SOUND POWER MEASUREMENT

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Abstract – *This paper presents the results of the sound power measurements of a commercial vacuum cleaner according the direct method procedure, explained in the standard ISO 3741. The measurement took place in a class room of reverberant characteristics with a volume of 95 m^3, at UNTREF's Annex.*

1. INTRODUCTION

In the present paper the results of the sound power measurements of a commercial vacuum cleaner are presented, being the measurement carried out under the ISO 3741 standard, which determines the levels of sound power and acoustic energy of noise sources by measuring the acoustic pressure in reverberant rooms. For this purpose, the reverberant time was measured using the procedure of the ISO 354 standard, with 2 different omnidirectional source positions and 8 microphone positions for each source position. The sound pressure level was measured for 3 different noise source positions and for 8 microphone positions, for each source position.

Sound power is the acoustical energy per time unit, produced by a sound source and it is measured in Watts. A sound source radiates power and as a consequence it creates sound pressure. While sound pressure depends on the room or environment, the sound power is independent of it.

The principle of the ISO 3741 direct method is that the sound source is placed in a known acoustic environment which is measured and in some cases modified. The sound power of the source is then calculated from the sound pressure measurements and from the room properties.

The objective of measuring the sound power of noise sources is mainly to prevent users hearing damage. For the customers it is important to consider the noise specification before they choose a product, so the measurements must be comparable. This is achieved by measuring under the same standards.

This paper first presents the concepts and mathematical calculation for the reverberation time and the sound power measurements, according to the ISO 354 and 3741 standards. Then, the measurement procedure is detailed. Finally, the uncertainty analysis and results are presented.

2. THEORETICAL BACKGROUND

2.1 Sound Power Level

The sound power level can be defined as the amount of energy per unit time, that's radiated from a sound source.

Equation 1 shows the sound power level, according to the ISO 3740 standard [1]:

$$L_w = 10\log\left(\frac{P}{P_0}\right) \tag{1}$$

where P_0 is the reference sound power:

$$P_0 = 1pW \tag{2}$$

Sound power level can be calculated using the sound pressure measurements made in the vicinity of a source [2], as it can be seen in equation 3:

$$L_p = L_w - 10logA + 6\ dB \tag{3}$$

where A is the total absorption area:

$$A = S\alpha = \frac{0.161V}{T} \tag{4}$$

ISO 3741 describes the sound power level measurements of a sound source in a reverberant room [3]. This standard includes two different methods. The direct method use the equivalent absorption area of the reverberant room. On the other hand, the comparison method use a reference sound source, with a known value of its sound power level. The measurements made for the present paper are based on the direct method.

According to ISO 3741, the sound power level is defined as it can be seen in equation 5,

$$L_W = \overline{L_p} + \left\{10log\frac{A}{A_0} + 4.34\frac{A}{S} + 10log\left(1 + \frac{S\,c}{8\,V\,f}\right) + C_1 + C_2 - 6\,dB\right\} \quad (5)$$

where $\overline{L_p}$ is the average sound pressure level, A_0=1m^2, S is the total area of the reverberant room, V, the volume and c, the sound velocity. The value of f corresponds to the central frequency of the band. C_1 and C_2 are corrections of the reference magnitude (dB) and the radiation impedance, respectively. They are detailed in equations 6 and 7,

$$C_1 = -10log\left(\frac{p_s}{p_{s,0}}\right) + 5log\left(\frac{273.15+\theta}{\theta_0}\right) \quad (6)$$

$$C_2 = -10log\left(\frac{p_s}{p_{s,0}}\right) + 15log\left(\frac{273.15+\theta}{\theta_0}\right) \quad (7)$$

where p_s is the static pressure, $p_{s,0}$ is the static reference pressure (101.325 kPa), θ is the air temperature (°C), θ_0=314 K and θ_1=296 K.

2.2 Measurement location

According to the standard used for the present paper (ISO 3741), the measurement must be made in a reverberant room, with a considerable volume and a low enough acoustic absorption, in order to obtain an appropriate reverberant acoustic field for the frequency band range of interest.

The recommended volume of the room is determined by the lowest band frequency of interest. These values are detailed on table 1:

Table 1: Minimum volume of the room according to the lowest frequency band of interest.

Lowest third octave band frequency of interest [Hz]	Minimum volume of the reverberant room [m^3]
100	200
125	150
160	100
≥200	70

In the section "Characteristics of the vacuum cleaner", the studied sound source will be described in detail. According to them, the principal frequency of interest is around 500 Hz. In that case, the reverberant room available, whose volume is 95.05 m^3, qualifies according to the basic volume range.

On the other side, the standard specifies appropriate values of the absorption of the chamber for its qualification, as well.

The standard specifies the frequency which determines an inflection point in the value of the absorption coefficient to be considered. This frequency was calculated using equation 8, where V is the volume of the chamber.

$$f = \frac{2000}{\sqrt[5]{V}} \quad (8)$$

For frequencies below that value, the absorption coefficient must be lower than 0.16. For frequencies above, this coefficient must be lower than 0.06. The result of the frequency is 438.4 Hz.

Also, the relation between the volume and the surface of the chamber, and the TR60, must be as it is described on equation 9.

$$T_{60} > \frac{V}{S} \quad (9)$$

2.3 Positions

The microphones should be located at least at 6 different positions in the room. The minimum distance between them is expressed in equation 10,

$$d_{min} = D_1\sqrt{\frac{V}{T_{60}}} \quad (10)$$

where D_1= 0.08 (0.16 is the value recommended for frequencies below 5000 Hz), V the volume of the room (in m^3) and T_{60} the reverberation time (in seconds). Also, the microphones must be located at a distance of 1 meter or more from any surface of the room.

