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EDT and *RT*: "The uniformity and no-uniformity in the distribution of absorption in a reverberant room is it a discussion between them?"

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ABSTRACT

In this publication we will study the behavior of a reverberant room analyzing two different cases: (a) Placing in a floor a little sample of absorption, and (b) Placing the same sample of absorption distributed in three mutually perpendicular walls.
In addition, we will analyze the results obtained using the following formulas of the theories: Sabine, Eyring, and Arau*. The first two theories are designed for uniform distribution and the third theory was developed assuming the existence of no-uniform absorption in a room. We will compare the results of the calculated reverberation time *RT* with the three theories, Sabine, Eyring and Arau* and we also compare the results of the reverberation time of Arau* with the results of the *EDT* (Early Decay Time), always calculated also by Arau's theory, because the other theories don't calculate it.
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Key Words: *EDT*, *RT*, Absorption.

1. INTRODUCTION

This work focuses its attention on a reverberating room built in accordance with the UNE-EN ISO 354: 2003: "*Medición de la absorción acústica en una sala reverberante*" [1] and its sample testing methodology.

The target is to calculate the values of reverberation time and *EDT* (Early Decay Time) in two cases: (a) reverberant room by placing on the floor a test sample of absorbent material with an area of 10 m^2 according to ISO 354 and (b) reverberant room distributing the same surface of absorbent material between two mutually collateral walls and the floor.

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First of all, to obtain these results, we use the statistical theories of Sabine (Equation 1), [2], Eyring (Equation 2), [3], valid for the calculation of the reverberation time when there is uniformity of absorbent material in the room, and the theory of Arau-Puchades (Equation 3), [4].

The formula of Arau allows to calculate the reverberation time for a no-uniform distribution of the acoustic absorption in any room and also takes into account the spatial directions x, y, z. The three directions correspond respectively to the ceiling (S_{x1}), to the floor (S_{x2}), the side walls (right S_{y1} and left S_{y2}) and the front (S_{z1}) and back (S_{z2}) walls.

$$T = \left[\frac{0.162\,V}{S\bar{\alpha} + 4mV}\right] \quad (1)$$

$$T = \left[\frac{0.162\,V}{-Sln(1-\bar{\alpha}) + 4mV}\right] \quad (2)$$

$$\boldsymbol{T} = \left[\frac{0.162\,V}{-S\ln(1-\bar{\alpha}_x) + 4mV}\right]^{S_x/S} \cdot \left[\frac{0.162\,V}{-S\ln(1-\bar{\alpha}_y) + 4mV}\right]^{S_y/S} \cdot \left[\frac{0.162\,V}{-S\ln(1-\bar{\alpha}_z) + 4mV}\right]^{\frac{S_z}{S}} \quad (3)$$

Secondly, Arau defined the three reasons for the decay of the sound D_i, D_m and D_f to calculate the three reverberation times associated with each slope, that is, the *EDT* (Equation 4), the *RT* and the *LDT* (Last Decay Time) (Equation 4), discovering the normal logarithmic dispersion factor *d* (Equation 7), [5].

$$\boldsymbol{EDT} = T_i = \frac{60}{D_i}, \qquad \boldsymbol{LDT} = T_f = \frac{60}{D_f} \quad (4)$$

$$D_i = \bar{D}\mathrm{d}, \qquad D_f = \bar{D}/\mathrm{d} \quad (5)$$

$$\bar{D} = \frac{60}{T} \quad (6)$$

$$\boldsymbol{d} = antilog\left[\frac{1}{6+\beta}\right]\{\left(\frac{S_x}{S}\right)(\log\bar{\alpha}_x)^2 + \left(\frac{S_y}{S}\right)(\log\bar{\alpha}_y)^2 + \left(\frac{S_z}{S}\right)(\log\bar{\alpha}_z)^2 + -\left[\frac{S_x}{S}\log\bar{\alpha}_x + \frac{S_y}{S}\log\bar{\alpha}_y + \frac{S_z}{S}\log\bar{\alpha}_z\right]^2\}^{1/2} \quad (7)$$

The initial reverberation time, known as *EDT*, is the time determined in the first 10 dB of sound decay. If a uniform distribution of absorption occurs, there will be the situation where *EDT* = *RT* = *LDT*, because the dispersion coefficient *d* will be close to unity. The correction coefficient $\beta = 0$ is assumed, allowing a good diffusion of the enclosure.

