NOISE REDUCTION METHODS FOR WALL GAS BOILERS

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SUMMARY

Noise emissions reduction methods for wall gas boilers are here investigated. An intensimetric and vibration measurement campaign has been carried out in order to individuate the suitable noise reduction solutions. Numerical simulations have been led by means of a volume finite code to verify the compatibility between such solutions and the boiler thermofluidodynamic properties. A 3.5dB average acoustic power reduction and a 5.0dB average vibration level reduction have been obtained. A measurement campaign has allowed to verify that the proposed methods do not affect the boiler thermofluidodynamic performances.

INTRODUCTION

Wall gas boilers allow to control a single apartment heating system independently from the other apartments ones. Wall gas boilers are usually characterized by high fluidodynamic performances and safety conditions. Thus, this kind of boilers is largely spread as civil houses heating system. Wall gas boilers are often installed indoors. For these reason, wall gas boiler noise emissions may cause annoyance, especially during the night, when human noise sensibility is very high [1].
Noise emissions reduction methods are here studied regarding a custom wall gas boiler. The investigated boiler is the model "EOLO 27 Maior @", realized by Immergas, an Italian manufacturer. The research has been carried out within an agreement between the Perugia University Acoustic Laboratory and Immergas.
An intensimetric and vibration measurements campaign has been led in order to individuate wall gas boiler noise characteristics. Measurements results have shown the boiler fan as the main noise source. Thus, some vibration and acoustic insulation solutions have been proposed and realized on pre-combustion chamber and exhaust fan surrounding area. Numerical simulations by means of a volume finite code (Fluent) and a measurement campaign have shown that the proposed noise reduction solutions do not affect the boiler thermofluidodynamic performances.
An intensimetric and vibration measurement campaign has been carried out after the realization of the noise reduction solutions. Measurement results have allowed to individuate the optimum noise insulation solution which introduces a 3.5dBA A-weighted power level reduction and a 5.0dB vibration level reduction.

WALL GAS BOILER NOISE CHARACTERIZATION

An intensimetric measurements campaign has been led in order to individuate the characteristics of the noise emitted by the wall gas boiler. Measurement room characteristics are:
- approximately 65 m^2 absorbing units;
- dimensions equal to 4.5m X 4.5m X 3m.

The wall the boiler is installed on is characterized by high absorbing coefficient, equal to 0.7 [2] [3]. Measurements have been carried out for three boiler working conditions:
A. only boiler pump is on;
B. only boiler fan is on;
C. all noise sources are on.

A) condition measurements have been led in 12 points, placed on a fictitious parallelepiped surface which surrounds the noise source [4]. Surface dimensions are x=1.2m, y=1.2m, z=0.6m (x–y plane is the wall the boiler is installed on). B) and C) conditions measurements have been led on 20 points, placed on a fictitious parallelepiped surface which surrounds the noise source. Surface dimensions are x=1.8m, y=1.8m, z=1.8m. Measurement points number and positions have been chosen in according to ISO 9614-1/93 [4]. Measured sound pressure levels have been processed by the data acquisition system in order to calculate noise power spectrum. Figs. 4 and 5 show the measured power level spectra relative to C) condition (indicated as BEFORE condition). Measured power levels have suggested the following considerations:
- 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 power level produced by the “EOLO 27 Maior @” wall gas boiler is:
- 39.5 dBA for A) condition;
- 55.0 dBA for B) condition;
- 55.0 dBA for C) condition.

Measurements results have shown that noise power spectra for B) and C) conditions are characterized by the same behavior and the same MNCF (200 Hz). Therefore, the exhaust gas fan is the boiler main noise source in the nominal working conditions. A remarkable contribute to the global boiler noise is solid-borne noise. Thus, a vibration measurement campaign has been led in order to individuate possible correlations between acceleration level spectra and the previously measured power levels ones. Measurements have been carried out for C) condition (all noise sources are on). 10 measurements points have been chosen on the boiler external panels. Vibration levels have been measured in 12.5-8000 Hz frequency range. The acceleration level average spectrum is reported in Fig. 6 (indicated as BEFORE condition). Measurements results show that vibration main component frequency (200 Hz) is equal to the power spectrum one due to the boiler fan. Therefore, also the boiler solid-borne noise is mainly due to the exhaust fan.

NOISE REDUCTION METHODS

Boiler fan power spectrum characteristics are:
- 80-1600 Hz frequency range;
- a tonal component whose frequency value (200 Hz) is proportional to the fan blades r.p.m.

