TP1 - ACOUSTIC SOUND POWER MEASUREMENT

Sebastián Carro Morais

National University of Tres de Febrero, Sound Engineering, Caseros, Buenos Aires, Argentina
email: sebastiancarrom@gmail.com

Alejo Cohen

National University of Tres de Febrero, Sound Engineering, Caseros, Buenos Aires, Argentina
email: alecohen00@gmail.com

Leonardo Sandez

National University of Tres de Febrero, Sound Engineering, Caseros, Buenos Aires, Argentina
email: leito.-mdp@hotmail.com

Matías Vereertbrugghen

National University of Tres de Febrero, Sound Engineering, Caseros, Buenos Aires, Argentina
email: matias.veree@gmail.com

This work presents the determination and comparison of the sound power levels of three commercial models of hand blenders. The direct method of the ISO 3743-2 standard was applied in a classroom whose acoustic characteristics, including the reverberation time (measured according to ISO 354), were previously characterized. The analysis was conducted in one-third octave bands to obtain the sound power spectrum and the overall A-weighted level (L_{WA}) for each device. The results show that the Liliana model had the highest emission level (L_{WA} = 86.8 dBA). The Top House (81.4 dBA) exhibited significant tonal components at 315 Hz and 630 Hz, and the Generic (78.4 dBA) model showed the lowest power levels. It is concluded that whilst the method allowed for a relative comparison between the devices, the deviations of the test environment from the standard's requirements limit the absolute validity of the results and highlight the importance of using qualified rooms for Grade 2 engineering measurements.

Keywords: Acoustic Power, ISO 3743-2, Household Appliance, Noise.

1. Introduction

Sound power is an intrinsic property of a sound source that describes the amount of acoustic energy it emits, regardless of the environment in which it is located. Unlike sound pressure level, sound power does not depend on distance or the enclosure, which allows for an objective comparison of different sources. Many manufacturers specify the sound power of their products; however, the conditions under which these measurements were taken are not always specified. For this reason, it is pertinent to experimentally verify these specifications through controlled tests.

The main objective of this study is to determine and compare the sound power levels of three models of hand blenders, commonly known as immersion blenders. To perform this characterization, the engineering method described in the ISO 3743-2 standard [12] will be applied, which is designed for determining the sound power levels of small, movable noise sources in reverberant fields. The measurements were conducted in Classroom 301 at the Caseros II campus of the National University of Tres de Febrero (UNTREF).

The analysis of the recorded data will allow for the determination of sound power levels by one-third octave bands and overall values, with both A-weighting (to approximate human auditory perception) and Z-weighting (linear). The results will be used to establish a comparative profile of the emissions of each device and will be compared with the scarce technical information publicly available from the manufacturers.

2. State of the Art

The measurement of the sound power of home appliances represents a field of research of considerable importance, due to the impact of noise on quality of life and the need to adhere to international regulations and standards.

In 1975, Jackson and Leventhall [5] analyzed the noise spectrum of various home appliances in domestic settings, such as kitchens, living rooms, and bathrooms. They concluded that food preparation devices, like blenders and mixers, generated the highest sound levels, while washing machines, though less powerful, were equally annoying due to the duration of their cycles.

In the following decades, sound measurement and labeling methods evolved significantly. Altinsoy [6] approached labeling from a psychoacoustic perspective, showing that the perception of noise differs from its objective power. His studies with vacuum cleaners and dishwashers indicated that levels above 35 sones were perceived as annoying by users, with no differences based on gender.

Among the standards that govern the determination of sound power for all types of machinery and equipment is the ISO 3740 series [2], whose variants establish procedures for measurement in different acoustic environments. Each one establishes a measurement method that offers a particular level of precision, which in turn implies more or less demanding requirements in terms of instrumentation and the characteristics of the test rooms necessary for its implementation.

According to the recommendations of the Occupational Safety and Health Administration (OSHA) of the United States [3], exposure to noise levels equal to or greater than 85 dB can cause hearing damage, depending on the duration. For example, at 90 dB, the maximum suggested exposure time is only 2 hours. This problem is exacerbated in environments such as kitchens, where the prolonged use of appliances and the presence of reflective surfaces intensify sound exposure. In response to this concern, the European Union implemented regulations requiring the inclusion of acoustic information on the energy efficiency labels of home appliances [4].

In Argentina, the measurement of sound power in home appliances is not regulated by mandatory legislation. There are no legal requirements that compel manufacturers to declare noise levels as a condition for the commercialization of these products in the national market or to present it on the energy efficiency label [10]. However, voluntary technical standards do exist that establish the appropriate procedures for such an evaluation.

The IRAM 4124 standard [7] defines the general methods for measuring airborne noise in domestic appliances and similar equipment, adapting the international standard IEC 60704-1 [9]. In turn, the IRAM 2404-2 standard [8] establishes complementary procedures for determining sound power levels and sound energy levels of stationary noise sources, based on the ISO 3744, ISO 3745, and ISO 3746 standards.

Noise levels in blenders can vary significantly depending on the model and motor design. For countertop blenders, serving as a reference for hand blenders, the sound pressure level is measured in decibels dBA, and typical values for domestic blenders range between 70 and 80 dBA in quieter models, while more powerful or budget models can reach 90 dBA or more. These differences are due to both the motor's power and the quality of the acoustic insulation and materials used in the device's housing [13].

In the specific case of hand blenders, a wide variability is observed in the noise levels declared by manufacturers, attributable to differences in the structural and mechanical design of the devices. For example, the SENCOR brand features models with sound emission levels as disparate as 48 dBA [14] and 82 dBA [15], without specifying the measurement method used. This difference reflects how factors such as motor power, the type of blade coupling, the housing insulation, and the airflow design can significantly affect noise generation, even within the same type of home appliance.

3. Theoretical Framework

3.1 Reverberation Time and its Measurement (ISO 354)

For the present study, the measurement of RT is a crucial step, as its value is an essential input for the calculation of sound power. For this reason, the measurement procedure is based on the recommendations of the ISO 354:2003 standard [1].

This standard defines RT (T_{60}) as the time required for the sound pressure level in a room to decay by 60 decibels (dB) after the sound source has stopped emitting. To measure it, the standard establishes the following guidelines:

- Integrated impulse response method: It uses the room's response to a sound impulse (such as that produced by a starting pistol, a balloon, or sweep signals) and processes it.
- Test Setup: To ensure adequate spatial sampling of the sound field, a minimum of 12 source and microphone position combinations is required (e.g., 2 source positions and 6 microphone positions). The standard also specifies minimum distances: microphones must be at least 1.5 m apart from each other and 1 m from any surface, while sources must be at least 3 m apart.
- Evaluation of the Decay Curve: The reverberation time is calculated from the slope of the decay curve. The evaluation of this slope must be performed over a dynamic range of 20 dB, starting 5 dB below the initial level and ending at least 10 dB above the background noise level.

3.2 Tonal Noise

Tonal noise is characterized by the presence of specific and clearly defined frequency components that stand out from the general noise spectrum. These tonal components are often perceived as tones or peaks in a frequency analysis and can be more annoying and perceptible to the human ear compared to broadband or random noise. According to the IRAM 4062 standard [19], the presence of tonal noise components is confirmed when the continuous equivalent sound level in one band exceeds that of both adjacent bands by a certain level difference, which varies with frequency as shown in Table 1.

Table 1: Criteria to distinguish tonal noise.

Center Frequency (Hz)	**Difference (dB)**
25 – 125	15
160 – 400	8
500 – 10000	5

3.3 Sound Power Measurement per ISO 3743-2

3.3.1 Justification of the Test Method

Given that the objective of this work is to characterize the sound power emitted by a small, movable source, the ISO 3743-2 standard is selected as the methodological framework, as it provides a Grade 2 (Engineering) level of precision. The direct method described in this standard was chosen because it does not require the use of a reference sound source, thus suiting the available equipment.

Additionally, this standard applies to reverberant chambers, which is the type of environment that the measurement room used for this test seeks to approximate.

3.3.2 Reverberation Chamber Requirements

According to Chapter 4 of the ISO 3743-2 standard, the test environment must meet several strict requirements to be considered a "special reverberation test room," which has the following characteristics:

- Volume: The volume of the chamber must be at least 70 m^3. If frequencies in the 4 kHz and 8 kHz bands are being measured, the volume should not exceed 300 m^3.
- Reverberation Time: The RT of the chamber, T, must be within the limits defined by the following expression:

  $$0.9 \cdot R \cdot T_{nom} \leq T \leq 1.1 \cdot R \cdot T_{nom} \tag{1}$$

  where the reverberation parameter, R, is calculated as:

  $$R = 1 + \frac{257}{fV^{1/3}} \tag{2}$$

  The nominal reverberation time of the chamber, T_{nom} (defined as the reverberation time T at 1 kHz), must be between 0.5 s and 1.0 s. For the measurement of this parameter, the ISO 3743-2 standard indicates that the methods described in the ISO 354 standard should be used.
- Surfaces: The floor must be acoustically reflective, with a sound absorption coefficient of less than 0.06. None of the other surfaces (walls and ceiling) should have absorption properties that differ significantly from one another.
- Background Noise: The sound pressure levels of the background noise must be at least 4 dB, and preferably more than 10 dB, lower than the sound pressure level produced by the source under test.

3.3.3 Source Installation and Operation

The standard specifies how the source should be installed and operated for the test. The source must be installed on the floor of the chamber at a minimum distance of 1 meter from any wall. The exact position of the source in the chamber must be described in the test report. If a typical mounting method exists for the equipment, it must be used or simulated. Precautions must be taken to ensure that the mounting structure does not radiate significant acoustic energy. The source should operate, if possible, in a manner characteristic of its normal use. One or more specific operating conditions must be selected (e.g., full load, no load, or the condition of maximum noise emission) and kept constant throughout the measurement. These conditions must be described in the test report.

