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EXPERIMENTAL RESEARCHES ON CORRELATION SOURCE-NOISE LEVEL GENERATED AT VENTILATING AND AIR CONDITIONING INSTALLATIONS

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Reducerea nivelelor de zgomot la instalațiile de ventilație şi condiționare a aerului presupune mai întâi înțelegerea exactă a cauzelor şi modalităților de producere a acestora, şi abia apoi modelarea unor soluții noi şi viabile pentru atingerea scopului propus. Cercetările experimentale realizate pe o instalație cu diverse regimuri de funcționare au avut în vedere aspecte precum condițiile atmosferice externe, zgomotul ambiental, ora de realizare a determinărilor, modalitatea de montare a instalației, izolarea fonică spațiilor respective.

For reducing noise levels at ventilating and air conditioning installations, an exact understanding of causes and their occurence are of primary interest. Then, one tries to find new and viable solutions for the proposed goal. Experimental researches performed on an installation with different operating conditions took into consideration external environment conditions, environmental noise, measuring time, installation settings, and sound isolation of the places.

Key words: noise levels, operating conditions, background noise

1. Introduction

For reducing noise levels at ventilating and air conditioning installations, an exact understanding of causes and their occurence are of primary interest. Then, one tries to find new and viable solutions for the proposed goal.

As it can be easly remarked, in the specialized literature there are lots of experimental researches based on different aspects of the analyses, for generating and reducing the noise levels in such installation. From the beginning of these analysis and experimental tests, our purpose was to identify the causes that generate noise at some air conditioning installations used in offices, houses, classrooms or conference rooms, etc [1].

For experimental researches, we chose a large capacity installation that can be used in different places and having lots of operating conditions. We have also taken into consideration factors like external atmospheric conditions,

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environmental noise, measuring time, installation settings, soundproofing of those spaces.

In this paper, we present thorough information on experimentally measuring conditions, receiving and processing data, as well as numerical and graphical results.

2. General working assumptions

The chosen working methodology provides a unitary approach from phenomena and experimental standpoint of the two aspects considered within the experimental researches: finding the noise levels at some types of installation for air conditioning and identifying the main causes of noise.

From the beginning some working assumptions were issued for the experimental measurements, such as:

1) The used air-conditioning installation has a cooling capacity of 5100W (about 17400 BTU) and a heating capacity of 5300W (about 18000 BTU).

2) It is placed in a 70 m^2 classroom (conference room) having eastward normal-type windows. The external unit is placed on an outside brick wall, eastward also.

3) According to technical documentation, the installation is provided with four distinct operating modes: cooling, heating, ventilating and de-moistening.

3. Equipment used

The flow chart of measuring chain used for sound level experimental measurements is shown in Figure 1.

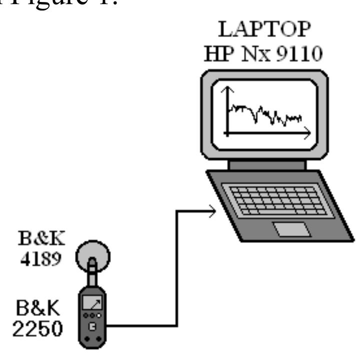

Fig. 1. Flow chart of measuring chain used for sound level experimental measurements

The equipment used for sound level measurements in different operating modes of the above mentioned air-conditioning installation as well as at different measuring points, has the following elements:

- Sonometer, type 2250 - Brüel & Kjær, Denmark;

Characteristics:
- ✓ Real time frequency analysis in 1/1 and 1/3 octave bands;
- ✓ Frequency range 3Hz – 20kHz;
- ✓ USB interface
  - Microphone, type 4189 - Brüel & Kjær, Denmark;

Characteristics:
- ✓ Sensibility 50 mV/Pa;
- ✓ Frequency 6.3Hz – 20kHz;
- ✓ Temperature: - 30ºC ÷ 150ºC;

4. Experimental measurements

As a place for measurements we used a 70 m^2 open-surface classroom (conference room) provided with an 18000 BTU air-conditioning installation.