Two kinds of noise reduction methods have been proposed and realized:
1) Airborne noise reduction. Two different solutions have been 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. 1.a). The panels are constituted by two polyurethane layers (35 Kg/m^3 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/m^3 density, 35.3 W/m K thermal conductivity, 130 J/Kg K specific heat at constant pressure). Material performances are guaranteed for working temperatures less than 120°C [5]. This condition always occurs for the boiler nominal working conditions.

1.b) 40mm thick glass-wool insulation panels (22 Kg/m^3 density, 0.034 W/m K thermal conductivity, 850 J/Kg K specific heat at constant pressure) have been installed on the boiler internal walls and the combustion chamber external walls (see Fig. 1.b). Panels have been compressed in order to reduce the volume they fill into the boiler. Material performances are guaranteed for boiler nominal working conditions [6].

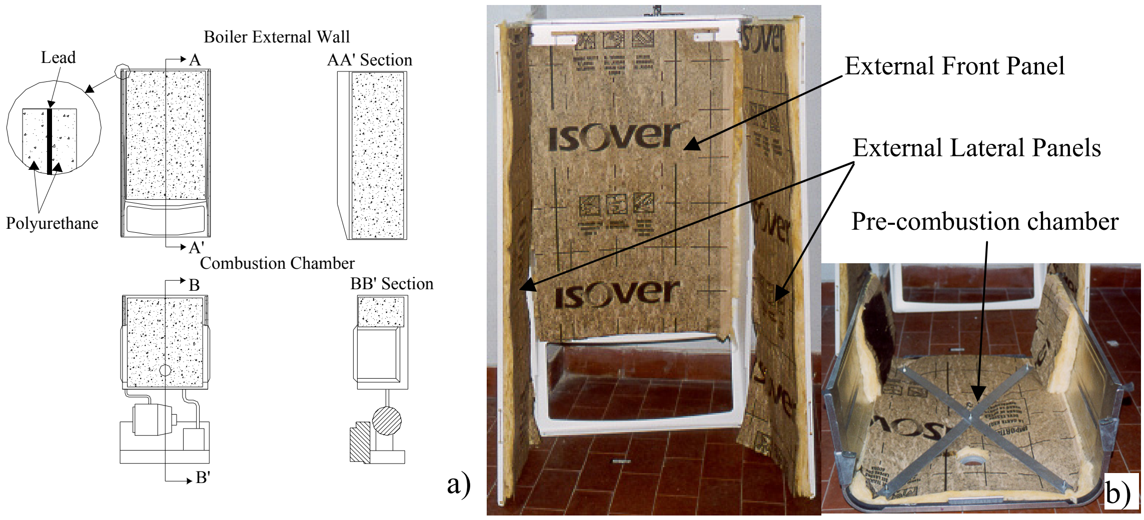

Figure 1: a) installation scheme of sound insulation multilayer panels; b) installation of glass-wool noise insulation panels

2) Solid-borne noise reduction: exhaust fan has been insulated from the boiler other 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. 2). A polyurethane gasket has been also installed where the boiler fan is connected to the exhaust duct. Combustion chamber panels have been insulated by means of 1mm thick Flexoid gaskets. Two 2mm thick steel stirrups have been installed over the pre-combustion chamber internal walls in order to make them more rigid.