3.3.4 Measurement Procedure

To measure acoustic power using the selected method, sound pressure levels are recorded at multiple points on a hemispherical surface, centered on the acoustic source, which is placed on the reflective floor of the room. At the same time, minimum distances are established for the placement of microphones. No position should be less than $\lambda/4$ from a chamber surface, nor less than $d_{min} = 0.3V^{1/3}$ from the noise source. The distance between any two microphone positions must be at least $\lambda/2$. The minimum number of measurement points is determined through an iterative procedure. It begins by measuring the sound pressure levels (L_{pi}) at $n = 6$ positions and calculates the spatial standard deviation of the measurements, s_M, according to:

$$s_M = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(L_{pi} - \overline{L_p})^2} \tag{3}$$

Using the value of s_M, one refers to Table 4 of the standard to determine the minimum number of microphone positions and source locations required to achieve the desired precision.

The measurement duration at each point must be at least 5 s if an integrator is used. If a moving microphone is used, the total path time must be at least 30 s for frequency bands below 160 Hz and 10 s for higher bands.

3.3.5 Calculation of Sound Power Level

First, the average sound pressure level in the room, $\overline{L_p}$, is calculated by energetically averaging the measurements from the n points:

$$\overline{L_p} = 10 \lg \left[\frac{1}{n} \sum_{i=1}^{n} 10^{0.1 L_{pi}} \right] \tag{4}$$

Then, the direct method formula is applied to obtain the sound power level, L_W:

$$L_W = \overline{L_p} - 10 \lg \left(\frac{T_{nom}}{T_0} \right) + 10 \lg \left(\frac{V}{V_0} \right) - 13 \text{ dB} \tag{5}$$

Where V is the volume of the chamber, T_{nom} is its nominal reverberation time, $T_0 = 1$ s, and $V_0 = 1$ m^3.

3.3.6 Criterion for Tonal Noise Detection

To determine the possible presence of tonal components based on the spatial standard deviation, s_M, calculated with Equation 3.

- If $s_M < 2.3$ dB, the spectrum is considered broadband.
- If 2.3 dB $\leq s_M \leq 4$ dB, narrowband noise components may exist.
- If $s_M > 4$ dB, a discrete tone is likely present in the analyzed frequency band.

3.3.7 Background Noise Correction

The standard establishes a criterion for the background sound pressure level to ensure the validity of the measurements. Ideally, the background noise level should be at least 10 dB lower than the level measured with the sound source in operation.

If the difference between the level measured with the source operating and the background noise level is between 4 dB and 10 dB, a correction must be applied to the measured sound pressure levels. This correction, which is subtracted from the measured value, is determined from Table 5 of the standard, reproduced in Table 2.

Table 2: Corrections for background sound pressure levels (ISO 3743-2, Table 5).

Difference $L_p - L_{\text{noise}}$ [dB]	**Correction to be subtracted [dB]**
4	2.0
5	2.0
6	1.0
7	1.0
8	1.0
9	0.5
10	0.5
> 10	0.0

If the difference is less than 4 dB, the standard indicates that the measurement precision is significantly reduced, and data should not be recorded unless it is explicitly stated that the background noise requirements have not been met.

3.3.8 Measurement Uncertainty

Section 1.4 of the standard quantifies the method's uncertainty through the standard deviation of reproducibility, σ_R. These values represent the expected dispersion if the same source were measured in different laboratories compliant with the standard.

- 5.0 dB for the 125 Hz band.
- 3.0 dB for the 250 Hz and 8000 Hz bands.
- 2.0 dB for the 500 Hz to 4000 Hz bands.
- 2.0 dB for A-weighting (for sources with a relatively flat spectrum).

The standard indicates that for a normal distribution, there is a 95% probability that the true value lies within the interval of $\pm 1.96\sigma_R$ of the measured value.

3.3.9 Combined Uncertainty Calculation

Since the standard only provides expected uncertainty values, its expression is obtained through error propagation, assuming the variables are independent. For Equation 5, and neglecting the uncertainty associated with the volume measurement, this law takes the following form:

$$u_c^2(L_W) = u^2(\overline{L_p}) + \left(\frac{-10}{T_{nom} \cdot \ln(10)}\right)^2 u^2(T_{nom}) \tag{6}$$

where:

- $u_c(L_W)$ is the combined standard uncertainty of the final sound power level.
- $u(\overline{L_p})$ is the standard uncertainty of the measurement of the average sound pressure level.
- $u(T_{nom})$ is the standard uncertainty of the measurement of the nominal reverberation time.

To solve this equation, it is necessary to determine the standard uncertainties (u) of each of the input measurements.

4. Procedure

The day of the measurement, the temperature was 11ºC and humidity was 78% in the Autonomous City of Buenos Aires [11]. The enclosure used for it was a classroom (301) at the 'Caseros 2' campus of the National University of Tres de Febrero. The following equipment was used to carry out the measurement: 10 Earthworks M-50 Microphones, RME UFC+ Interface with RME Octamicm Svantek SV-30-A Calibrator and Svantek SVAN 959 Sound Level Meter.

To characterize the selected machines by their sound power, measurements of equivalent continuous sound pressure level are carried out using 10 microphone positions in the reverberant room. Three 30 second measurements are taken for each configuration in order to obtain a greater number of samples. Then, using a Python script, the recorded signals are processed to obtain an average sound pressure level (A-weighted and Z-weighted). Subsequently, the sound power level is calculated using Equation 5.

4.1 Devices Under Evaluation

Three types of hand blenders were selected, as shown in Figure 1. One belongs to the Top House brand, another to Liliana, and the brand of the third one is unknown. Each machine model is not specified.

Two of the devices have two blade speed settings: a normal mode and a 'turbo' mode. The third device only has a single speed, which is comparable to the normal modes of the other two. Therefore, the measurements were carried out using this standard operating mode, in order to ensure valid comparisons between measurements, avoiding large discrepancies caused by different speed modes.

(a) Top House's hand blender. (b) Liliana's hand blender. (c) Unknown brand's hand blender.

Figure 1: Hand blenders used for the measurement.

Since the blenders use momentary switches (they must be held down to operate and stop when released), a marble was taped in place under pressure to keep the button pressed. The devices were then turned on and off using the switch of the power strip to which they were connected.

The only device with manufacturer-provided information is the Top House blender (Figure 2). However, it is known that all three were manufactured in Argentina and have been in use for at least 10 years. Besides, none of the manufacturers provide acoustic power data due to the lack of mandatory requirements to disclose such information in the country.

ARTICULO XB-985
LICUADORA DE MANO
MARCA TOP HOUSE
FABRICADO EN.CHINA
IMPORTADOR: COTO CIC SA
PAYSANDU 1842 BS AS - ARGENTINA
CUIT Nº: 30-54808315-6
VOLTAJE / FRECUENCIA: 230 Vac ~ 50 Hz
POTENCIA: 170W
CLASE: II

Figure 2: Top House hand blender data provided by manufacturer.

4.2 Characteristics of the Measurement Room

The room where the measurement is perfomed is chosen to approximate the 'special reverberation test room' requirements outlined in the standard. While many requirements are met, some do not satisfy the specified criteria; these deviations are consequently addressed as measurement limitations in the analysis. In the following section, the room's characteristics are described in detail and compared with the standard's specifications.

Figure 3 shows a diagram of the room. Its volume is $V = 87.35\ m^3$, which meets the standard's requirement. The materials of the surfaces are detailed in Table 3. While the floor satisfies the absorption criteria, the absorption of the walls and ceiling differ, since they are made of different materials. This latter characteristic affects the homogeneity of the sound field and deviates from the standard's recommendation.

The reverberation time (RT) values of the room, used for this study, were obtained from a previous project (Report 11) [18] due to time constraints during the main power measurement session. This pre-existing data is considered applicable as the measurements were conducted in the same room and originally performed in accordance with the ISO 354 standard. The detailed procedure for the RT measurement is presented in the referenced report and those results will be used for the necessary calculations.

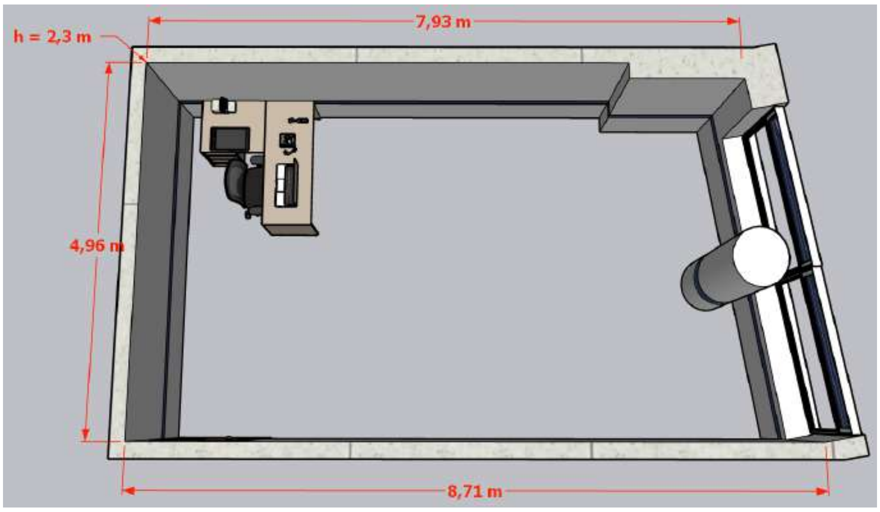


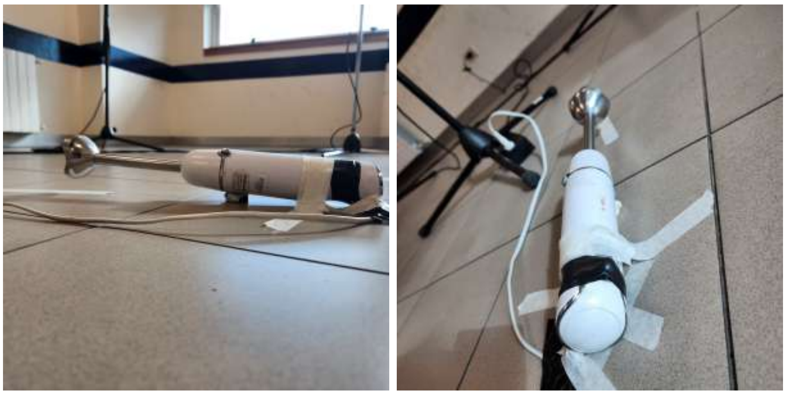
Figure 3: Diagram of the room and dimensions.