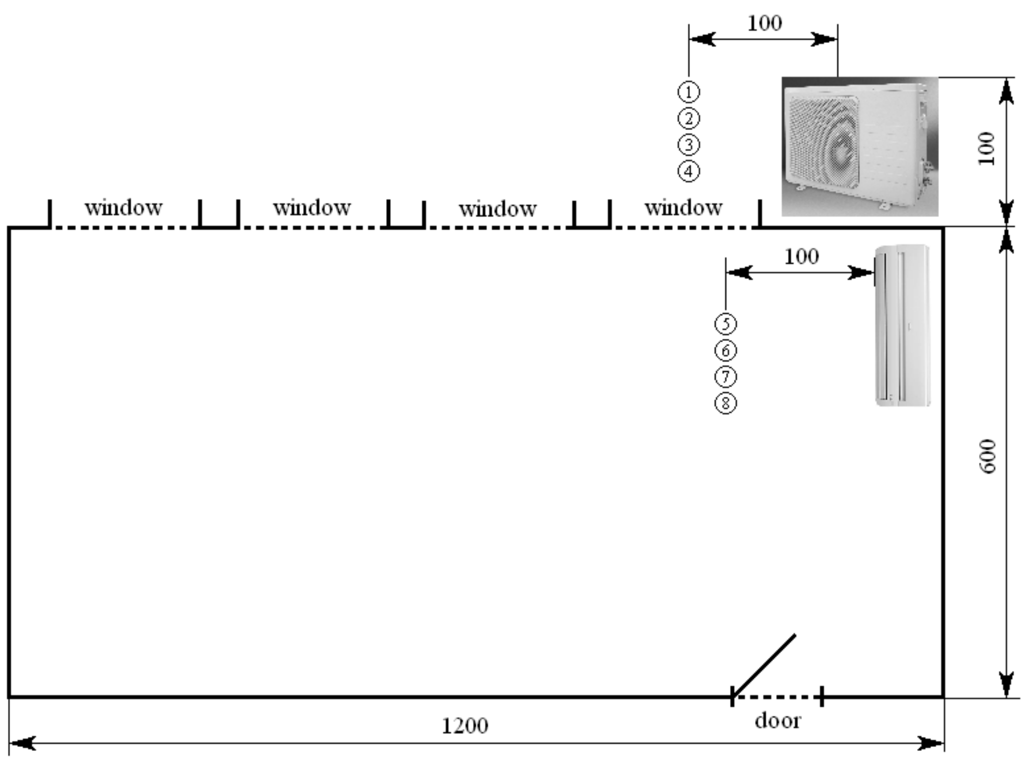

Fig. 2. Diagram of measuring points for sound levels

A number of eight record sets were acustically performed for the two exterior and interior units, in different operating conditions. The measuring points (figure 2) were chosen in different types of places, on the strength of the norms on the noise level. The conditions and technical aspects for each measurement are detailed in table 1.

Table 1

Table of sound level measuring points and related observations

Measuring point	Observations
1 Exterior background noise	*Measuring place*: outdoor, 1m lateral to exterior unit; *Operating conditions*: NO operation; *Environment temperature*: 25ºC; *Time:* 9^{25}
2	*Measuring place*: outdoor, 1m lateral to exterior unit; *Operating conditions*: cooling (COOL); *Environment temperature*: 25ºC; *Time:* 9^{30}
3	*Measuring place*: outdoor, 1m lateral to exterior unit; *Operating conditions*: heating (HEAT); *Environment temperature*: 25ºC; *Time:* 9^{35}
4	*Measuring place*: outdoor, 1m lateral to exterior unit; *Operating conditions*: de-moistening (DRY); *Environment temperature*: 26ºC; *Time:* 9^{40}
5 Interior background noise	*Measuring place*: indoor, 1m front to exterior unit; *Operating conditions*: NO operation; *Environment temperature*: 24ºC; *Time:* 9^{45}
6	*Measuring place*: indoor, 1m front to interior unit; *Operating conditions*: cooling (COOL); *Environment temperature*: 24ºC; *Time:* 9^{50}
7	*Measuring place*: indoor, 1m front to exterior unit; *Operating conditions*: heating (HEAT); *Environment temperature*: 24ºC; *Time:* 9^{55}
8	*Measuring place*: indoor, 1m front to interior unit; *Operating conditions*: de-moistening (DRY); *Environment temperature*: 24ºC; *Time:* 10^{00}

When we analyze from the acoustic point of view, it is important to mention that the conference room is provided with metal frame normal-type window and its total surface ($70m^2$) is an open one without other interior walls.