Thirdly, we will calculate the values of T_{mid}, Tl_{ow}, T_{high} and the indices of warmth and brightness of the sound in the threes how theories of reverberation.

In addition, with the help of comparative tables, we verify that the values of the *EDT* and the *RT* of Arau obtained are almost equal. This means demonstrating that the uniformity of sound has been achieved in a reverberating room.

2. METHODOLOGY

The calculations were made with the program "*Acústic Sales*", software developed by "*Arau Acústica*" in 1989, which allows to calculate all the main acoustic parameters mentioned above.

The dimensions of the reverberant room are described in Table 1 and its geometry can also be seen in Figure 1 [1].

Table 1

Volume	**239.5**	[m^3]
Ground	47.72	[m^2]
Ceiling	56.73	[m^2]
Right wall	48.70	[m^2]
Left wall	29.38	[m^2]
Frontal wall	32.28	[m^2]
Back wall	26.31	[m^2]
Total area	**241.1**	[m^2]

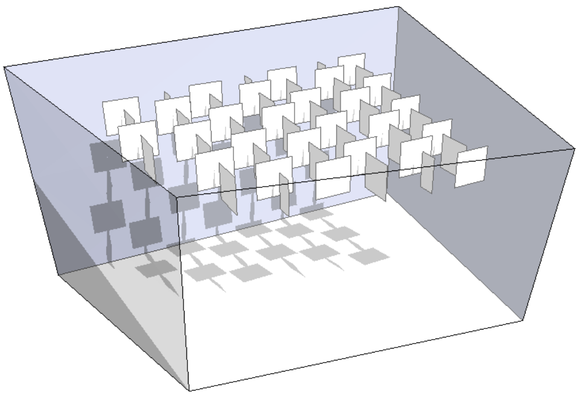


Figure 1

A diffuser was installed on the ceiling to create a better sound diffusion effect in this room. This diffuser consists of plywood panels made by two layers of Okume with an iron sheet in the middle. This iron sheet has the aim of increasing the density of the panels.

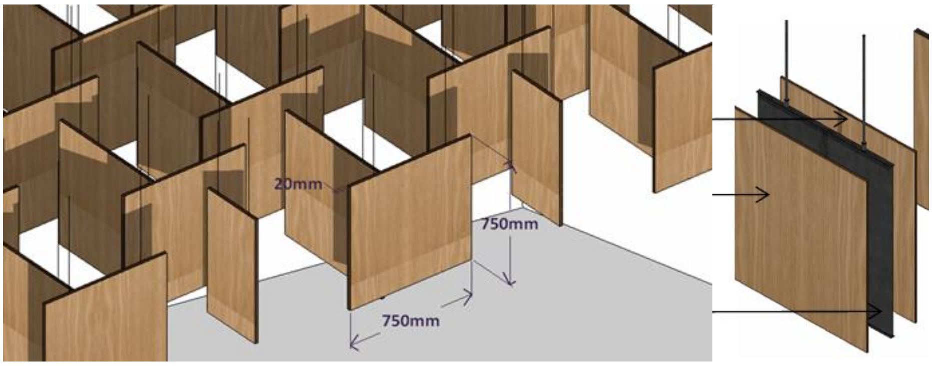


Figure 2

From this reverberating room we will do two types of calculation. First putting on the floor a sample of absorbent material of 10 m^2 of 22 mm of thickness, density of 45 kg / m^3, measured by the ISO 354 standard. They are data supplied by the manufacturing company. Second, we will put three samples of the same absorbent material that we equally distribute between two mutually collateral walls and the floor, where the sum of the surface must always result in 10 m^2.