Table 3: Materials of the room's surfaces.

Surface	**Material**
External Walls	Plastered hollow brick
Internal Walls	Plaster
Floor	Granite mosaic tile
Ceiling	Painted concrete
Door	Wood
Windows	Glass

4.3 Measurement Setup

The devices under test are fixed directly to the floor, as shown in the arrangement in Figure 4. The purpose of the fixation is to ensure that the device does not move due to the vibrations generated by its own operation. In turn, contact with the floor was limited as much as possible, both for the casing covering the motor and for the other end where the blades are located, leaving only one point of contact in the grip area. This way, the aim is to prevent the noise generation from the blender by hitting the floor when vibrating.



(a) (b)

Figure 4: Method of floor mounting the blender under test.

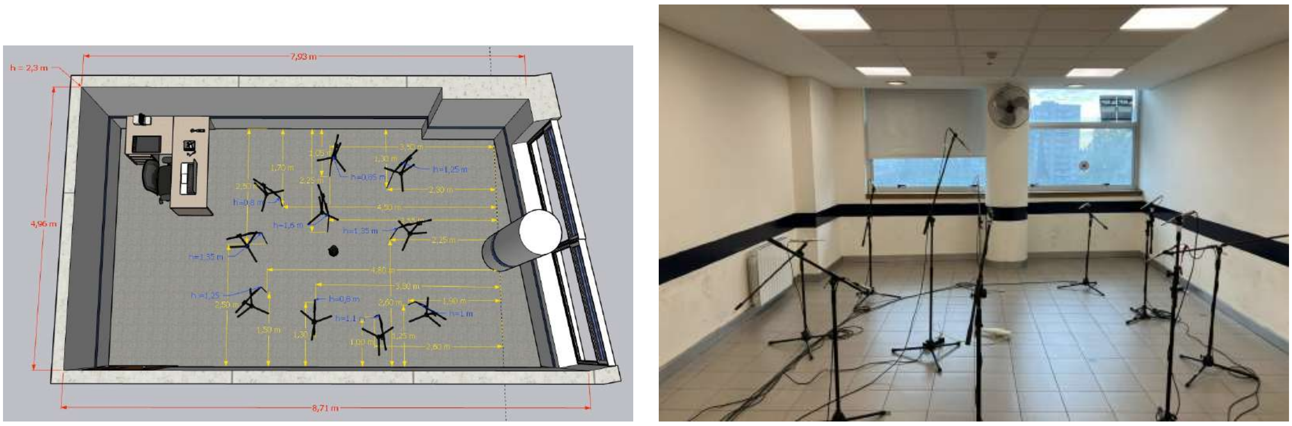
This configuration differs from the standard's recommendation of simulating normal use. However, this approach is chosen to ensure measurement reproducibility for the following reasons.

The typical mode of operation involves the device being held by an operator over a table or marble. This setup introduces two significant sources of variability:

- The acoustic energy reflected in the surface differs depending on its surface, material, and size.
- The operator's body creates a significant and variable acoustic shadow, and its close proximity to the device alters the sound field in an uncontrolled manner.

By fixing the source to the floor, the measurement is decoupled from these variables. This configuration represents a repeatable, 'worst-case' scenario where the source radiates over a large, acoustically reflective plane.

The arrangement of the microphones and the position of the source is shown in Figure 5. (A larger view of the dimensions can be seen in the Figure12 in the Annex). Between each measurement, the device is rotated by $120°$. The standard does not specify rotating the device; however, this step is introduced to average the source's directional radiation pattern. This procedure is considered particularly important for obtaining a representative result in a room with non-homogeneous surfaces, as is the case in this study.



(a) Sketch of the microphone layout in the room.

(b) Image of the real measurement.

Figure 5: Setup of the measurement. Microphones positions surrounding the source.

The distance between the source and all microphone positions is set to 1.5 m. This placement exceeds the minimum required distance (d_{min}) is calculated to be 1.33 m. Furthermore, the minimum distance from any microphone to a room surface is maintained at 1.0 m. This satisfies the standard's $\lambda/4$ criterion for all frequencies down to approximately 86 Hz.

4.3.1 Background Noise and SPL (SNR)

In order to ensure that the signal-to-noise ratio (SNR) meets the standard's specifications, both the background noise and the sound pressure levels (SPL) emitted by each hand blender were measured using the Svantek sound level meter.

Additionally, to obtain the a SPL reference for the measurements, a pure tone of $1\ kHz$ at $94\ dBSPL$ was recorded with the microphones using the Svantek calibrator. A reference level is established for each microphone, ensuring proper calibration during subsequent processing.

This procedure ensures absolute level calibration and compensates for potential differences in microphone sensitivities or preamp gains, allowing all channels to be referenced to the same SPL. As a result, it enables accurate comparisons between measurement results.

Subsequently, the background noise corrections specified by the standard (Table 2) are applied to the measurements, when applicable.

5. Results and Analysis

5.1 Reverberation Time (RT)

Figure 6 shows the measured RT curve normalized (T/T_{nom}) compared against the constraints established by the standard in Equation 1. The normal reverberation time curve in seconds can be seen in the Annex, Figure 14. Red and green curves indicate the upper and lower ISO standard limits, and the vertical purple line the Schroeder Frequency of the room.

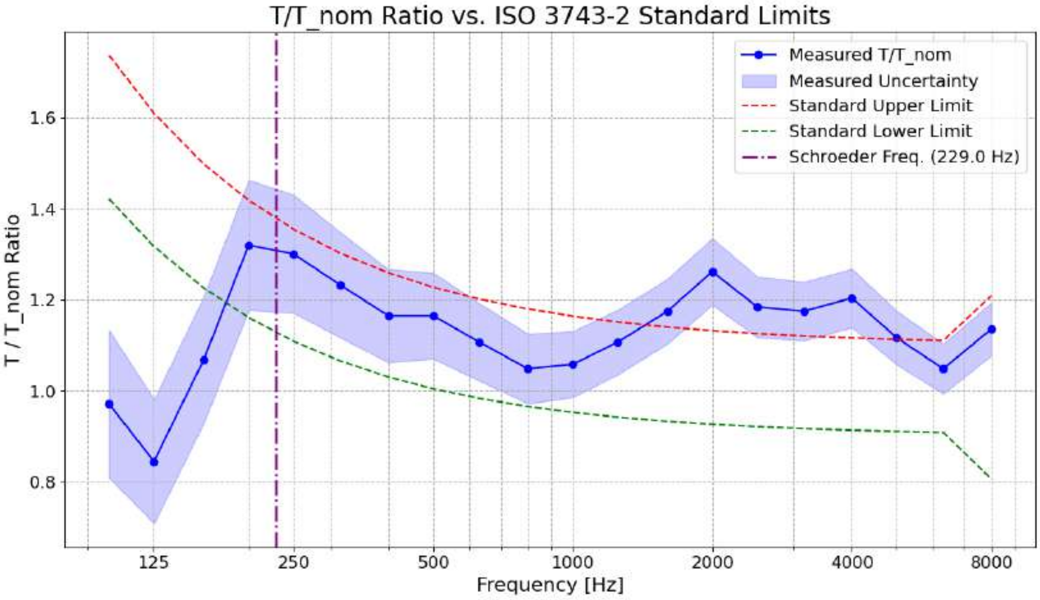


Figure 6: Ratio of T/T_{nom} compared with the standards limits.

As shown, the compliance criterion is strictly satisfied only within the approximate frequency range of 170 Hz to 1750 Hz. Deviations are observed at low frequencies, likely attributable to high absorption from the ceiling's air gap, and at higher frequencies, where the room's overall absorption decreases. Furthermore, the high standard deviation of the measurements indicates that the sound field is not entirely homogeneous. Therefore, only the sound power levels (Lw) calculated within this range (170 to 1750 Hz) can be considered to strictly meet the engineering-grade (Grade 2) precision of the standard. Any results outside this range carry a greater uncertainty and are not formally compliant with the standard.

Also, the resulting nominal reverberation time is $T_{\text{nom}} = 1.05$ s, which exceeds by 5% the maximum limit of 1.0 s established by the standard. The results and their validity will be presented and discussed in consideration of these significant limitations.

5.2 Sound Pressure Levels (Lp)

5.2.1 Sound Level Meter

Initial SPL measurements were taken using the Svantek sound level meter to establish a reference for the background noise and its relationship to the machines constant noise emissions. Global values are presented in Table 4, while the analysis by frequency bands will be carried out using the microphone measurements.

Significant differences are observed in the Leq A values, reaching at least 23.2 dB for the Generic device. For Leq Z, the variation ranges from 1.6 dB (Generic) to a maximum of 11.8 dB (Top House). This may be due to a higher low-frequency content of the background noise compared to the noise emitted by the blenders, given the differences between A-weighting and Z-weighting filters. Only the

Table 4: Global Leq measurements taken with the sound level meter SVAN 959.

	Background noise	**Tophouse**	**Liliana**	**Generic**
Leq (dB A)	38.7	73.1	78.6	61.9
Leq (dB Z)	70.6	82.4	82.2	72.2

Generic measurement under Z-weighting does not comply with the standard specifications (at least a SNR of 4 dB).

5.2.2 Calibrated Measurement Microphones

Calibrating the measurements taken with the microphones also allows for the analysis of background noise and the signal-to-noise ratio in third octave bands. Figure 7 shows the global average of the measurements obtained from the 10 microphones, along with the associated uncertainty. (For greater detail, the curves obtained from each microphone can be seen in Figure 16 of the Annex).