5. Numerical and graphical results

As mentioned above, we performed eight record sets for both the exterior unit and the interior one in different operating conditions of the air-conditioning installation. The measuring points places are presented in Figure 2 and the installation functional parameters and the environmental conditions are mentioned in Table 1. Values of the measured parameters and of the frequency spectrum in the 1/3 octave bands for all measuring points are shown in Figures 3 ÷ 10. Several parameters were measured among which one can mention:

➢ LA_{eq}- equivalent noise level, LA_{eq} A-weighted sound pressure level, average for a period of time and given by [3]

$$LA_{eq} = 10\log\left(\frac{1}{T}\int_0^T p_A^2 dt / p_{ref}^2\right) \quad dB(A) \qquad (1)$$

where T – measurement averaging period, p_A is the instantaneous sound pressure measured by a A-weighted frequency filter and p_{ref} is the reference pressure $20\mu Pa$ $(2 \cdot 10^{-5}\, N/m^2)$.

➢ LC_{peak} - peak value on C-weighted curve (≈ linear) in the measured time, determined by the difference (Stop Time – Start Time) [2].

➢ LAF_{min} - minimum sound pressure level on A-weighted curve, time constant F (fast);

➢ LAF_{max} - maximum sound pressure level on A-weighted curve, time constant F (fast);

➢ *LAF90.0* - sound pressure level of background noise, A-weighted.

The frequency spectrum for each measurement is in the 1/3 octave band in the acoustic frequency range (12.5 Hz-20 kHz).

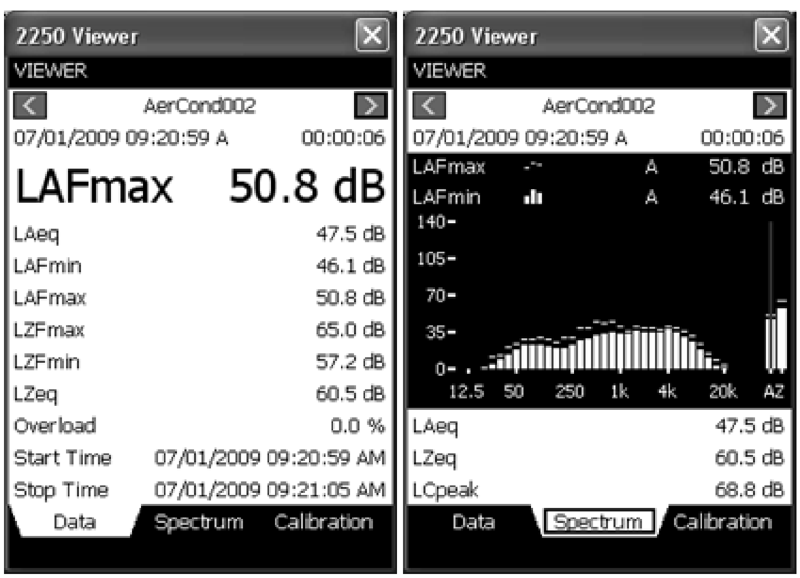

Fig. 3 – Measuring point 1 - outdoor, 1m lateral to the exterior unit; Operating conditions: NO operation (exterior background noise)

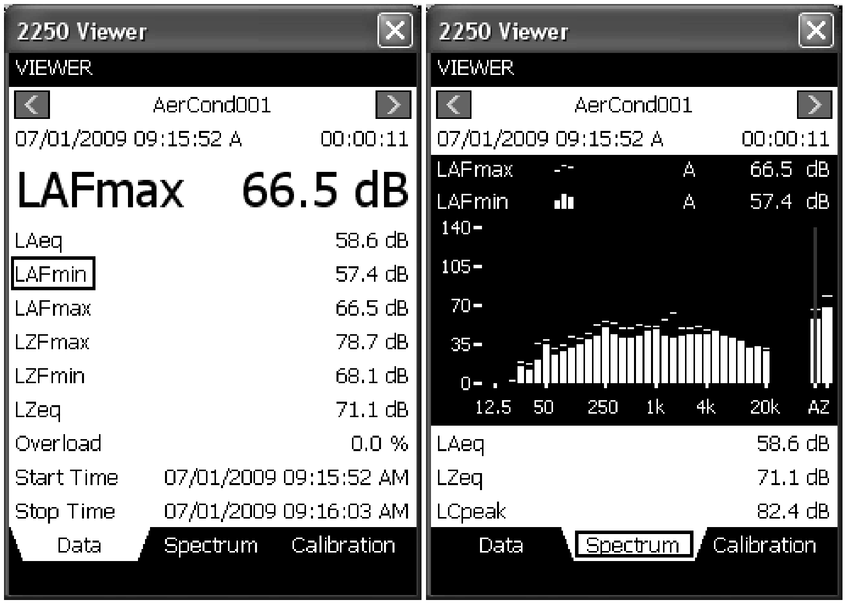

Fig. 4 – Measuring point 2 - outdoor, 1m lateral to the exterior unit; Operating conditions: cooling (COOL)