The values of the absorption coefficients are shown in Table 2, where the absorption coefficients of all the materials used for the floor, ceiling, walls and panels of the diffuser are also reported.

Table 2

Materials							
Frequency [Hz]	**125**	**250**	**500**	**1000**	**2000**	**4000**	**α_w**
Plaster [1]	0.01	0.01	0.015	0.022	0.026	0.027	0.02
Floor [1]	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Okume Panels [1]	0.1	0.05	0.05	0.03	0.02	0.01	0.04
Absorbent material	0.55	0.9	0.95	0.9	1	1	0.88

3. RESULTS AND ANALYSIS OF DATA

We have compared the results of the reverberation time using the theories of Sabine, Arau-P and Eyring, the values of the *EDT*, *RT* of Arau and *LDT*, the values of T_{mid}, T_{low}, T_{high}, the indexes of warmth and brightness of sound and the values of the normal logarithmic factor *d* for the two mentioned cases. In addition, we will show the results achieved with tables, histograms and linear graphs.

3.1. Empty room case with absorption placed on the floor with an area of 10 m^2

In Table 3 we have represented the data of the reverberation time calculated with the three theories and the results of the *EDT*, also the values of the T_{mid}, T_{low}, T_{high} and the indices of warmth and brightness of the sound for the empty reverberant room with the absorption of 10 m^2 placed on the floor.

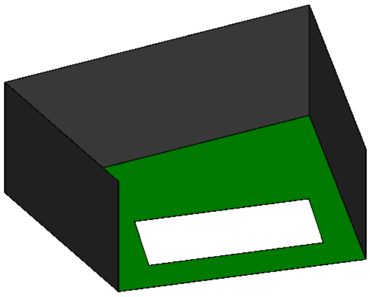


Figure 3

Table 3

Frequency (Hz)	125	250	500	1000	2000	4000	T_{mid}	T_{low}	T_{high}	I_{war}	I_{br}
EDT (s)	4.49	3.88	3.10	2.64	2.15	1.73	2.87	4.19	1.94	1.46	0.68
RT Arau (s)	5.32	4.68	3.63	2.97	2.38	1.87	3.30	5.00	2.13	1.52	0.64
RT Sabine (s)	3.53	2.87	2.57	2.46	2.09	1.74	2.51	3.20	1.91	1.27	0.76
RT Eyring (s)	3.46	2.8	2.5	2.39	2.03	1.7	2.44	3.13	1.86	1.28	0.76

Table 4

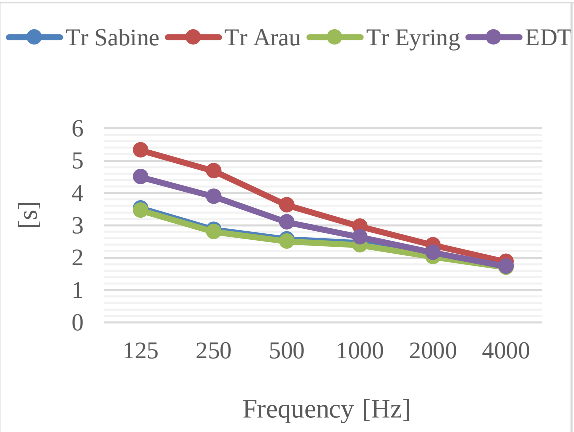
Frequency (Hz)	125	250	500	1000	2000	4000
ΔT = EDT – RT Arau (s)	-0.83	-0.80	-0.53	-0.33	-0.23	-0.14