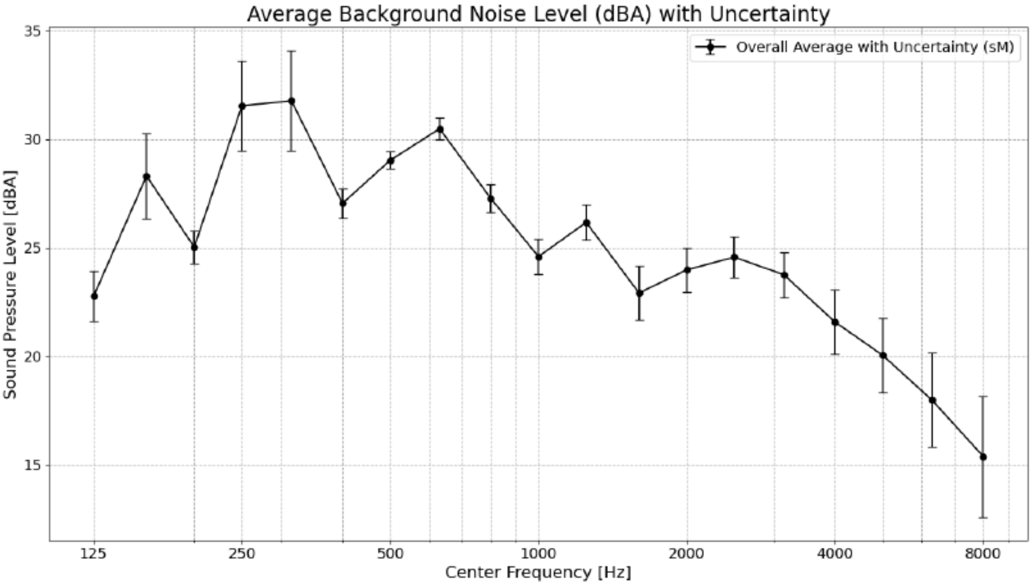


Figure 7: Average background noise levels in dBA.

The global background noise level calculated with this method is 39.58 dBA, showing a minor difference of 0.88 dB compared to the sound level meter measurement, which confirms the microphone was properly calibrated. Although a frequency-band comparison could also be performed, due to time constraints, only the shown global levels will be used.

The analysis of the background noise levels reveals a non-uniform spectrum, characteristic of building environments, with a peak in the low-mid frequencies (around 250-315 Hz). The higher uncertainty (s_M) observed in this low-frequency range is explained by the significant spatial dispersion shown in the individual microphone measurements (Annex, Figure 16). This variability can be evidence of the presence of room modes below the Schroeder frequency, confirming that the sound field is not homogeneous in that area.

The signal-to-noise ratio (S/N) is a critical parameter for assessing the validity of the measurements against the limits established by the standard. Figure 8 shows the S/N ratio for each machine in one-third octave bands, with horizontal lines indicating the minimum (4 dB) and recommended (10 dB) thresholds. It is evident that the S/N ratio decreases at low frequencies (125 Hz and 160 Hz bands), which is attributed to the room's lack of acoustic insulation in this range, and, in the Generic case, to a low level in that range.

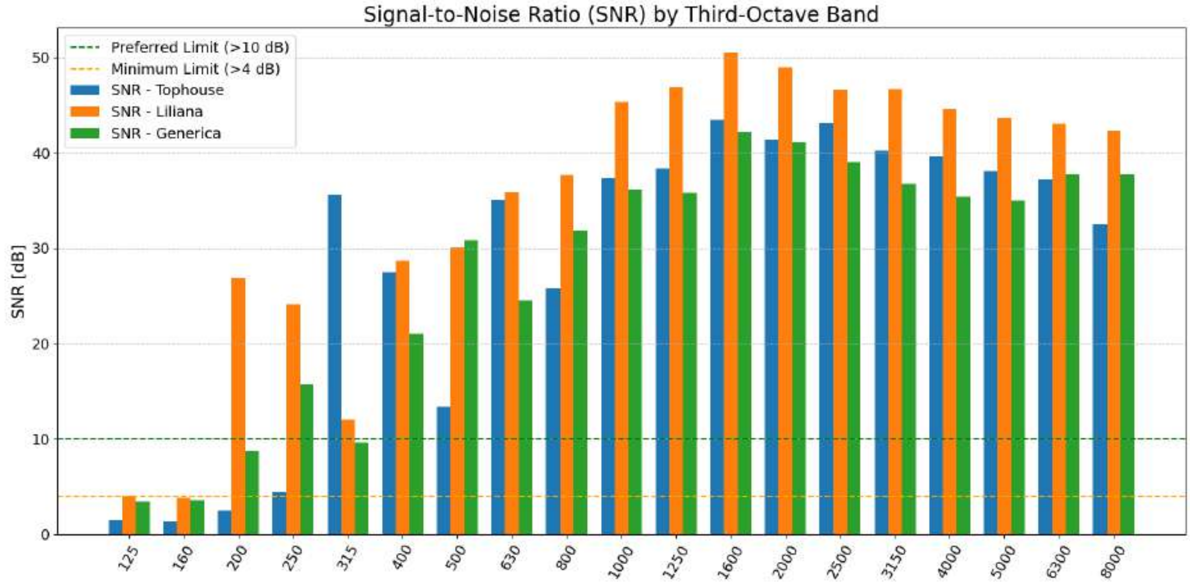


Figure 8: Signal-to-noise ratio for each machine.

It can be seen that for the majority of the spectrum, from 250 Hz upwards, all three devices exhibit an SNR well above the 10 dB preferred limit established by the standard, which indicates a high quality for these measurements. However, at low frequencies (below 250 Hz), the SNR drops significantly for all models, with the Tophouse and Generica blenders falling below the 4 dB minimum limit. This is a direct consequence of the background noise spectrum, which has its highest energy content in this same range (this behavior can be seen in the global values shown in 4 too). Among the devices, the Liliana blender consistently shows the highest SNR, indicating its sound emissions are the most dominant over the background noise.

Based on these results, and after applying the background noise corrections specified by the standard (Table 2), the sound pressure level values for each machine —by one-third octave bands— are obtained and shown in Figure 9. This represents a fundamental preliminary step prior to determining the sound power levels.

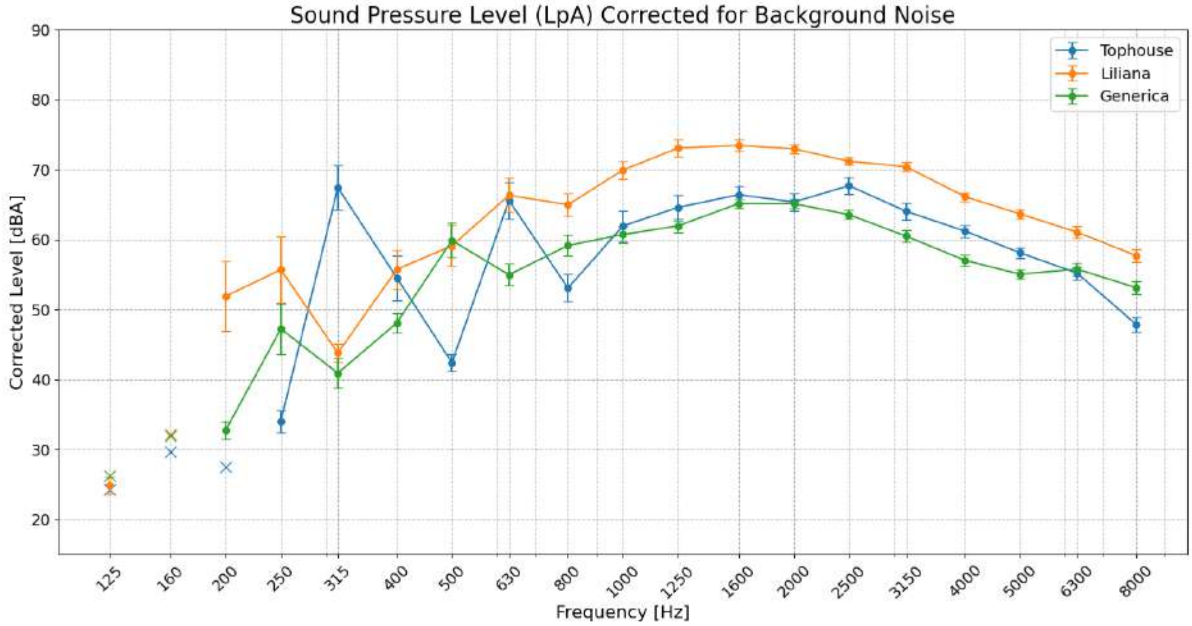


Figure 9: A-Weighted SPL values for each machine, with the background noise correction.

The 'Liliana' and 'Generic' models exhibit relatively smooth spectral profiles, with the Liliana blender consistently showing the highest overall level. In contrast, the 'Top House' model's spectrum is distinguished by two prominent peaks at 315 Hz and 630 Hz. This observation is consistent with both the subjective auditory perception during the measurements and a preliminary spectrogram analysis, which visually confirmed higher energy content at these specific frequencies (see Annex, Figure 13). The presence of these sharp peaks suggests that the Top House blender may be generating tonal noise, a characteristic that will be formally analyzed in a later section.

5.3 Acoustic Power Levels (Lw)

The A-weighted sound power levels L_w for each machine are presented in Figure 10, calculated based on the previously obtained SPL values, limited to the valid values of SN ratio.