In order to calculate if it's necessary to add more microphones positions, the deviation must be taken into account, which is shown in equation 11,

$$s_M = \sqrt{\sum_{i=1}^{N_{M(pre)}} \frac{\left[L'_{pi(pre)} - L'_{pm(pre)}\right]^2}{N_{M(pre)} - 1}} \quad (11)$$

where $N_{M(pre)}$ is the initial number of microphone positions, $L'_{pi(pre)}$ is the sound pressure level for each third octave band and $L'_{pm(pre)}$ is the average of the SPL for each third octave band.

The number of positions, N_M, is detailed on table 2:

Table 2: Number of microphone positions.

Central frequency of the third octave band [Hz]	**Deviation, s_M dB**		
	s_M≤1.5	1.5≤s_M≤3	s_M>3
	Minimum value of N_M		
100, 125, 160	6	6	6
200, 250, 315		6	12
400, 500, 630		12	24
≥800		15	30

If the deviation is bigger than 1.5 dB, then the sound source has significant discrete frequencies. In that case, one of the options is to add more source positions (N_S), as it can be observed in equation 12:

$$N_S \geq K_S\left[\left(\frac{T_{60}}{V}\right)\left(\frac{1000}{f}\right)+\frac{1}{N_M}\right] \quad (12)$$

On table 3, the minimum number of sound source positions and the value K_S are detailed.

Table 3: Sound source position minimum number and K_S value

Central frequency of the third octave band [Hz]	Deviation, s_M dB		
	$s_M \leq 1.5$	$1.5 \leq s_M \leq 3$	$s_M > 3$
	K_S		
100, 125, 160	-	2.5	5
200, 250, 315		5	10
400, 500, 630		10	20
≥800		12.5	25
N_S minimum value	1	Use equation 11	

If it has been used more than one sound source position, then the average sound pressure level must be calculated with equation 13,

$$L'_{pi(ST)} = 10log\left\{\frac{1}{N_s}\sum_{j=1}^{N_S} 10^{0.1[L'_{pi(ST)}]_j}\right\} \quad (13)$$

where $L'_{pi(ST)}$ is the average in the time of third octave band of the sound pressure level.

2.4 Uncertainty

The ISO 3741 standard explains that the uncertainty can be study in two parts. The first is related to the machine's specific deviation, which corresponds to its functioning. The second is about the external parameters of the measurement, as temperature, humidity, deviation of the instruments, among others. The total uncertainty can be obtained from laboratory conditions, so this option was discarded.

The deviation of the functioning of the machine was estimated. Equation 14 shows the calculation in order to make and approximation, where $L_{p,j}$ is the SPL for each microphone positiom, after the noise correction, L_{pav} is the arithmetic average of all measurements, and N the number of repetitions.

$$\sigma_{omc} = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}\left(L_{p,j} \quad L_{pav}\right)^2} dB \quad (14)$$

The deviation corresponding to the external factors of the measurement, besides the machine deviation (σ_{R0}) wasn't calculated correctly, due the lack of measurements instruments for that purpose. Instead, an estimation was made. According to the standard, one of the worst cases is when σ_{R0}=0.5dB, and it doesn't modify the final uncertainty value.

The total deviation is the combination of these two values, expressed in equation 15.

$$\sigma_{tot} = \sqrt{\sigma_{R0}^2 + \sigma_{omc}^2} dB \quad (15)$$

3. MEASUREMENT

3.1 Measurement equipment and software

The following equipment was used for the measurement:

- Sound Level Meter Svantek SVAN 959, with extension cable
- Earthworks Microphones M50
- Electronic Turntable Outline ET230-3D
- Calibrator Svantek SV-30-A
- Outline Globe Source Radiator (dodecahedron), and Global Subwoofer Source (subwoofer).
- Laser rangefinder Bosch DLE 70
- Tascam US-4x4
- Laptop ASUS i7

Also, the following software was used:

- Adobe Audition 3.0 with Aurora plug-in
- SVANPC++
- Smaart 6
- Audacity 2.0.5

3.2 Calibration

Before and after the measurement, the sound level meters were calibrated. A Svantek calibrator was used, with a frequency of 1 KHz and a level of 94 dB. The values corresponding to "Cal Factor" were obtained for each sound level meter. The values that are detailed in table 4 are used in the uncertainty section.

Table 4: Calibration factors.

Sound level meter	Cal factor: Initial	Cal factor: Final
1	0.29	0.28
2	0.18	0.12
4	0.36	0.31
5	-0.07	-0.07

In order to obtain the same levels with all the measurement microphones, a calibration was made, also using the Svantek calibrator. The levels of the four microphones were paired at 1 KHz, regarding the results of the calibration in the software Adobe Audition.

3.3 Characteristics of the vacuum cleaner

3.3.1 Technical specifications

A Philips® commercial vacuum cleaner was used for the sound power measurements. Its model is the FC8344/02, whose serial number is 1010.

The manufacturer's specifications of this model is shown on table 5.

Table 5: Technical specifications of the measured vacuum cleaner.

Functionality specifications	
Max line power	1400 W
IEC line power	1200 W
Max intake air	200 kPa
Max air flow	29 l/s
Noise level (Lc IEC)	82 dB

Constructive characteristics	
Dust storage capacity	2 l
Bag type	Paper bag
Exhaust filter	AFS microfilter
HEPA AirSeal	No
Action radius	8 m
Tube type	Telescopic tube 2
Carrying handle	front
Coupling	Conical
Wheel type	Rubber

The dimensions (in cm.) of the commercial vacuum cleaner are presented in figures 1 and 2.

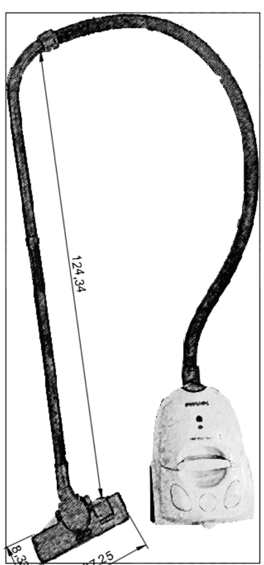

Figure 1: Dimensions of the Philips® vacuum cleaner.