Table 5

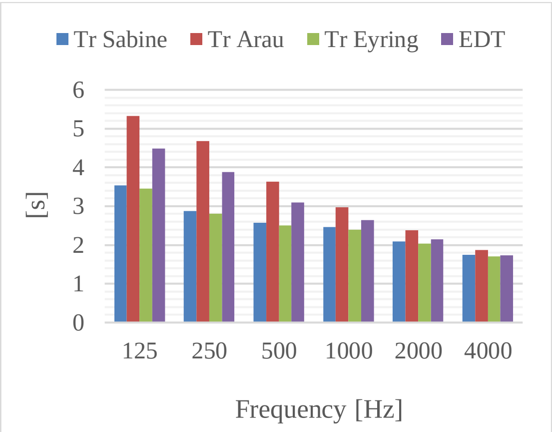
Frequency (Hz)	125	250	500	1000	2000	4000
Dispersion factor d	1.18	1.20	1.17	1.12	1.11	1.08

Table 6

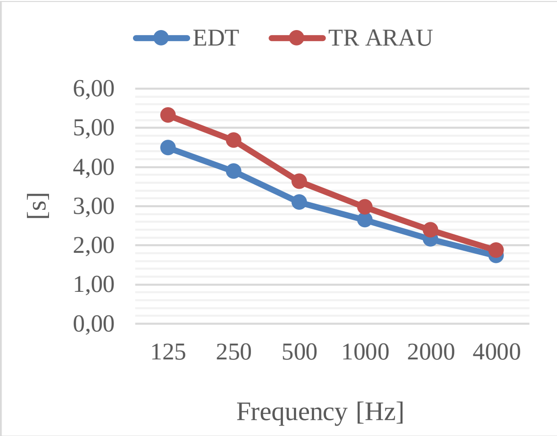
Frequency (Hz)	125	250	500	1000	2000	4000	T_{mid}	T_{low}	T_{high}	I_{war}	I_{br}
EDT (s)	4.49	3.88	3.10	2.64	2.15	1.73	2.87	4.19	1.94	1.46	0.68
RT Arau (s)	5.32	4.68	3.63	2.97	2.38	1.87	3.30	5.00	2.13	1.52	0.64
LDT (s)	6.29	5.63	4.24	3.34	2.63	2.02	3.79	5.96	2.33	1.57	0.61