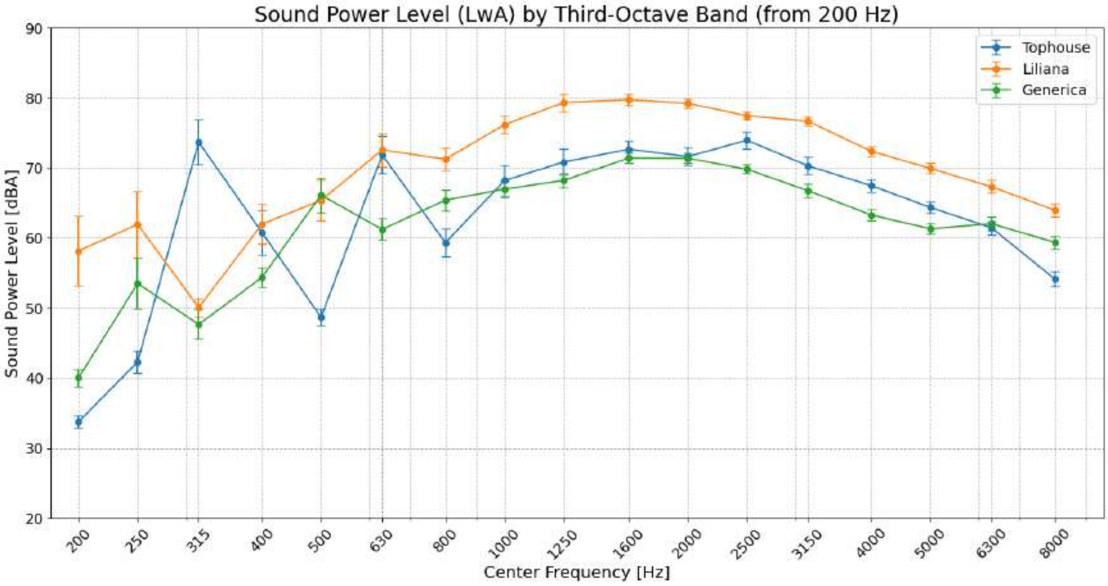


Figure 10: A-Weighted L_w values for each machine, by third octave bands.

It is interesting to note that the Top House machine exhibits a prominent tonal peak at 315 Hz, with its corresponding second harmonic at 630 Hz. This signature is characteristic of rotating machinery; the peak at the fundamental frequency (315 Hz) is a strong indicator of rotational unbalance [21]. While friction between a rotating and a fixed part can generate harmonics, the presence of a significant second harmonic is also a classic sign of mechanical misalignment [20].

Similarly, the Generic machine presents a fundamental frequency at 250 Hz and its second harmonic at 500 Hz, suggesting a similar mechanical issue. However, the amplitudes of these peaks are considerably lower than those of the Top House machine.

Finally, in Table 5 is presented the overall sum of sound power levels for each machine, both with and without A-weighting. Additionally, two cases are considered: one using values within the 250–1250 Hz bandwidth, strictly adhering to the frequency bands that meet the ISO standard's RT limits; and another using a 250–8000 Hz bandwidth, which, although not compliant with the standard, is more representative of the actual use of the machines.

As the measurement does not comply with the standard, the uncertainty presented is calculated using the Equation 6 considering the spatial (due to the microphones different positions) and RT deviation.

Table 5: Global Sound Power Levels in different frequency ranges.

Machine	Frequency Range	Global LwA [dBA]	Global LwZ [dBZ]
TOP HOUSE	250 Hz – 1250 Hz	77.77 ± 1.50	81.86 ± 2.28
	250 Hz – 8000 Hz	81.43 ± 0.72	83.32 ± 1.64
LILIANA	250 Hz – 1250 Hz	82.21 ± 0.78	82.67 ± 0.77
	250 Hz – 8000 Hz	86.83 ± 0.35	86.35 ± 0.38
GENERIC	250 Hz – 1250 Hz	73.26 ± 0.70	74.53 ± 0.87
	250 Hz – 8000 Hz	78.40 ± 0.31	78.22 ± 0.42

The results show a clear hierarchy in noise emission, with the ’Liliana’ model being the most powerful source (86.83 dBA) and the ’Generic’ model the quietest (78.40 dBA). The spectral character also differs significantly: the ’Liliana’ blender’s noise is concentrated in the mid-to-high frequencies, as indicated by the proximity of its L_{wA} and L_{wZ} values.In contrast, the ’Top House’ and ’Generic’ models have more prominent low-frequency content (evidenced by $L_{wZ} > L_{wA}$), with the difference being more pronounced in the ’Top House’ model, which is consistent with the tonal components identified at 315 Hz and 630 Hz. The considerable increase in acoustic power for all models when expanding the bandwidth to 8000 Hz confirms that a significant amount of acoustic energy is radiated at frequencies above 1250 Hz.

Considering the SENCOR hand blenders mentioned earlier, the devices analyzed in this study show levels between 77 dBA and 86 dBA, placing them within the upper range of commercially available models.

5.4 Tonal Noise Analysis

A tonal noise analysis was performed following the IRAM 4062 standard, which identifies tones by comparing a frequency band’s sound pressure level to its adjacent bands. The results for each machine are summarized in Table 6.

Table 6: Tonal Noise analysis results.

Machine	Tonal Frequencies Detected
TOPHOUSE	315 Hz; 630 Hz
LILIANA	None detected
GENERICA	None detected

Based on these results, the Top House blender was the only device to exhibit significant tonal components. As discussed previously, tones were clearly identified at 315 Hz and its second harmonic, 630 Hz. At the fundamental frequency, its level of 73.71 dBA surpassed the adjacent bands (at 42.33 dBA and 60.80 dBA) by more than the required 8 dB. Similarly, at 630 Hz, the level of 71.88 dBA was over 5 dB higher than its neighbors (at 48.70 dBA and 59.35 dBA). In contrast, both the ’Liliana’ and ’Generic’ models showed no evidence of tonal components according to the IRAM 4062 criteria, suggesting their noise character is predominantly broadband.

This is consistent with the level curve shown in Figure 9, the auditory perception during the measurement, and a brief spectrogram analysis, shown in Figure 13 in the Annex, which identified the frequencies with the highest energy content.

6. Conclusions

In this study, the sound power levels of three hand blender models (Top House, Liliana, and Generic) were determined by applying the methodology of the ISO 3743-2 standard in a non-ideal acoustic environment. The characterization allowed for a comparative analysis of their sound emissions.

The primary finding is that the Liliana model was the device with the highest sound power level, reaching an overall value of $L_{WA} = 86.8.0$ dBA. In contrast, the Top House (81.4 dBA) and Generic (78.4 dBA) models exhibited lower levels. Furthermore, the tonal analysis revealed that only the Top House blender produced significant tonal components, with prominent peaks at 315 Hz and its second harmonic, 630 Hz. This suggests the presence of mechanical phenomena such as unbalance or misalignment, which are not evident in the other two devices that showed a broadband noise character.

Another aspect to consider is the non-flat nature of the background noise, which underscores the importance of performing a per-band Signal-to-Noise Ratio (SNR) analysis, as the validity of the machine measurements critically depends on the specific frequencies of their noise emissions.

A central conclusion of this work relates to the measurement methodology. It was determined that the test room did not fully comply with the requirements for a 'special reverberation test room' as specified in ISO 3743-2. The reverberation time characteristics, in particular, fell outside the normative limits. This non-compliance would lead to expect a measurement uncertainty significantly higher than the standard deviation of reproducibility (σ_R) specified by the standard.

Had the test setup fully complied with the standard's specifications, it is likely that the measurement validity could have extended over a wider frequency range than the one effectively achieved (approximately 250 to 1250 Hz). This would have increased the overall applicability of the results and enabled a more comprehensive spectral analysis.

However, a detailed uncertainty analysis performed via error propagation revealed that the calculated combined uncertainty is surprisingly comparable to, and in some frequency bands even lower than, the values proposed by the standard. This suggests that, for the specific conditions of this test and the nature of the sources, the deviations from the normative requirements did not critically impact the statistical stability of the final result. Nevertheless, it must be emphasized that due to the non-compliance with the initial setup conditions, the results cannot be formally declared as having Grade 2 Engineering precision.

Regarding the selection of appliances analyzed, it is worth noting that the limited availability of detailed specifications for most of the measured devices constrained the scope of the analysis. The study would have been enriched by the availability of more technical specifications for the devices tested, which would have allowed for direct comparisons and the extraction of more conclusive insights. Additionally, it might be advisable to conduct further measurements on a different type of appliance for which more models with publicly available acoustic power data can be found online, thereby providing a broader and more diverse set of market references for comparison.

For future measurements aiming for strict compliance, two main recommendations are proposed. First, to perform the test in a qualified reverberation chamber. Alternatively, if a non-ideal room must be used, the application of a comparative standard such as ISO 3747, which uses a reference sound source to compensate the room's acoustic deficiencies, would be a more suitable approach.

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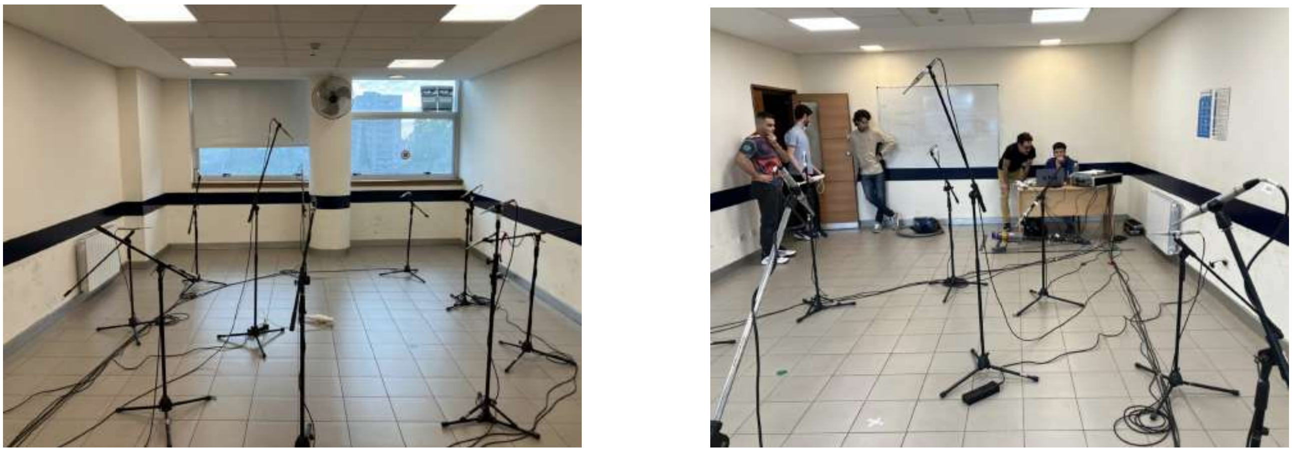
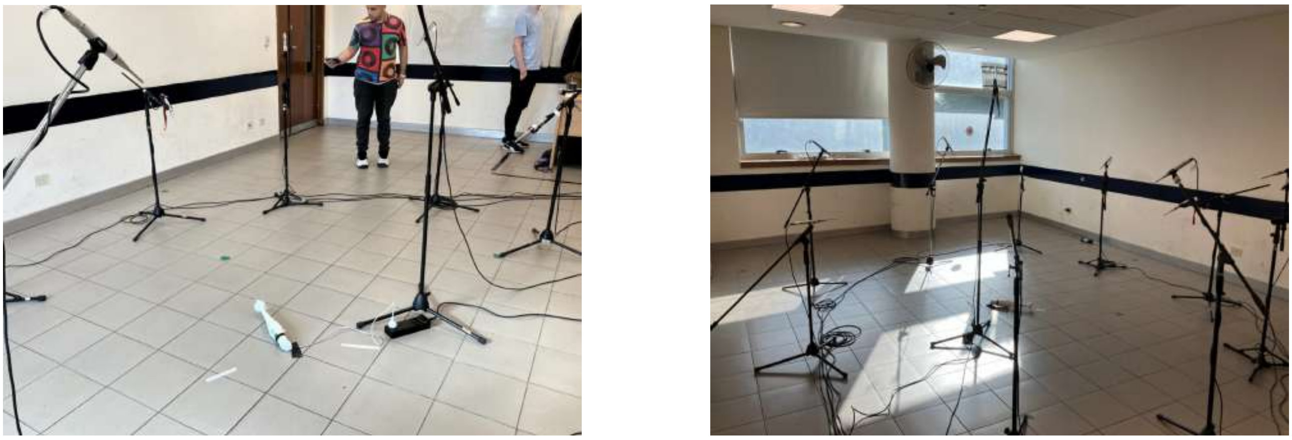
Annex A - Measurement Photographs