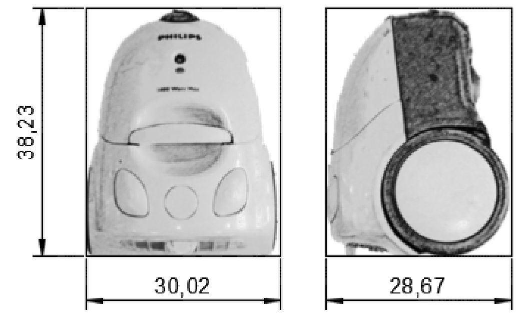

Figure 2: Front and lateral view of the vacuum cleaner.

The vacuum cleaner that's been measured for the present paper is not new. Also, several technical repairs had been made to the machine.

3.3.2 Vacuum cleaner noise spectrum

Before measuring the reverberation time and sound pressure the frequency spectrum of the vacuum cleaner noise was measured with 2 microphones using the software Smaart 6. The results obtained can be observed in figure 3. The noise of the machine is tonal at the band frequency between 500 and 630 Hz.

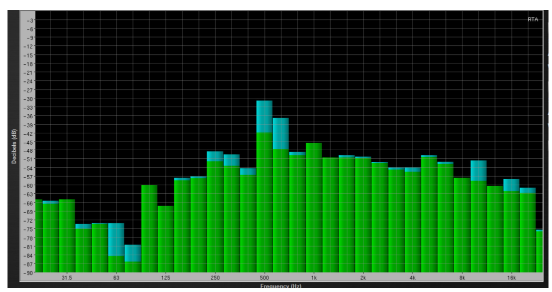

Figure 3: Noise spectrum of the vacuum cleaner.

3.4 Background noise corrections

Before the sound power measurement was made, SPL of the background noise for each three octave band was obtained. This was necessary to determine the qualification of the measurement space. In accordance with the ISO 3741 standard, the difference between the measurement of the background noise and the machine sound was considerable. The relation between them was of 6 dB for frequencies below 200 Hz and 6 dB for frequencies above 6300 Hz. For any other frequencies, the relation is of 10 dB. In case of no qualification of any third octave band, a comparison with the values on table 6 was made. If the background noise is below those values, then the band qualifies.

Table 6: Maximum absolute background noise levels in the room.

Central frequency of third octave band	Maximum pressure level dB
50	42
63	39
8	36
100	33
125	30
160	27
200	24
250	21
315	18
400	15
500	12
630	11
800	11
1000	10
1250	10
1600	10
2000	10
2500	10
3150	10
4000	10
5000	10
6300	10
8000	10
10000	10

It was necessary to apply a correction due to the background noise. This correction is specified on the standard, and corresponds to equation 16, where L_{Ei} is the difference between the sound of the machine measured, and the background noise, for each microphone position.

$$K_{1i} = -10log\left(1 - 10^{-0.1\Delta L_{Ei}}\right)dB \tag{16}$$

3.5 Room characteristics and environment

The location used for the measurement was a class room at UNTREF's Annex. The dimensions of the room are 5.22 meters width, 6.07 meters length and 3 meters high. Its volume is of 95.05 m^3. It has concrete walls and the floor is covered with a rubber carpet. Before the measurement all kinds of desks were removed from the room. It's necessary to consider the proximity of the building with the train station. This affects directly the measurements, especially because of the low frequency noise produce by the trains. Figure 3 shows the top view of the room.

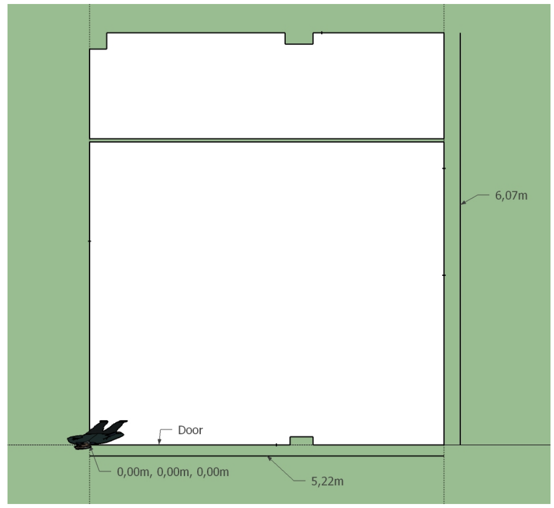

Figure 3: Measurement location - Annex 2.

A measurement of temperature, humidity and static pressure was impossible to obtain, due of the lack of instruments. But an approximation with meteorological services was made. The temperature register in that moment was between 20 and 22°C, the humidity at 60% and the static pressure was around 101.32 Pa. These values were in the permissible range for measurement expressed on the standard.

4. RESULTS

4.1 Reverberation time

For the reverberation time measurement, according to the ISO 354 standard, an omnidirectional source and 8 microphone positions were used [4]. The positions of the sound source are detailed on table 7.

Table 7: RT measurement and the sound source positions.

Sound source positions (in meters)			
	x	**y**	**z**
Position 1 (S1)	3.8	1.12	1.576
Position 2 (S2)	2.83	3.24	1.39

Table 8 shows the microphone positions for each location of the sound source.

Table 8: Microphones positions for RT measurement.

Microphones for S1 (in meters)			
Microphone	**x**	**y**	**z**
P1	1.76	1.56	1.11
P2	1.66	3.32	1.29
P3	2.63	4.35	1.33
P4	3.96	3.49	1.1
P5	1.28	2.59	1.17
P6	1.54	4.72	1.63
P7	2.92	3.28	1.59
P8	3.39	4.95	1
Microphones for S2 (in meters)			
Microphone	**x**	**y**	**z**
P1	1.28	2.59	1.17
P2	1.54	4.72	1.63

P3	2.92	3.28	1.59
P4	3.39	4.95	1
P5	1.28	1.78	1.67
P6	1.19	4.94	1.32
P7	4.29	5.15	1.88
P8	3.43	1.19	1

Before recording the sine sweep from the omnidirectional source, the microphones were calibrated. The exponential sine sweep was generated and then the inverse filter was created, with the software Adobe Audition. The noise recorded by the 8 different microphones positions were convolved with the impulse response of the room with the software Audacity and Aurora plug-in. Then, T60 values by third octave bands were calculated.