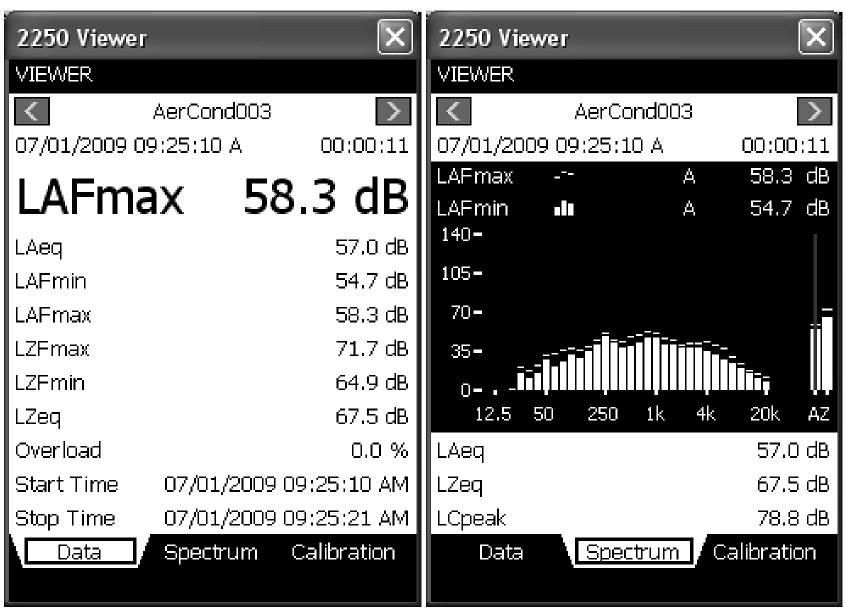

Fig. 5 – Measuring point 3 - outdoor, 1m lateral to the exterior unit; Operation conditions: heating (HEAT)

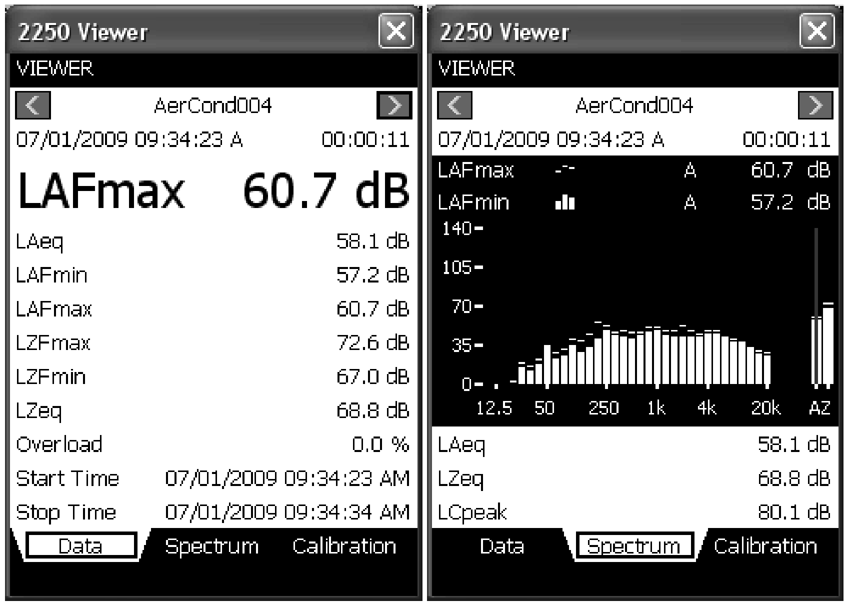

Fig. 6 – Measuring point 4 - outdoor, 1m lateral to the exterior unit; Operating conditions: de-moistening (DRY)