(a) Microphone layout surrounding the machine under test.

(b) Arrangement of the audio recording equipment (computer, audio interface) and measurement team.



(c) Detailed view of the machine positioned on the floor.

(d) Microphone layout surrounding the machine under test, another perspective.

Figure 11: Photographs of the measurement setup from different angles.

Annex B - Tables and Figures

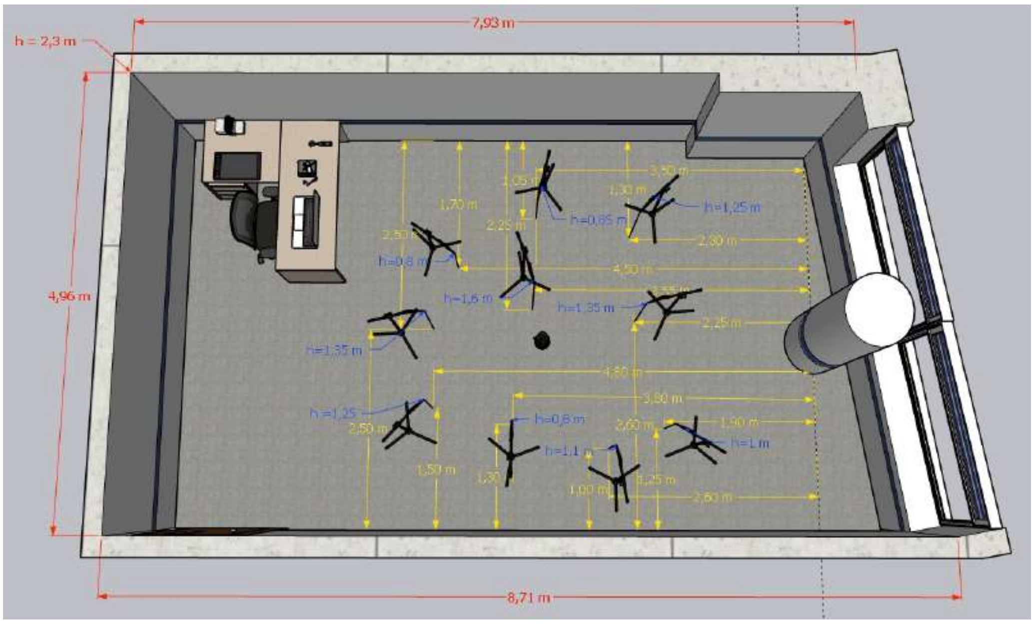


Figure 12: Sketch of the microphone layout in the room, with dimensions.

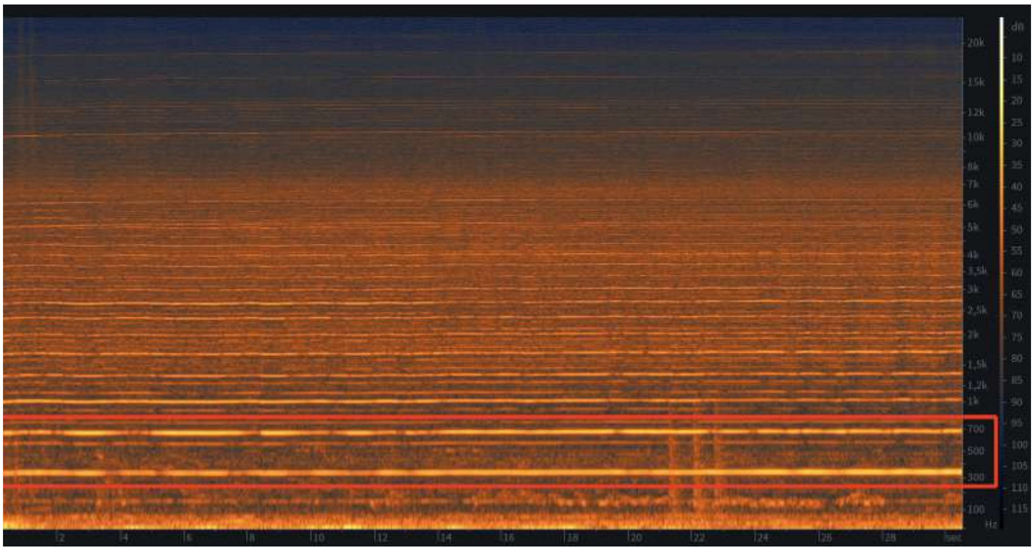


Figure 13: Spectrogram of the Tophouse blender recording, highlighting the extracted tonal components in red.

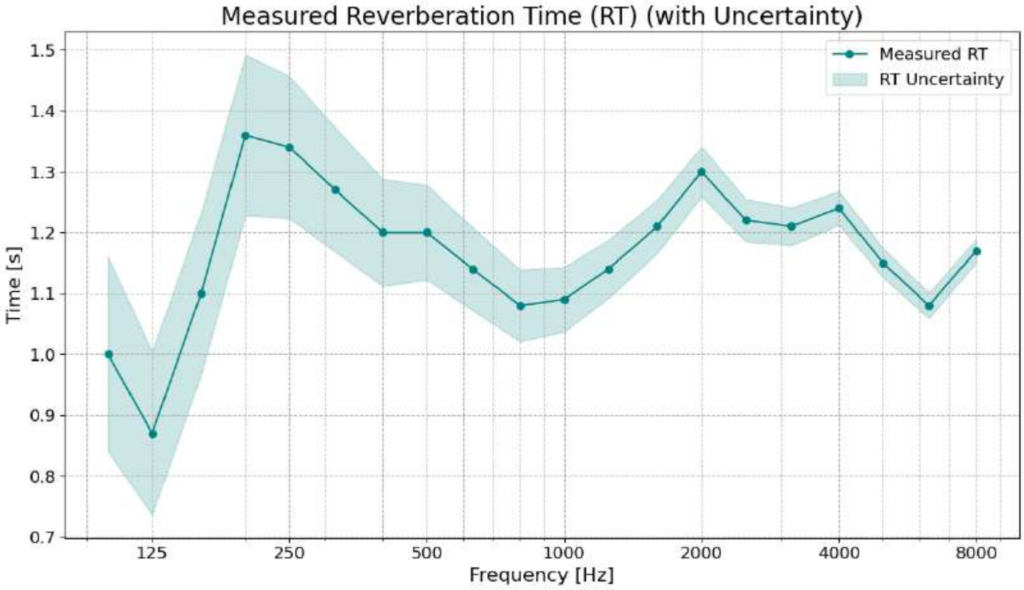


Figure 14: Reverberation Time (T20) of the room, by third octave frequency bands.

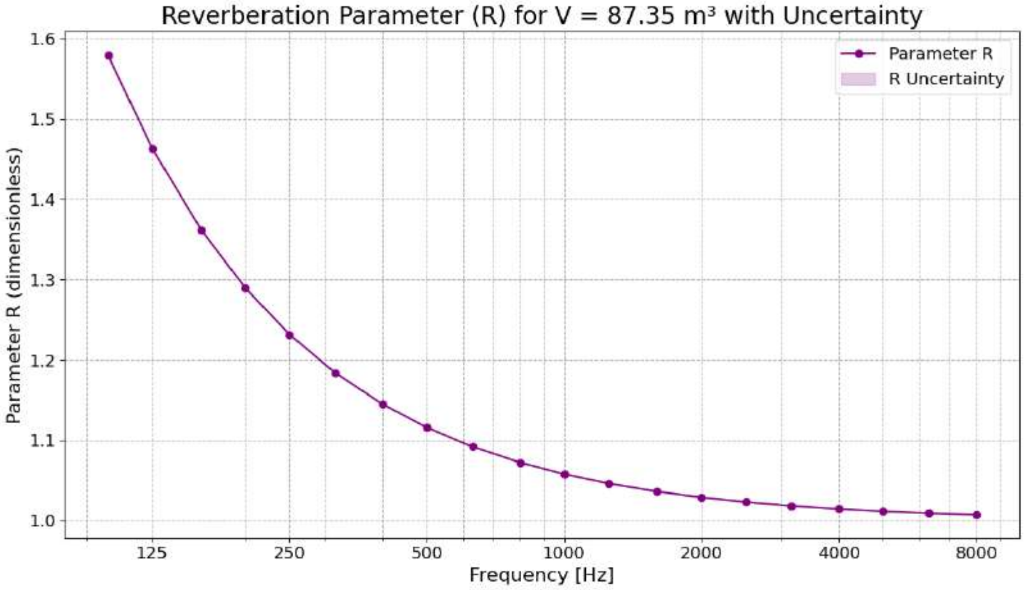


Figure 15: Reverberation Parameter (R) of the room, by third octave frequency bands, according to the ISO standard.

