the boiler fan is the main noise source of both vibration and airborne noise. Two noise treatments were proposed and compared: measurement results show that the highest noise reductions are obtained by means of polyurethane-lead multilayer panels (airborne noise reduction) and polyurethane and flexoid gaskets (vibration reduction). The proposed noise treatments do not modify the fan operating point, as shown by measurements. The volumetric flow measurements were verified by numerical simulations. The following noise and vibration levels reductions were obtained

Table 3 - Comparison between measured acceleration levels relative to BEFORE and AFTER I conditions

Measurement Point	La_T (dB) BEFORE	La_T (dB) AFTER I	ΔLa_T (dB) AFTER I	La_f (dB) BEFORE	La_f (dB) AFTER I	ΔLa_f (dB) AFTER I
1	107.5	101.5	6.0	104.5	95.5	9.0
2	107.5	102.0	6.0	103.5	94.5	9.0
3	106.5	101.5	5.0	104.0	95.5	8.5
4	107.5	102.0	6.0	104.0	95.5	8.5
5	106.5	101.5	4.5	103.5	95.5	8.0
6	105.5	102.0	5.0	102.5	94.5	8.0
7	105.0	100.5	4.5	102.5	95.0	7.5
8	105.5	101.0	4.5	103.0	96.0	7.0
9	106.0	101.0	4.5	102.5	96.0	7.5
10	105.5	101.0	4.5	102.0	95.0	7.0

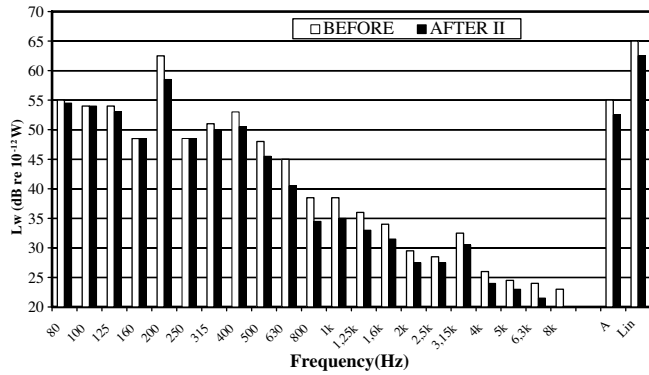


Fig. 9. Comparison between power levels relative to BEFORE and AFTER II conditions (C) boiler working condition

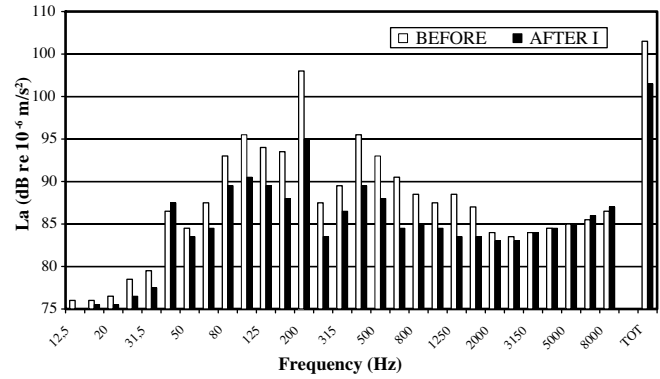


Fig. 10. Comparison between measured average acceleration levels relative to BEFORE and AFTER I conditions (C) boiler working condition.

by means of the preferred noise insulation solution:

- 3.5 dB A-weighted power level reduction;
- 6.0 dB main noise component (200 Hz) power level reduction;
- 5.0 dB global vibration level reduction;
- 8.0 dB main noise component (200 Hz) vibration level reduction.

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