Using the equation 17 the absorption area for every frequency band was calculated.

$$A = \frac{55.26}{c}\frac{V}{T60} \tag{17}$$

Then, the absorption coefficient was obtained, using the equation 4.

The results of T60 can be observed in figure 4. The values of absorption area and absorption coefficient are presented in Annex 3. The qualification of the room was made by the conditions presented at item 2.2, corresponding to ISO 3741 standard.

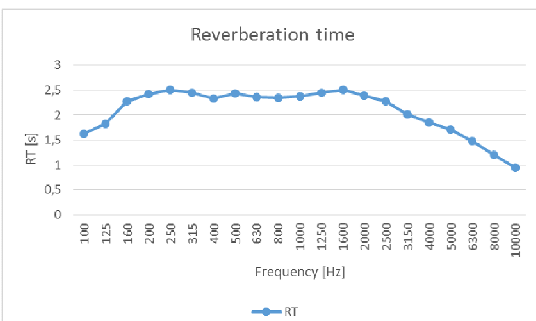

Figure 4: Reverberation time measurement results.

The qualification, according to the characteristics of the room, is correct from 200 Hz to 4000 Hz.

4.2 Sound power measurement

4.2.1 Positions and background noise considerations

After the reverberation time results were calculated and analyzed, the microphones were replaced by sound level meters. They were configured and then calibrated, obtaining the calibration factors detailed in section 3.2.

For the sound pressure measurement, 3 source positions and 8 microphone positions for every source position were used. The positions were chosen by considering the distances required for the qualification of the measurement, presented at item 2.3. They are presented in table 9 and 10.

Table 9: Sound source positions for the sound power measurement.

Sound source positions (in meters)			
	x	y	Z
Position 1 (S1)	3.42	4.07	0
Position 2 (S2)	1.60	3.00	0
Position 3 (S3)	4.21	2.51	0

Table 10: Microphone positions for the sound power measurement.

Microphones for S1 (in meters)			
Microphone	**x**	**y**	**z**
P1	3.55	4.34	1.22
P2	1.8	4.35	1.27
P3	3.68	1.68	1.05
P4	1.95	1.66	1
P5	3	1.76	1.17
P6	2	4.13	1
P7	3.68	3.94	1.5
P8	1.42	2.69	1.45
Microphones for S2 and S3(in meters)			
Microphone	**x**	**y**	**z**
P1	1.88	1.19	1.15
P2	1.8	4.35	1.27
P3	3.68	1.68	1.05
P4	1.95	1.66	1
P5	3.18	1.32	1.16
P6	1.52	3.69	1.57
P7	3.92	4.08	1.29
P8	2.61	2.38	1.45

In figure 5, the configuration of 4 microphone positions can be observed.

Figure 5: Sound power measurement. Four microphone positions and the vacuum cleaner.

For each position the source noise and the background noise were measured. The results of the 8 sound level meters positions were averaged, for each frequency band. Then the difference between the averaged noise sound pressure level and the averaged background noise sound pressure level was calculated. The qualification of each frequency band was analyzed considering the requirements of the ISO 3741 standard. These results are presented in annex 3.

For frequency bands from 200 Hz to 4000 Hz, which are the frequency bands considered for the present measurement, the background noise does not represent a problem.

4.2.2 Typical deviation

The typical deviation was calculated by equation 11; the results are presented at table 11.

Table 11: Typical deviation.

Central Frequency [Hz]	Typical Deviation S_M	Qualification
50	4.08	Not Qualified
63	1.67	Not Qualified
80	2.09	Not Qualified
100	0.84	Qualifies
125	1.12	Qualifies
160	4.09	Not Qualified
200	2.72	Not Qualified
250	1.60	Qualifies
315	1.18	Qualifies
400	0.73	Qualifies
500	1.23	Qualifies
630	1.34	Qualifies
800	0.65	Qualifies
1000	0.78	Qualifies
1250	0.89	Qualifies
1600	0.76	Qualifies
2000	0.53	Qualifies
2500	0.81	Qualifies
3150	0.43	Qualifies
4000	0.64	Qualifies
5000	1.67	Not Qualified
6300	0.97	Qualifies
8000	1.17	Not Qualified
10000	3.77	Not Qualified

To avoid the room contributions in the results, 2 sound level meter positions were added, and 3 sound source positions were used.

4.2.3 Sound power level calculations

For each sound source position, the background noise correction was calculated, and then the correction of the sound pressure level measurement for every frequency band was made. After that, the corrections C1 and C2, described at item 2.1, were calculated.

The sound power level for each frequency band was calculated using equation 5. These values are presented in annex 3.

In order to calculate the global sound power level, the frequency band values were averaged. To obtain the sound power level with A weigh, every frequency band was calculated and then averaged. The results of the 3 different sound source positions are presented at table 12.

Table 12: Sound power levels of the 3 sound source positions.

	Position 1	Position 2	Position 3
Global sound power level (dB)	87.92	85.09	83.93
Global sound power level - A weighting (dBA)	85.99	83.32	82.11

The global sound power level obtained is shown at table 13:

Table 13: Global sound power level measured.

Global sound power level	**85.98 dB**
Global sound power level A weighting	**84.12 dBA**

5. DISCUSSION

Since there wasn't a reverberant chamber available for the measurements, the room with the most similar characteristics was a classroom from the University. Although the results showed were similar to the conditions of a reverberant room, the measurement would had a larger frequency range if the room had been larger and with a smaller absorption coefficient.

Another limitation to consider is that the background noise changed constantly because of the train station near the University. The difference sometimes was of 10 dB. In some cases the background noise is higher than the measurement possibly because of this issue. A possible correction would have been to make more background noise measurements or to wait until the background noise level was low enough to measure both, the vacuum noise and the background noise considered.