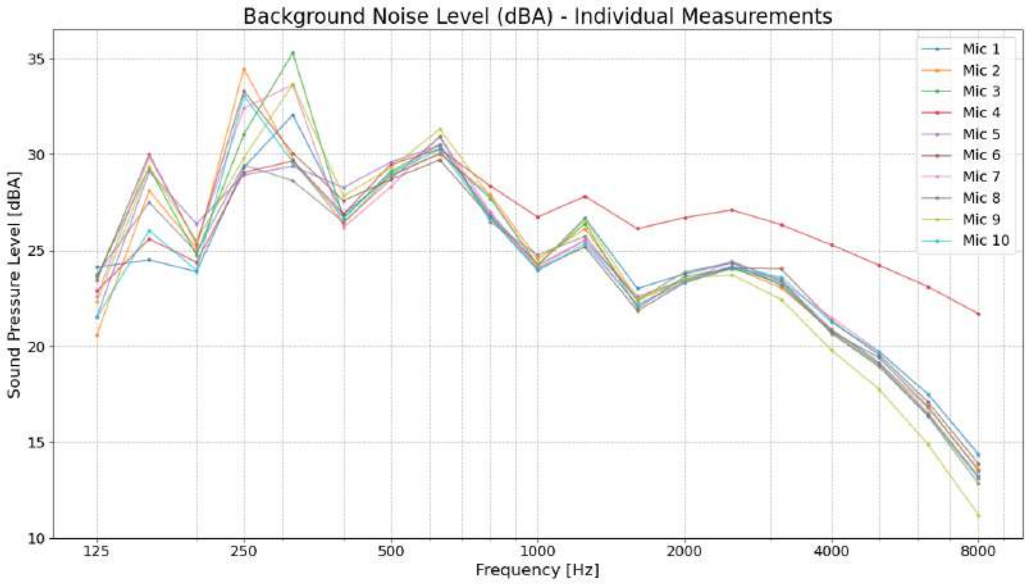


Figure 16: Background noise levels measured in dBA for each microphone.

Table 7: Background noise measured at each microphone per third-octave band in dBA, with associated uncertainty.

	Mic											
f [Hz]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Global**	**Std. Dev.**
125	24.12	20.60	23.64	22.89	21.55	23.46	22.59	23.75	22.31	21.51	22.77	1.15
160	24.51	28.11	29.32	25.60	29.11	30.01	29.88	27.50	29.37	26.04	28.30	1.96
200	23.89	25.13	24.76	24.39	26.39	25.33	25.42	24.92	25.48	23.96	25.03	0.76
250	29.32	34.48	31.06	29.07	28.93	33.31	32.41	29.46	29.83	33.07	31.55	2.06
315	32.07	29.74	35.30	29.67	29.39	30.07	33.63	28.63	33.66	29.60	31.77	2.30
400	26.88	26.40	26.66	26.88	28.28	27.60	26.20	26.48	27.83	26.70	27.04	0.68
500	28.89	28.95	29.12	29.49	29.60	28.69	28.30	28.71	29.31	29.04	29.03	0.39
630	30.08	30.01	30.50	30.28	30.49	29.73	30.96	30.93	31.32	30.27	30.48	0.49
800	27.71	27.91	26.77	28.36	26.91	26.72	26.99	26.48	27.78	26.68	27.27	0.65
1000	24.21	24.55	24.29	26.74	24.24	24.04	24.09	24.76	24.24	23.93	24.59	0.82
1250	26.69	26.13	26.40	27.82	25.52	25.18	25.52	25.74	26.59	25.34	26.17	0.81
1600	23.01	22.38	21.98	26.13	22.59	21.85	22.11	22.40	22.49	22.18	22.91	1.25
2000	23.77	23.48	23.64	26.71	23.45	23.32	23.35	23.87	23.53	23.38	23.98	1.02
2500	24.35	24.13	24.06	27.11	24.17	24.08	24.45	24.38	23.73	24.06	24.56	0.96
3150	23.18	23.04	23.31	26.34	23.41	24.04	23.38	23.49	22.45	23.62	23.76	1.04
4000	20.75	20.84	20.72	25.28	20.87	21.32	21.49	20.66	19.79	21.25	21.58	1.48
5000	19.40	19.11	19.02	24.23	19.16	19.55	19.74	18.94	17.77	19.70	20.05	1.70
6300	16.87	16.79	16.41	23.11	16.51	17.10	17.51	16.37	14.89	17.52	17.98	2.17
8000	13.51	13.59	13.13	21.69	13.22	13.87	14.40	12.83	11.20	14.32	15.39	2.79

Table 8: Background noise measured at each microphone per third-octave band in dBZ, with associated uncertainty.

	Mic											
f [Hz]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Global**	**Std. Dev.**
125	40.22	36.70	39.74	38.99	37.65	39.56	38.69	39.85	38.41	37.61	38.87	1.15
160	37.91	41.51	42.72	39.00	42.51	43.41	43.28	40.90	42.77	39.44	41.70	1.96
200	34.79	36.03	35.66	35.29	37.29	36.23	36.32	35.82	36.38	34.86	35.93	0.76
250	37.92	43.08	39.66	37.67	37.53	41.91	41.01	38.06	38.43	41.67	40.15	2.06
315	38.67	36.34	41.90	36.27	35.99	36.67	40.23	35.23	40.26	36.20	38.37	2.30
400	31.68	31.20	31.46	31.68	33.08	32.40	31.00	31.28	32.63	31.50	31.84	0.68
500	32.09	32.15	32.32	32.69	32.80	31.89	31.50	31.91	32.51	32.24	32.23	0.39
630	31.98	31.91	32.40	32.18	32.39	31.63	32.86	32.83	33.22	32.17	32.38	0.49
800	28.51	28.71	27.57	29.16	27.71	27.52	27.79	27.28	28.58	27.48	28.07	0.65
1000	24.21	24.55	24.29	26.74	24.24	24.04	24.09	24.76	24.24	23.93	24.59	0.82
1250	26.09	25.53	25.80	27.22	24.92	24.58	24.92	25.14	25.99	24.74	25.57	0.81
1600	22.01	21.38	20.98	25.13	21.59	20.85	21.11	21.40	21.49	21.18	21.91	1.25
2000	22.57	22.28	22.44	25.51	22.25	22.12	22.15	22.67	22.33	22.18	22.78	1.02
2500	23.05	22.83	22.76	25.81	22.87	22.78	23.15	23.08	22.43	22.76	23.26	0.96
3150	21.98	21.84	22.11	25.14	22.21	22.84	22.18	22.29	21.25	22.42	22.56	1.04
4000	19.75	19.84	19.72	24.28	19.87	20.32	20.49	19.66	18.79	20.25	20.58	1.48
5000	18.90	18.61	18.52	23.73	18.66	19.05	19.24	18.44	17.27	19.20	19.55	1.70
6300	16.97	16.89	16.51	23.21	16.61	17.20	17.61	16.47	14.99	17.62	18.08	2.17
8000	14.61	14.69	14.23	22.79	14.32	14.97	15.50	13.93	12.30	15.42	16.49	2.79

Table 9: Reverberation parameters: T, T/Tnom, R, and T limits calculated with their deviations.

f [Hz]	T_{20} **[s]**	T_{20} **Dev [s]**	T/T_{nom}	(T/T_{nom}) **Dev**	**R**	T_{min} **[s]**	T_{max} **[s]**
125	1.000	0.160	0.971	0.1623	1.579	1.464	1.790
160	0.870	0.134	0.844	0.1364	1.463	1.357	1.659
200	1.100	0.133	1.068	0.1391	1.362	1.263	1.544
250	1.360	0.132	1.320	0.1433	1.290	1.196	1.462
315	1.340	0.117	1.301	0.1300	1.232	1.142	1.396
400	1.270	0.102	1.233	0.1157	1.184	1.098	1.342
500	1.200	0.088	1.165	0.1025	1.145	1.062	1.297
630	1.200	0.078	1.165	0.0945	1.116	1.035	1.265
800	1.140	0.068	1.106	0.0851	1.092	1.013	1.238
1000	1.080	0.059	1.048	0.0767	1.072	0.994	1.215
1250	1.090	0.053	1.058	0.0727	1.058	0.981	1.199
1600	1.140	0.048	1.106	0.0712	1.046	0.970	1.186
2000	1.210	0.044	1.174	0.0713	1.036	0.961	1.174
2500	1.300	0.041	1.262	0.0731	1.029	0.954	1.166
3150	1.220	0.035	1.184	0.0668	1.023	0.949	1.160
4000	1.210	0.031	1.174	0.0645	1.018	0.944	1.154
5000	1.240	0.028	1.204	0.0645	1.014	0.941	1.150
6300	1.150	0.024	1.116	0.0591	1.012	0.938	1.146
8000	1.080	0.021	1.048	0.0549	1.009	0.936	1.144

Table 10: A-Weighted Sound Pressure Levels (LpA) with Uncertainty (sM) by Third-Octave Band.