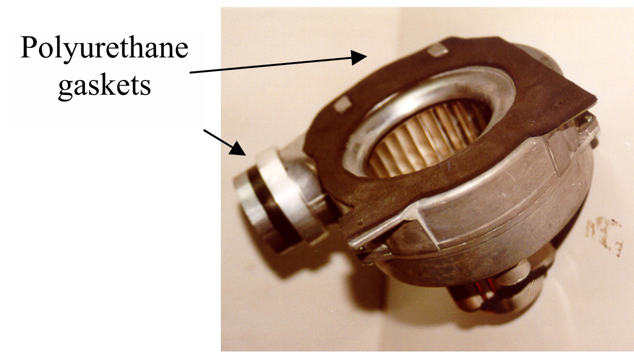

Figure 2: solid-borne noise reduction solution by means of polyurethane gaskets

NOISE REDUCTION METHODS COMPATIBILITY WITH BOILER THERMOFLUIDODYNAMIC PERFORMANCES

The proposed noise reduction methods (additional gaskets and noise insulation panels) may decrease the boiler aspiration air flow rate. This fact may induce a boiler thermofluidodynamic performances worsening: the exhaust gases flow rate may decrease and the internal temperature may increase. A measurement campaign has been carried out in order to evaluate the boiler thermofluidodynamic characteristics. In particular, the characteristics of the aeraulic circuit constituted by aspiration circuit, combustion chamber and exhaust gas duct have been determined. Air flow rate has been measured by varying the pressure difference (ΔP) between boiler inlet and outlet. Thus, the aeraulic circuit characteristic curve (ΔP-flow rate) has been evaluated (see Fig. 3, BEFORE condition). At last, air temperature has been measured at boiler inlet by means of a sensor placed at the aspiration duct outlet; exhaust gases temperature has been measured at boiler outlet by means of a sensor placed at the exhaust duct inlet. Boiler fan working point is obtained as the intersection between the aeraulic circuit characteristic curve (ΔP-flow rate) and the fan characteristic curve (see Fig. 3) [7]. Air and exhaust gases flow rates are equal to 115.5m^3/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.

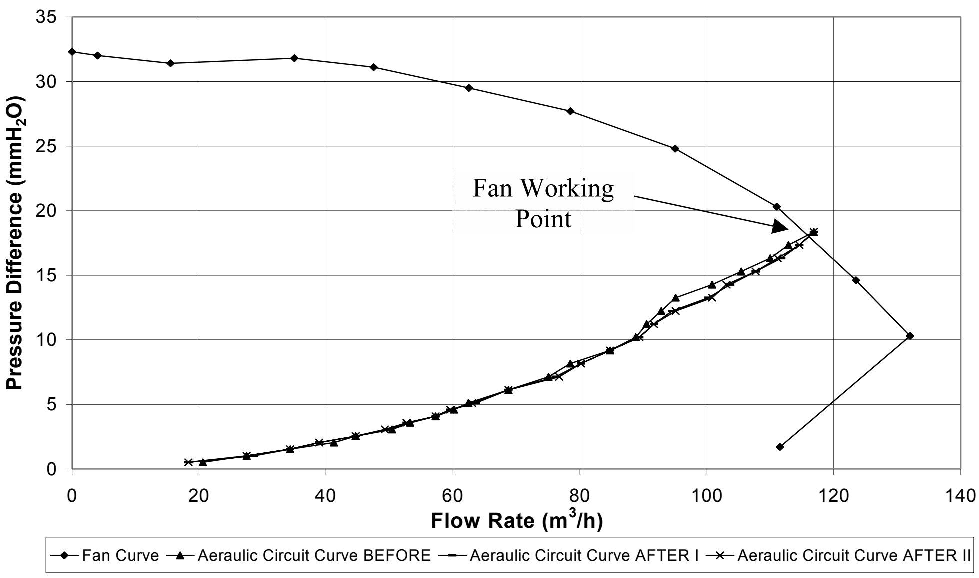

Figure 3: boiler fan working point after the realization of noise reduction interventions.

Boiler thermofluidodynamic characteristics have been also studied by means of a volume finite numerical code (Fluent) [8]. A numerical simulation has been led: boiler internal volume has been divided into about 500.000 tetrahedral elements. Boiler internal pressure, velocity and temperature have been simulated in the following conditions:
- boiler before the noise reduction solutions realization (BEFORE condition);
- boiler after the realization of 1.a) and 2) noise reduction solutions (AFTER I condition);
- boiler after the realization of 1.b) and 2) noise reduction solutions (AFTER II condition);

Simulations have been carried out by applying the following boundary conditions: boiler inlet pressure equal to the boiler outlet one; pressure difference between exhaust fan inlet and outlet equal to the one individuated by means of the aeraulic measurements campaign; boiler

inlet and outlet temperature equal to the measured ones (respectively 27°C and 125°C); 31.5kW heat flux generated by the boiler burner; 28.5kW heat flux absorbed by the boiler heat exchanger, placed in the combustion chamber upper side.
Simulation results have shown no remarkable alterations in the boiler thermofluidodynamic properties due to the noise reduction solutions (both AFTER I and AFTER II). Therefore, boiler thermofluidodynamic performances are not affected by the proposed noise reduction procedures. Thus, the proposed noise reduction methods have been applied to the boiler; a thermofluidodynamic measurement campaign has been carried out for AFTER I and AFTER II conditions. Fig. 3 shows the comparison among the boiler aeraulic circuit characteristics curves relative to BEFORE, AFTER I and AFTER II conditions. Fan characteristic curve is reported too. It can be observed a negligible displacement of the aeraulic circuit curve after the realization of the noise reduction solutions. Fan working point is not modified: thus, exhaust gases flow rate is 115.5m^3/h for BEFORE, AFTER I and AFTER II conditions. Also aspirated air and exhaust gases temperatures are not modified by the proposed noise reduction solutions.