Also the lack of some instrument to measure different variables and determine the exactly deviation of the measurement procedure was another limitation. These variables were temperature, static pressure, among others. This lack of instruments doesn't involve a big change on the results, but implies an improve of the reliability.

6. CONCLUSIONS

Sound power level measurements of a commercial vacuum cleaner were made, according to ISO 3741 standard.

Although some limitations discussed at item number 5 were considered, the results obtained were similar those provided by the manufacturer. The technical specifications of the machine shows a level of 82 dB. The sound power level obtained for the present paper was 85.98 dB. The difference between these values could be explained due to the limitations and possible errors of the measurements made. Besides, it doesn't exist an explanation of the procedure made by the manufacturer, in order to obtain the sound power level of the vacuum cleaner. That's the reason why comparing these values could be complex.

It's important to consider that the machine that's been measured is not new, and several repairs had been made.

It was not possible to achieve more precision at the measurement due to the lack of the resources and because the chamber was not a reverberant room. So the results are not as reliable as the standard requires.

However, considering a shorter frequency range, the results appear to be acceptable. The conditions mentioned can be accepted to measure the sound power level for a medium or small machines, with a deviation around 5 dB for each frequency, or lower.

Thus improving some factors can achieve qualification of measurement conditions more adequately to the standard.

7. REFERENCES

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[3] ISO 3741:2010 (E). "*Acoustics - Determination of sound power levels of noise sources using sound pressure. Precision methods for reverberation test rooms*". 2010.

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Annex 1
Answers

This section presents questions to emphasize a few topics.

1. When a noise source is considered tonal? Reference in relation to a standard.

The Argentinian Standard IRAM 4062 explains that the presence of tonal components in noise can be observed when the equivalent sound level (Leq), in an specific band, exceeds the levels of the adjacent bands in:

a) 15 dB for frequencies between 25 Hz and 125 Hz;
b) 8 dB for frequencies between 160 Hz and 400 Hz;
c) 5 dB for frequencies between 500 Hz and 10 000 Hz.

2. What conclusions can you extract when comparing the information provided by the manufacturer and the results?

The result of the measurements and the manufacturer specifications were compared. Their values were very close to each other. The disadvantage of the manufacturer was the lack of information about the measurement procedure. But, due to the similarity between the results, it can be concluded that the manufacturer's specifications were according to the standard.

In the order hand, if the manufacturer's method was right, the new value can be interpreted as a deterioration due to aging of the machine.

3. Which is the uncertainty of the measured results?

The uncertainty of the measured results was approximated. The maximum deviation was around 5dB in a few frequencies. For other frequencies, the deviation does not exceed the unit. The specified values of each frequency and the calculation method were presented.

4. What are the most significant error factors of the measurement and how to associate them to the uncertainty obtained

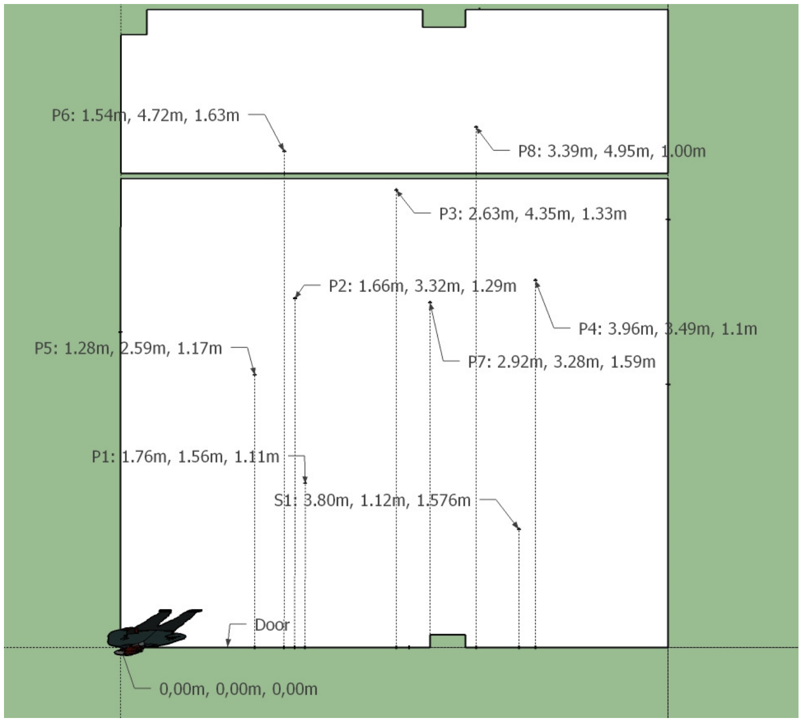
The most influential errors in the measurement to be considered can be included in two groups: human mistakes or ambient factors.
In the first group can be mentioned errors like:

- Not representative microphone location: due to the not homogenous reverberant field on the chamber, better microphone locations can be chosen in order to obtain most representative results of the sound level of the machine.
- Insufficient number of microphone positions: due to the deviation of the results, a bigger number of locations could improve the reliability of the results.

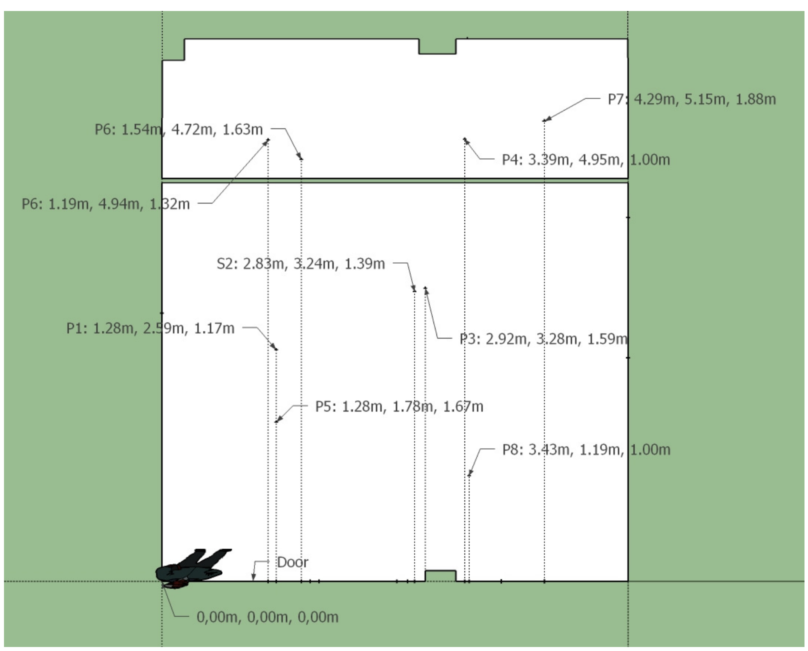
In the second group, can be mentioned errors like:

- An unstable background noise.
- High level background noise: close to the limit values of the standard.
- Reverberant field is not completely homogeneous.

Annex 2
Reverberation time measurement: Sound source and microphone positions



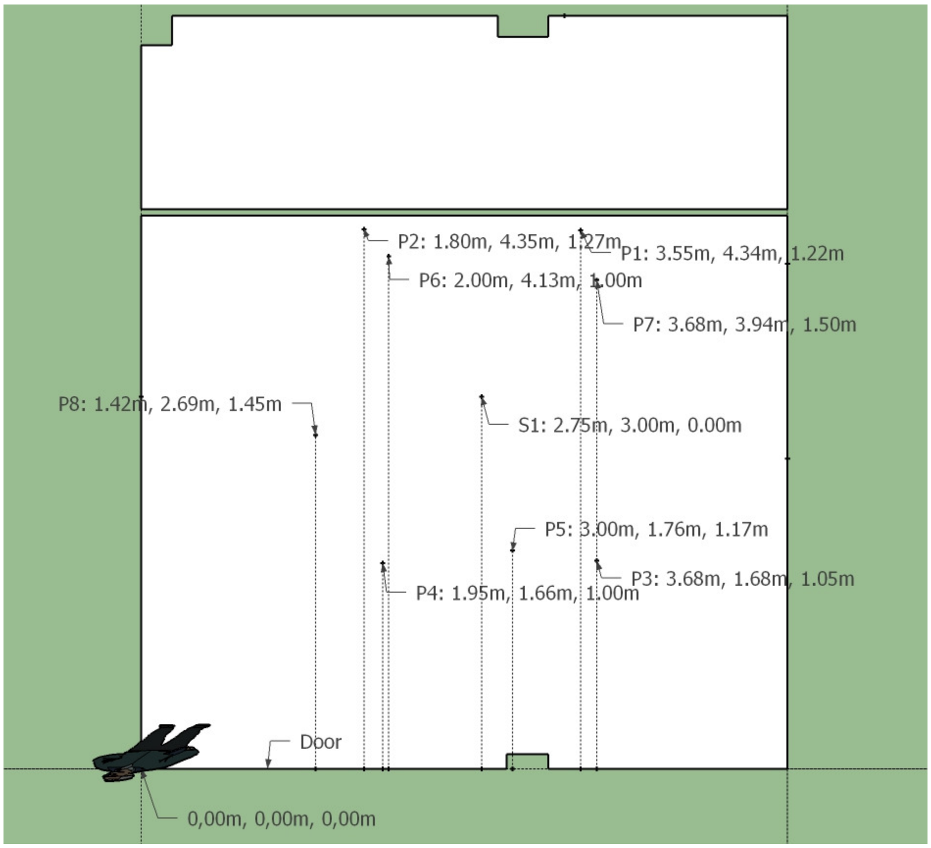
First sound source position.



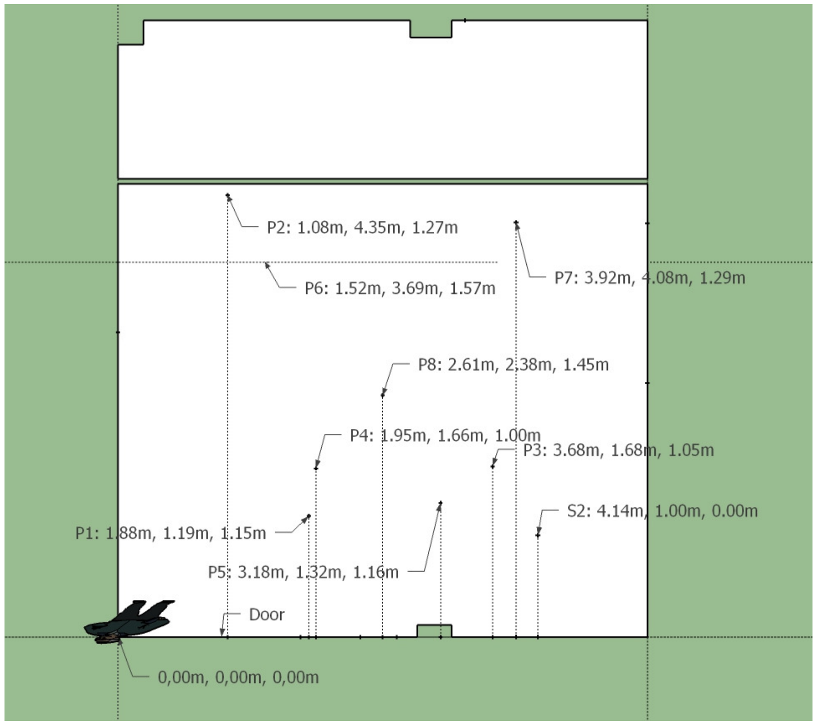
Second sound source position.