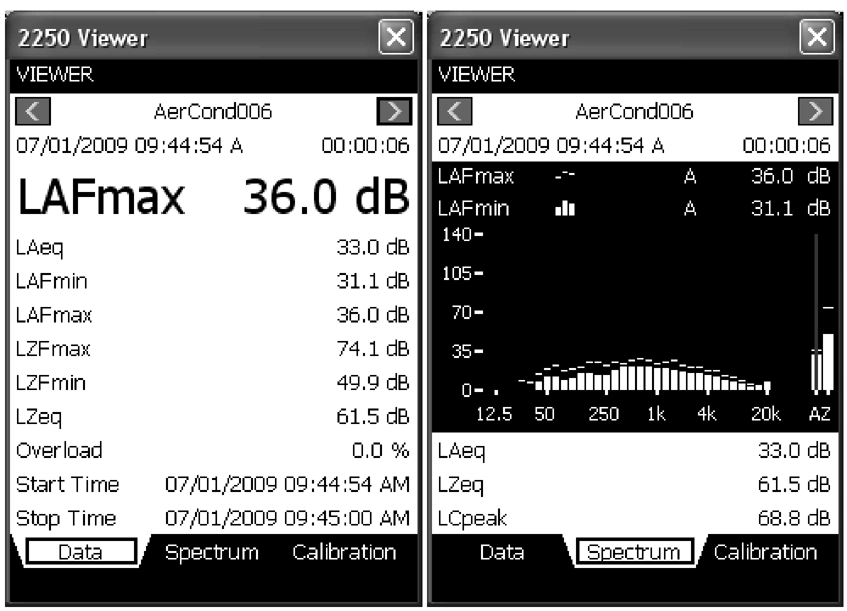

Fig. 7 – Measuring point 5 – indoor, 1m frontal in front of the interior unit; Operation conditions: NO operation (inside background noise)

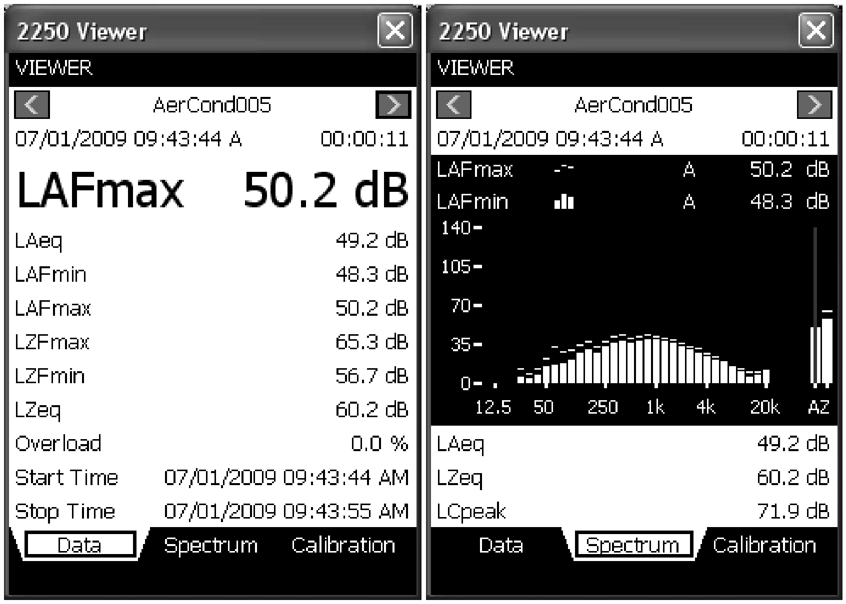

Fig. 8 – Measuring point 6 – indoor, 1m frontal in front of the interior unit; Operation conditions: cooling (COOL)