INDIVIDUATION OF THE OPTIMUM NOISE REDUCTION SOLUTION

The intensimetric measurements campaign has been repeated after the realization of the noise reduction solutions. The campaign has been carried out in according to ISO 9614-1/93 [4]. Fig. 4 and 5 show the comparison between the measured power level spectra for C) boiler working condition relative to:
- BEFORE and AFTER I conditions (Fig. 4);
- BEFORE and AFTER II conditions (Fig. 5).

A-weighted Lw_A power level reductions are reported in Table 1. A-weighted Lw_f power level reductions relative to the MNCF (125Hz for A) condition, 200Hz for B) and C) conditions) are reported in Table 2.

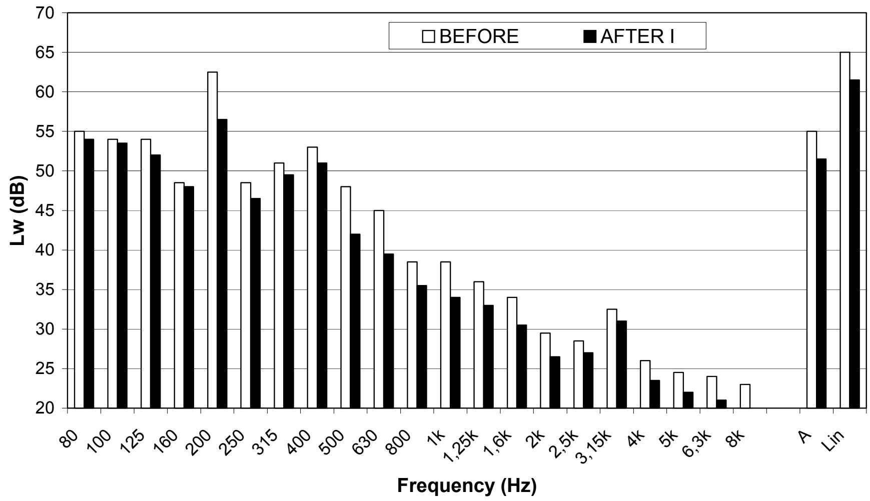

Figure 4: comparison between power level spectra relative to BEFORE and AFTER I conditions (C) boiler working condition)

Measurements results show AFTER I solution allows to obtain more remarkable sound power level reductions than AFTER II ones. In particular, results relative to the boiler nominal working conditions (C) measurement condition) point out a 6.0dB MNCF reduction for AFTER I solution with respect to a 4.0dB one for AFTER II solution. Thus, AFTER I is the optimum solution for airborne noise reduction. The obtained AFTER I A-weighted power

level reductions are:
- 2.5 dBA for A) condition;
- 3.5 dBA for B) condition;
- 3.5 dBA for C) condition (boiler nominal working conditions).

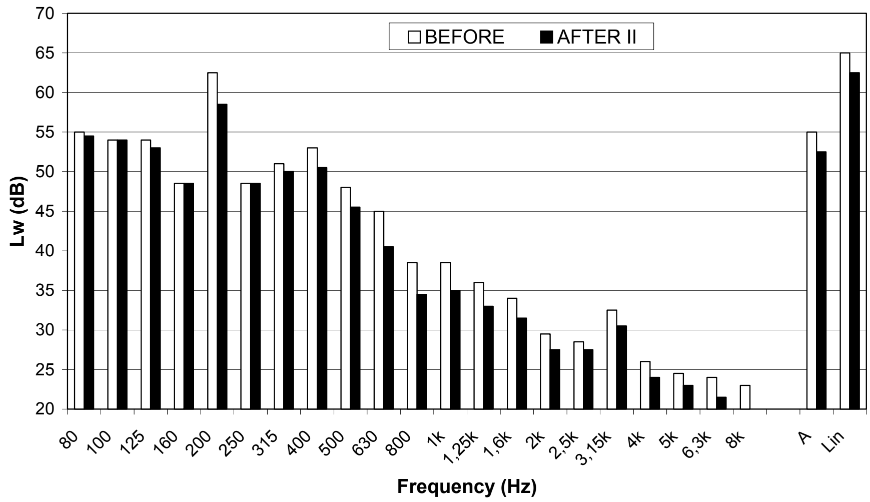

Figure 5: comparison between power level spectra relative to BEFORE and AFTER II conditions (C) boiler working condition)

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 reduction methods.