Sound power measurement: Sound source and microphone positions

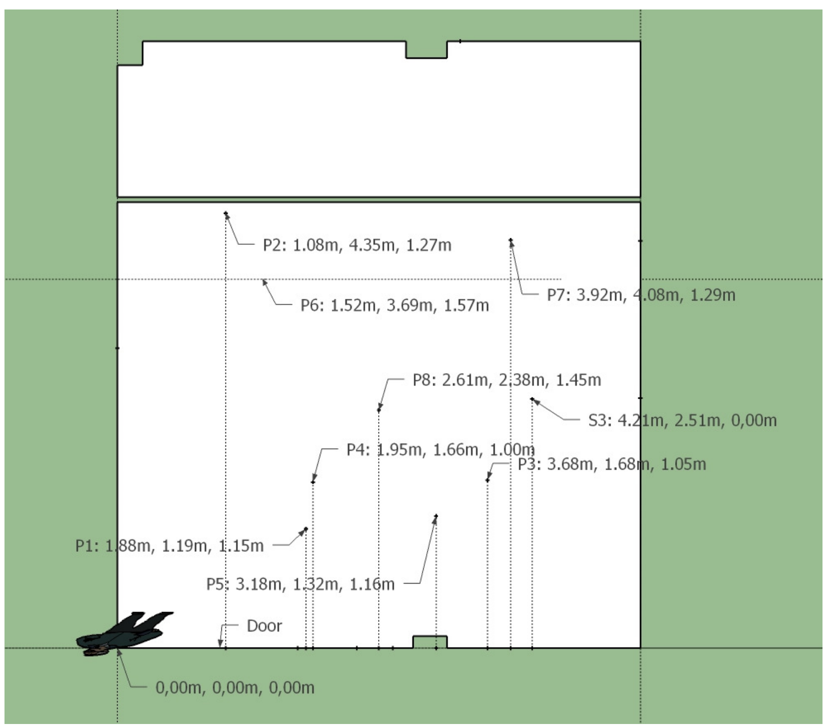
The sound source and microphone positions for the sound power measurement made at University's class room "Annex 2" are presented. Sound source positions are expressed with an "S" and the microphones with "P".



First sound source position and the firsts eight microphone position.



Second sound source position, and the following eight microphones positions.



Third sound source position and eight microphones positions.

Annex 3
Tables of results

Central Frequency(Hz)	T60	Absorption Area A	Absorption coefficient	Qualification
50	1.281	12.042	0.092	Not Qualified
63	1.165	13.240	0.101	Not Qualified
80	1.817	8.488	0.065	Not Qualified
100	1.625	9.489	0.072	Not Qualified
125	1.822	8.463	0.065	Not Qualified
160	2.269	6.796	0.052	Not Qualified
200	2.423	6.366	0.049	Qualifies
250	2.498	6.174	0.047	Qualifies
315	2.444	6.311	0.048	Qualifies
400	2.335	6.604	0.050	Qualifies
500	2.436	6.330	0.048	Qualifies
630	2.361	6.532	0.050	Qualifies
800	2.344	6.578	0.050	Qualifies
1000	2.373	6.498	0.050	Qualifies
1250	2.450	6.296	0.048	Qualifies
1600	2.509	6.147	0.047	Qualifies
2000	2.386	6.463	0.049	Qualifies
2500	2.268	6.799	0.052	Qualifies
3150	2.009	7.674	0.059	Qualifies
4000	1.849	8.339	0.064	Not Qualified
5000	1.711	9.014	0.069	Not Qualified
6300	1.477	10.442	0.080	Not Qualified
8000	1.204	12.804	0.098	Not Qualified
10000	0.952	16.200	0.124	Not Qualified

Results obtained from the reverberation time measurements.

Central Frequency(Hz)	Averaged SPL L'pi(ST) P.1	Averaged background Noise SPL Lpi(B) P.1	Difference	Qualification
50	37.39	39.94	-2.55	Not Qualified
63	39.29	41.38	-2.09	Not Qualified
80	38.37	44.20	-5.83	Not Qualified
100	47.57	44.42	3.15	Not Qualified
125	48.02	37.81	10.21	Qualifies
160	56.27	32.27	24.01	Qualifies
200	62.58	32.35	30.23	Qualifies
250	66.33	34.95	31.39	Qualifies
315	62.21	32.90	29.30	Qualifies
400	59.87	29.72	30.15	Qualifies
500	73.88	29.56	44.33	Qualifies
630	80.47	30.88	49.59	Qualifies
800	65.24	27.29	37.95	Qualifies
1000	67.70	31.38	36.32	Qualifies
1250	66.05	29.54	36.51	Qualifies
1600	65.37	26.19	39.18	Qualifies
2000	64.74	24.17	40.57	Qualifies
2500	62.11	24.07	38.04	Qualifies
3150	61.12	19.90	41.23	Qualifies
4000	60.15	20.57	39.58	Qualifies
5000	62.83	23.97	38.87	Qualifies
6300	61.32	21.41	39.91	Qualifies
8000	57.49	22.42	35.07	Qualifies
10000	63.18	25.08	38.09	Qualifies

Results obtained considering the background noise for the position number 1.

Central Frequency(Hz)	Avereged SPL L'pi(ST) P.2	Averaged background Noise SPL Lpi(B) P.2	Difference	Qualification
50	37.39	39.94	-2.55	Not Qualified
63	39.29	41.38	-2.09	Not Qualified
80	38.37	44.20	-5.83	Not Qualified
100	47.57	44.42	3.15	Not Qualified
125	48.02	37.81	10.21	Qualifies
160	56.27	32.27	24.01	Qualifies
200	62.58	32.35	30.23	Qualifies
250	66.33	34.95	31.39	Qualifies
315	62.21	32.90	29.30	Qualifies
400	59.87	29.72	30.15	Qualifies
500	73.88	29.56	44.33	Qualifies

630	80.47	30.88	49.59	Qualifies
800	65.24	27.29	37.95	Qualifies
1000	67.70	31.38	36.32	Qualifies
1250	66.05	29.54	36.51	Qualifies
1600	65.37	26.19	39.18	Qualifies
2000	64.74	24.17	40.57	Qualifies
2500	62.11	24.07	38.04	Qualifies
3150	61.12	19.90	41.23	Qualifies
4000	60.15	20.57	39.58	Qualifies
5000	62.83	23.97	38.87	Qualifies
6300	61.32	21.41	39.91	Qualifies
8000	57.49	22.42	35.07	Qualifies
10000	63.18	25.08	38.09	Qualifies

Results obtained considering the background noise for the position number 2.