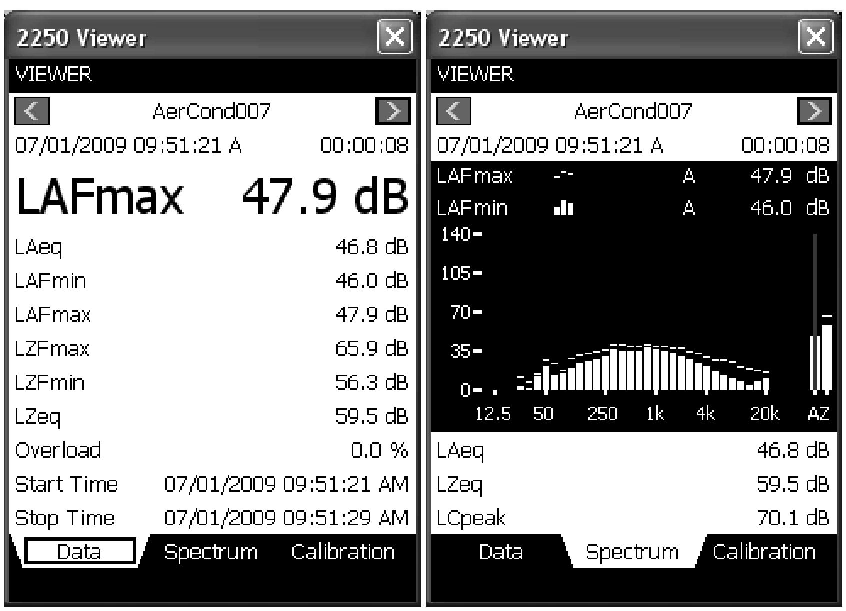

Fig. 9 – Measuring point 7 – indoor, 1m frontal in front of the interior unit; Operation conditions: heating (HEAT)

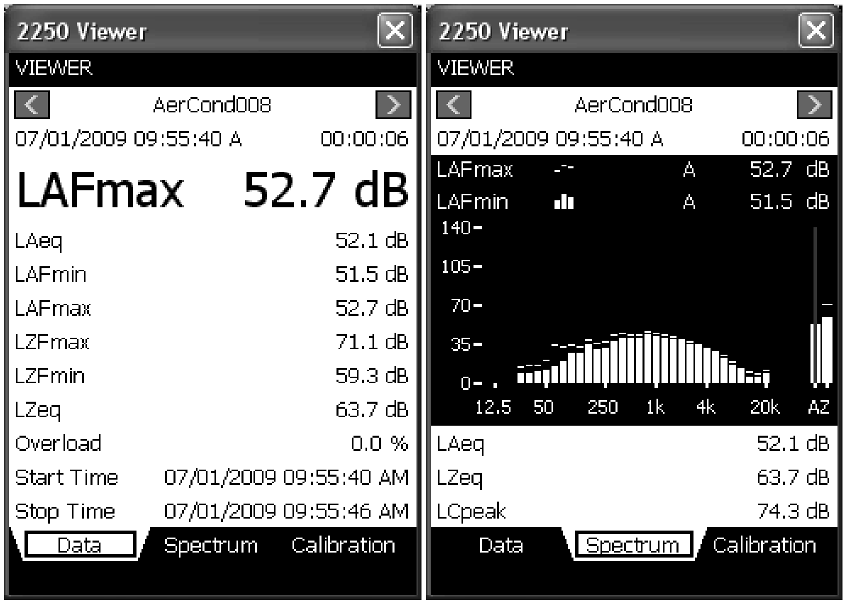

Fig. 10 – Measuring point 8 – indoor, 1m frontal in front of the interior unit; Operation conditions: de-moistening (DRY)

6. Discussion of the results and conclusions

The first step in the results interpretation was when chosing the measurements place. General characteristics: the installation has a capacity of 18000 BTU and is placed in a classroom (conference room) having an open surface of 70m^2, without any interior wall; the room windows are normal; the room acoustics is normal; the room has no other special improvements. The exterior unit is placed on an eastward outside wall of the brick building.

According to the technical documentation of the installation subject to the experimental researches, the appliance is provided with four distinct operating modes: cooling (COOL), heating (HEAT), ventilation (FAN) and de-moistening (DRY).

The experimental researches took place during warm season, in a normal temperature day for the chosen period.

The influence of the inside/outside thermal conditions as well as the background noise levels in the results can be easily identified in a possible development of the experimental measurements on the same installation but in two or three different periods of the day [4].

As one can remark, the value of the outside background noise level recorded is common (47.5 dBA) and normal for the existing situation – the outside wall being towards an open area with average traffic. In case of inside background noise level, the value is 33 dBA and is influenced by both the lack of persons in the room during measuring and the increasing persons traffic in the room exterior hall [5].