Freq [Hz]	**TOPHOUSE [dBA]**	**LILIANA [dBA]**	**GENERICA [dBA]**
125	24.24 ± 1.29	26.84 ± 1.28	26.19 ± 1.37
160	29.70 ± 2.59	32.13 ± 1.76	31.90 ± 1.82
200	27.50 ± 0.81	51.90 ± 5.00	33.77 ± 1.23
250	36.04 ± 1.61	55.69 ± 4.74	47.25 ± 3.59
315	67.43 ± 3.19	43.81 ± 1.31	41.42 ± 2.07
400	54.52 ± 3.19	55.72 ± 2.80	48.11 ± 1.36
500	42.41 ± 1.16	59.10 ± 2.92	59.87 ± 2.46
630	65.59 ± 2.64	66.32 ± 2.40	54.96 ± 1.54
800	53.06 ± 1.95	64.98 ± 1.57	59.14 ± 1.48
1000	61.94 ± 2.20	69.93 ± 1.23	60.71 ± 1.19
1250	64.58 ± 1.84	73.07 ± 1.22	61.95 ± 0.98
1600	66.41 ± 1.21	73.47 ± 0.80	65.15 ± 0.66
2000	65.37 ± 1.27	72.96 ± 0.66	65.12 ± 0.66
2500	67.70 ± 1.19	71.20 ± 0.54	63.55 ± 0.59
3150	64.03 ± 1.20	70.41 ± 0.63	60.49 ± 0.90
4000	61.20 ± 0.85	66.12 ± 0.64	57.02 ± 0.80
5000	58.09 ± 0.78	63.66 ± 0.71	55.05 ± 0.67
6300	55.19 ± 0.93	61.04 ± 0.89	55.76 ± 0.94
8000	47.87 ± 1.03	57.71 ± 0.93	53.12 ± 0.89

Table 11: Z-Weighted Sound Pressure Levels (LpZ) with Uncertainty (sM) by Third-Octave Band.

Freq [Hz]	**TOPHOUSE [dBZ]**	**LILIANA [dBZ]**	**GENERICA [dBZ]**
125	40.34 ± 1.29	42.94 ± 1.28	42.29 ± 1.37
160	43.10 ± 2.59	45.53 ± 1.76	45.30 ± 1.82
200	38.40 ± 0.81	62.80 ± 5.00	44.67 ± 1.23
250	44.64 ± 1.61	64.29 ± 4.74	55.85 ± 3.59
315	74.03 ± 3.19	50.41 ± 1.31	48.02 ± 2.07
400	59.32 ± 3.19	60.52 ± 2.80	52.91 ± 1.36
500	45.61 ± 1.16	62.30 ± 2.92	63.07 ± 2.46
630	67.49 ± 2.64	68.22 ± 2.40	56.86 ± 1.54
800	53.86 ± 1.95	65.78 ± 1.57	59.94 ± 1.48
1000	61.94 ± 2.20	69.93 ± 1.23	60.71 ± 1.19
1250	63.98 ± 1.84	72.47 ± 1.22	61.35 ± 0.98
1600	65.41 ± 1.21	72.47 ± 0.80	64.15 ± 0.66
2000	64.17 ± 1.27	71.76 ± 0.66	63.92 ± 0.66
2500	66.40 ± 1.19	69.90 ± 0.54	62.25 ± 0.59
3150	62.83 ± 1.20	69.21 ± 0.63	59.29 ± 0.90
4000	60.20 ± 0.85	65.12 ± 0.64	56.02 ± 0.80
5000	57.59 ± 0.78	63.16 ± 0.71	54.55 ± 0.67
6300	55.29 ± 0.93	61.14 ± 0.89	55.86 ± 0.94
8000	48.97 ± 1.03	58.81 ± 0.93	54.22 ± 0.89

Table 12: A-Weighted Sound Power Levels (LwA) with Uncertainty by Third-Octave Band.

Freq [Hz]	TOPHOUSE [dBA]	LILIANA [dBA]	GENERICA [dBA]
125	30.52 ± 1.31	33.13 ± 1.30	32.47 ± 1.38
160	35.98 ± 2.59	38.41 ± 1.77	38.18 ± 1.83
200	33.78 ± 0.83	58.18 ± 5.01	40.05 ± 1.25
250	42.33 ± 1.62	61.97 ± 4.75	53.53 ± 3.59
315	73.71 ± 3.20	50.09 ± 1.33	47.70 ± 2.08
400	60.80 ± 3.20	62.01 ± 2.80	54.39 ± 1.37
500	48.70 ± 1.18	65.39 ± 2.93	66.15 ± 2.47
630	71.88 ± 2.65	72.60 ± 2.41	61.24 ± 1.55
800	59.35 ± 1.96	71.27 ± 1.58	65.42 ± 1.50
1000	68.22 ± 2.21	76.21 ± 1.25	67.00 ± 1.21
1250	70.86 ± 1.85	79.35 ± 1.24	68.23 ± 1.00
1600	72.69 ± 1.23	79.75 ± 0.83	71.43 ± 0.69
2000	71.65 ± 1.29	79.24 ± 0.69	71.41 ± 0.70
2500	73.98 ± 1.21	77.48 ± 0.58	69.84 ± 0.63
3150	70.32 ± 1.22	76.69 ± 0.66	66.77 ± 0.92
4000	67.49 ± 0.88	72.41 ± 0.68	63.30 ± 0.82
5000	64.38 ± 0.81	69.94 ± 0.74	61.33 ± 0.70
6300	61.47 ± 0.95	67.33 ± 0.91	62.05 ± 0.96
8000	54.15 ± 1.05	64.00 ± 0.95	59.40 ± 0.91
Overall LwA	**81.43 ± 0.72**	**86.84 ± 0.35**	**78.41 ± 0.31**

Table 13: Z-Weighted Sound Power Levels (LwZ) with Uncertainty by Third-Octave Band.

Freq [Hz]	TOPHOUSE [dBZ]	LILIANA [dBZ]	GENERICA [dBZ]
125	46.62 ± 1.31	49.23 ± 1.30	48.57 ± 1.38
160	49.38 ± 2.59	51.81 ± 1.77	51.58 ± 1.83
200	44.68 ± 0.83	69.08 ± 5.01	50.95 ± 1.25
250	50.93 ± 1.62	70.57 ± 4.75	62.13 ± 3.59
315	80.31 ± 3.20	56.69 ± 1.33	54.30 ± 2.08
400	65.60 ± 3.20	66.81 ± 2.80	59.19 ± 1.37
500	51.90 ± 1.18	68.59 ± 2.93	69.35 ± 2.47
630	73.78 ± 2.65	74.50 ± 2.41	63.14 ± 1.55
800	60.15 ± 1.96	72.07 ± 1.58	66.22 ± 1.50
1000	68.22 ± 2.21	76.21 ± 1.25	67.00 ± 1.21
1250	70.26 ± 1.85	78.75 ± 1.24	67.63 ± 1.00
1600	71.69 ± 1.23	78.75 ± 0.83	70.43 ± 0.69
2000	70.45 ± 1.29	78.04 ± 0.69	70.21 ± 0.70
2500	72.68 ± 1.21	76.18 ± 0.58	68.54 ± 0.63
3150	69.12 ± 1.22	75.49 ± 0.66	65.57 ± 0.92
4000	66.49 ± 0.88	71.41 ± 0.68	62.30 ± 0.82
5000	63.88 ± 0.81	69.44 ± 0.74	60.83 ± 0.70
6300	61.57 ± 0.95	67.43 ± 0.91	62.15 ± 0.96
8000	55.25 ± 1.05	65.10 ± 0.95	60.50 ± 0.91
Overall LwZ	**83.32 ± 1.64**	**86.44 ± 0.39**	**78.24 ± 0.41**

Annex C - Cuestionario

- 1. ¿Cuándo una fuente de ruido es considerada tonal? Referencie en relación a una norma.

  Una fuente de ruido se considera tonal cuando una o más frecuencias específicas sobresalen claramente del espectro de ruido general, haciéndolo más molesto que un ruido de banda ancha de igual nivel. Objetivamente, se clasifica como tonal según dos criterios principales:
  Criterio Normativo (IRAM 4062): Se confirma la presencia de un tono si el nivel de una banda de frecuencia supera al de sus dos bandas adyacentes por un umbral de decibeles definido (por ejemplo, 5 dB para frecuencias sobre 500 Hz).
  Criterio Psicoacústico (TTNR/PR): Un tono se considera prominente cuando su nivel es perceptiblemente más alto (típicamente 8-9 dB) que el ruido de fondo que lo enmascara dentro de una misma banda crítica del oído.

- 2. *¿Qué conclusiones puede extraer al comparar la información brindada por el fabricante y los resultados obtenidos?*

  Los fabricantes de los equipos ensayados no proporcionan especificaciones técnicas sobre sus emisiones sonoras. Una investigación de aparatos similares reveló que la información disponible es limitada y carece de rigor técnico, omitiendo generalmente la metodología de medición. Se concluye que la ausencia de un marco legal que exija la declaración de niveles de ruido para estos electrodomésticos es un factor determinante en la falta de datos estandarizados por parte de los fabricantes.

- 3. *¿El fabricante tiene laboratorios propios o envía las unidades a medir fuera de sus instalaciones?*

  No existe evidencia que sugiera que los fabricantes de los equipos ensayados realicen mediciones formales de potencia acústica, ya sea en laboratorios propios o externos. Esta conclusión se fundamenta en la ausencia total de especificaciones acústicas en la documentación técnica de los productos analizados, así como en la de aparatos similares disponibles en el mercado.

- 4. *¿Cuáles son los factores de error más importantes en la medición realizada y cómo puede asociarlos a la incertidumbre obtenida?*

  El método propuesto por esta norma asume que el campo difuso es completamente homogéneo, y calcula la desviación espacial a partir de la diferencia entre mediciones. Sin embargo, en la práctica, incluso en salas que cumplan con las condiciones de una cámara anecoica de laboratorio, esta homogeneidad no se verifica completamente.
  Por otra parte, la norma establece un procedimiento para corregir el efecto del ruido de fondo, pero no contempla la incertidumbre que esta corrección puede introducir en los resultados.

- 5. *Producir una pregunta clara y simple relacionada con el tema bajo estudio, que no tenga una respuesta directa (ni en papers ni en libros), y que necesite de investigación concreta, realizable por el estudiante con equipamiento propio y/o de la universidad.*

  ¿Es posible desarrollar un método de medición de potencia acústica que sea independiente de las características de la sala, mediante la medición del dispositivo bajo prueba en campo cercano? Esta aproximación probablemente requeriría un muestreo espacial más denso para capturar adecuadamente la distribución del campo sonoro.