Central Frequency(Hz)	Avereged SPL L'pi(ST) P.3	Averaged background Noise SPL Lpi(B) P.3	Difference	Qualification
50	40.24	39.65	0.59	Not Qualified
63	39.26	41.27	-2.01	Not Qualified
80	36.75	44.16	-7.42	Not Qualified
100	44.38	44.40	-0.02	Not Qualified
125	47.42	37.58	9.84	Qualifies
160	53.76	31.87	21.89	Qualifies
200	58.50	32.15	26.34	Qualifies
250	61.51	34.71	26.81	Qualifies
315	57.49	32.69	24.80	Qualifies
400	56.96	29.55	27.41	Qualifies
500	73.29	29.42	43.87	Qualifies
630	79.74	30.73	49.02	Qualifies
800	62.52	27.12	35.41	Qualifies
1000	64.67	31.17	33.50	Qualifies
1250	63.80	29.30	34.50	Qualifies
1600	63.18	26.03	37.15	Qualifies
2000	62.22	23.90	38.31	Qualifies
2500	60.54	23.57	36.97	Qualifies
3150	58.49	19.40	39.10	Qualifies
4000	57.17	20.06	37.10	Qualifies
5000	59.68	23.45	36.23	Qualifies
6300	58.58	20.94	37.64	Qualifies
8000	54.50	21.96	32.54	Qualifies
10000	60.02	24.59	35.42	Qualifies

Results obtained considering the background noise for the position number 3.

Central Frequency(Hz)	Corrected SPL measurement Lpi(ST)	Correction C1	Correction C2	Sound Power Level
50	35.96	-0.13	-0.02	44.36
63	36.47	-0.13	-0.02	44.80
80	36.79	-0.13	-0.02	42.56
100	56.39	-0.13	-0.02	62.30
125	47.46	-0.13	-0.02	52.50
160	57.65	-0.13	-0.02	61.36
200	58.79	-0.13	-0.02	61.97
250	59.88	-0.13	-0.02	62.71
315	61.03	-0.13	-0.02	63.78
400	59.45	-0.13	-0.02	62.26
500	79.01	-0.13	-0.02	81.52
630	83.43	-0.13	-0.02	85.98
800	65.64	-0.13	-0.02	68.15
1000	68.02	-0.13	-0.02	70.41
1250	67.92	-0.13	-0.02	70.12
1600	65.90	-0.13	-0.02	67.94
2000	64.88	-0.13	-0.02	67.13
2500	62.77	-0.13	-0.02	65.22
3150	60.82	-0.13	-0.02	63.80
4000	60.23	-0.13	-0.02	63.58
5000	63.53	-0.13	-0.02	67.23
6300	61.53	-0.13	-0.02	65.90
8000	57.53	-0.13	-0.02	62.85
10000	64.38	-0.13	-0.02	70.84

Sound power level for the position number 1.

Central Frequency(Hz)	Corrected SPL measurement Lpi(ST)	Correction C1	Correction C2	Sound Power Level
50	36.13	-0.13	-0.02	44.53
63	38.03	-0.13	-0.02	46.36
80	37.11	-0.13	-0.02	42.88
100	46.31	-0.13	-0.02	52.22
125	47.59	-0.13	-0.02	52.63
160	56.27	-0.13	-0.02	59.99
200	62.58	-0.13	-0.02	65.75
250	66.33	-0.13	-0.02	69.17
315	62.21	-0.13	-0.02	64.96
400	59.87	-0.13	-0.02	62.68
500	73.88	-0.13	-0.02	76.39

630	80.47	-0.13	-0.02	83.03
800	65.24	-0.13	-0.02	67.74
1000	67.70	-0.13	-0.02	70.09
1250	66.05	-0.13	-0.02	68.25
1600	65.37	-0.13	-0.02	67.42
2000	64.74	-0.13	-0.02	66.98
2500	62.11	-0.13	-0.02	64.56
3150	61.12	-0.13	-0.02	64.11
4000	60.15	-0.13	-0.02	63.49
5000	62.83	-0.13	-0.02	66.53
6300	61.32	-0.13	-0.02	65.69
8000	57.49	-0.13	-0.02	62.82
10000	63.18	-0.13	-0.02	69.63

Sound power level for the position number 2.

Central Frequency(Hz)	Corrected SPL measurement Lpi(ST)	Correction C1	Correction C2	Sound Power Level
50	39.19	-0.13	-0.02	47.59
63	38.27	-0.13	-0.02	46.60
80	35.68	-0.13	-0.02	41.45
100	43.17	-0.13	-0.02	49.07
125	46.94	-0.13	-0.02	51.98
160	53.76	-0.13	-0.02	57.48
200	58.50	-0.13	-0.02	61.67
250	61.51	-0.13	-0.02	64.35
315	57.49	-0.13	-0.02	60.24
400	56.96	-0.13	-0.02	59.78
500	73.29	-0.13	-0.02	75.80
630	79.74	-0.13	-0.02	82.30
800	62.52	-0.13	-0.02	65.03
1000	64.67	-0.13	-0.02	67.06
1250	63.80	-0.13	-0.02	66.00
1600	63.18	-0.13	-0.02	65.23
2000	62.22	-0.13	-0.02	64.46
2500	60.54	-0.13	-0.02	62.99
3150	58.49	-0.13	-0.02	61.47
4000	57.17	-0.13	-0.02	60.52
5000	59.68	-0.13	-0.02	63.37
6300	58.58	-0.13	-0.02	62.95
8000	54.51	-0.13	-0.02	59.83
10000	60.02	-0.13	-0.02	66.47

Sound power level for the position number 3.