Measurement Condition	Lw_A (dBA) BEFORE	Lw_A (dBA) AFTER I	Lw_A (dBA) AFTER II	ΔLw_A (dBA) AFTER I	ΔLw_A (dBA) 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 reduction methods.

Measurement Condition	Lw_f (dB) BEFORE	Lw_f (dB) AFTER I	Lw_f (dB) AFTER II	ΔLw_f (dB) AFTER I	ΔLw_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

Vibration measurements have been repeated after the realization of the noise reduction solutions. Solid-borne noise reduction is mainly due to 2) noise reduction method. Thus, it has been verified that AFTER I obtained reductions are very similar to AFTER II ones. AFTER I solution is optimum for airborne noise reduction; thus, vibration measurement results are reported only for AFTER I condition. In Table 3 La_T global acceleration level and main component (200Hz) La_f acceleration level are reported relatively to each measurement point. Fig. 6 shows the comparison between acceleration levels spectra relative to BEFORE and AFTER I conditions. Average acceleration level reduction is 5.0dB. It is higher than 4.5dB for each measurement point. Average main component reduction is 8.0 dB; maximum main component reduction is 9.0 dB. Maximum reductions correspond to the points near the boiler fan. In fact, solid-borne noise reduction solutions are intensified in that area.

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

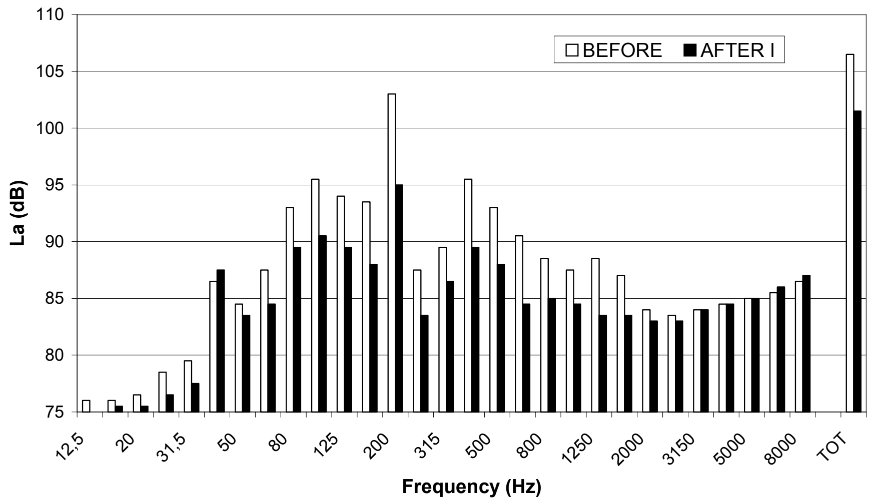

Fig. 6: comparison between measured average acceleration levels spectra relative to BEFORE and AFTER I conditions (all noise sources are on).

CONCLUSIONS

Wall gas boilers noise problematics have been here investigated. A custom wall gas boiler has been studied in order to individuate its main noise sources. Intensimetric and vibration measurements results have allowed to identify the boiler fan as the main noise source, both solid-borne and airborne. Two noise insulation solutions have been proposed and compared:

measurement results have shown that the highest noise reductions are obtained by means of polyurethane-lead multilayer panels (airborne noise reduction) and polyurethane and flexoid gaskets (solid-borne noise reduction). The proposed noise reduction methods does not modify fan working point, as a numerical simulation and aeraulic measurements results have shown. The following noise and vibration levels reductions have been obtained by means of the optimum noise insulation solution:
- 3.5 dBA 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.

SYMBOLS

Symbol	*Description*	*Units*
ΔP	Boiler inlet-outlet pressure difference	mmH_2O
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	dBA
ΔLw_f	Difference between MNCF power levels before and after noise reduction	dB
La_f	MNCF acceleration level	dB
La_T	Global acceleration level	dB
Lw_A	A-weighted sound power level	dBA
Lw_f	MNCF power level	dB

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