In order to come to some conclusions on the noise levels of the installation subject to researches, we first searched the technical documentation of the installation to find out the information provided by manufacturers. They give information on the sound pressure levels on both the entire frequency range (dB – the entire frequency range 2 Hz – 20 kHz) and the A-weighted curve (dBA - range 22 Hz – 20 kHz). The values in the technical documentation take into consideration both the operating conditions and the two interior/exterior units. We have to mention in addition that during operation, regardless the conditions, the analysed appliance has variations (the order of dB) of the generated noise level. The causes of these variations can not be always exactly determined. The most possible causes are the environmental noise level or the irregularity of the compressor operation.

When looking into the obtained frecquency spectra one can remark that for the low frequencies interval, regardless of the operating conditions or the outside conditions, the noise level has admissible values by small increases for operating at de-umidification.

The frequency range of 250 Hz – 2 kHz is interesting for the analysis of the obtained graphical results. When the device operates at different conditions, the frequency spectrums have a maximum around 1 kHz.

At the 50 Hz frequency there is also a maximum tallying with the compressor frequency, that is acknowledged when measuring the background noise with stopped installation. This especially occurs on the frequency spectrums surroundingly recorded, at one meter frontal from the exterior unit.

For frequencies over 4 kHz, regardless of the existing conditions, the results have no importance at all in the spectral analysis of the noise generated by these types of installation.

In order to correctly identify the reasons that generate noise in the frequency spectra and for a better accuracy of the spectral analysis, it is necessary a separation of the noise generated by an installation from the environmental one, which can be obtained only in a special acoustics room.

The values of the A-weighted curve equivalent noise level (LA_{eq}) are in the table below, being measured in different operating conditions both indoor and outdoor.

Table 2

Values of the equivalent noise levels (LA_{eq}) on the A-weighted curve in all considered measuring points

Operating conditions	Equivalent noise level LA_{eq} (dBA)	
	INSIDE	OUTSIDE R
COOL	49,2	58,6
HEAT	46,8	57,0
DRY	52,1	58,1

From the above mentioned values, the following could be concluded:

✓ A poor correlation exists between the noise level values measured on the weighted curve (dBA) and the values mentioned in the appliance technical documentation. The installation wear during several operating years as well as a small overestimation of technical performances by the manufacturer in the first stage could be among the main causes. The interpretation of graphic data could lead to an exact identification of highly weared components whose contribution are significant at increasing the measured levels.

✓ For the exterior unit, the exceeding is smaller and is between 3 and 4 dBA for each of the analysed situation.

✓ For the interior unit, the exceeding of the noise levels is significant, by values between 4 and 7 dBA.

✓ The capacity difference of this type of installation automatically determines a difference of the maximum air flow conditioned by such an installation in an hour, which automatically leads to higher noise levels.

✓ Relating to the last observation, we have to mention the following technical values: the cooling/heating capacity of the measured installation is 18000 BTU, the maximum air conditioned flow is 972 – 984 m^3/h. The conclusion from these information is that the influence of the aerodynamic noise generated by the interior units of these installation prevails in the measured noise level.

✓ From the above mentioned, one concludes that the most important research orientation for decreasing the noise level at interior units is given by the aerodynamic noise and especially by the one generated when the conditioned air is flowing through blades, grilles or diffusers of most systems of ventilating, conditioning and air distribution.

✓ De-moistening mode is the most sensible in terms of noise level related to the installation capacity. The above mentioned conclusion comes from the different de-moistening capacity of each type of installation. Thus, for our installation of 18000 BTU the de-moistening capacity is 2.9 l/h as shown in the technical documentation while, for instance, the de-moistening capacity is only 0.9 l/h for appliances of 9000 BTU of the same range. It can be noted that for a double capacity, the de-moistening level increases 3.22 times, determining thus an increase of the noise level.

✓ By comparing the obtained data [7], [8], [9] with the noise levels admissible in houses, offices, classrooms or small conference rooms, one can conclude that: the noise generated by the installation subject to the experimental researches ranges, with a few exceptions, between the admissibile limits for day operation (48 dBA). For night operation the theoretical admissible level is much smaller (35 dBA) that means an exceeding by values between 4 and 15 dBA in our case. Our installation is used in a conference room with no night activity so the admissible noise level norms are observed.

The facts presented in the last paragraph are only a part of many interpretations, observations and conclusions obtained from the results of the experimental researches. Some of these results confirm various theoretical aspects in the scientific literature, others do not; in either of these cases, they open the development way to constructive solutions for reducing the noise levels in these types of installation.

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