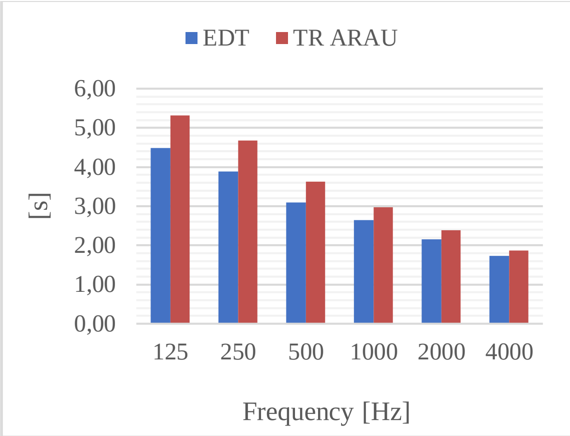
Graph 1



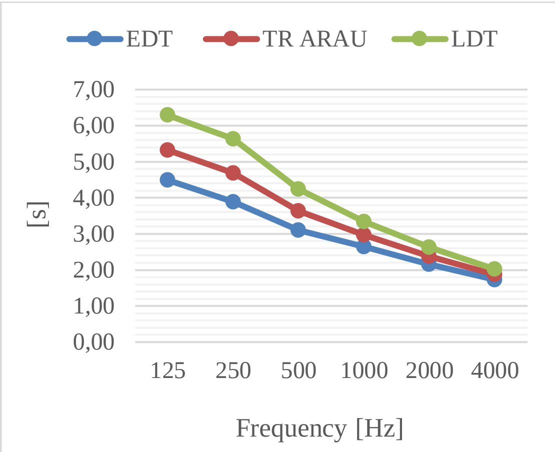
Graph 2



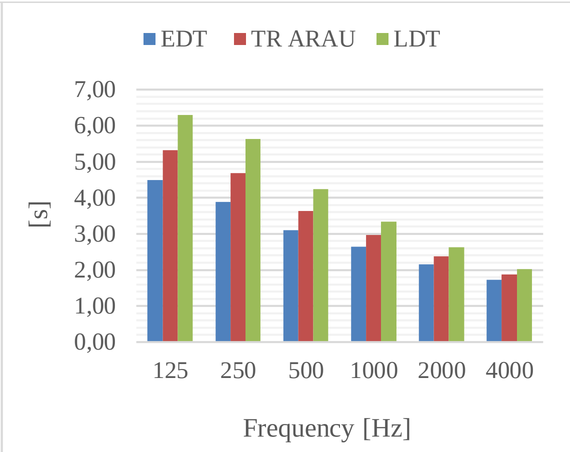
Graph 3



Graph 4



Graph 5



Graph 6

Examining what it is shown in the comparative figures (Graph 1 and Graph 2) of the calculated reverberation times, the results obtained with the theories of Sabine and Eyring are almost similar, while Arau's results differ a lot in the low frequencies with higher values: in the bands of 125 Hz and 250 Hz there is a difference of almost two seconds with the other two theories. The values of the *EDT* are placed in the middle of the results of the theory of Arau and Sabine, getting closer to the values of Arau.

Secondly, we have Graph 3 and Graph 4 where the results of the *EDT* and the *RT* of Arau are compared. You can see how the two values do not get too close, bearing in mind that the task of this work is to achieve almost complete uniformity in a reverberating room. Table 4 shows the minimum discrepancy between the two values.

The fact that there is a discernible difference in the two results of the *EDT* and *RT* of Arau is clarified by the values of the normal logarithmic dispersion factor which, in all frequencies, is always greater than unity and in particularities closer to value one in the frequency of 4000 Hz and is characterized by the highest value of 1.20 in the frequency of 250 Hz (Table 5).

Finally, you can see in Graph 5 and Graph 6, where the values of the *EDT*, *RT* of Arau and *LDT* are compared, that the three results respectively show increasing values in all the octaves displaying a lot of discrepancy between them, except in the frequency of 4000 Hz where the three parameters are very close.

3.2. Empty room case with absorption of the same area distributed between two mutually collateral walls and the floor

In Table 7 we have represented the data of the reverberation time calculated with the three theories and the results of the *EDT*, also the values of the T_{mid}, T_{low}, T_{high} and the indexes of warmth and sound brightness for the empty reverberant room with the absorption distributed in the three mutually perpendicular walls: one third of the surface of 10 m^2 each wall.

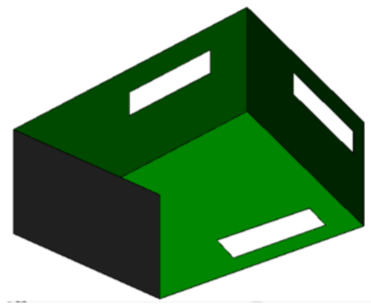


Figure 4

Table 7

Frequency (Hz)	125	250	500	1000	2000	4000	T_{mid}	T_{low}	T_{high}	I_{war}	I_{br}
EDT (s)	3.39	2.74	2.45	2.35	2.00	1.67	2.40	3.07	1.84	1.28	0.76
RT Arau (s)	3.47	2.79	2.5	2.41	2.06	1.71	2.46	3.13	1.89	1.27	0.77
RT Sabine (s)	3.51	2.85	2.55	2.45	2.08	1.74	2.50	3.18	1.91	1.27	0.76
RT Eyring (s)	3.44	2.77	2.48	2.38	2.02	1.7	2.43	3.11	1.86	1.28	0.76

Table 8

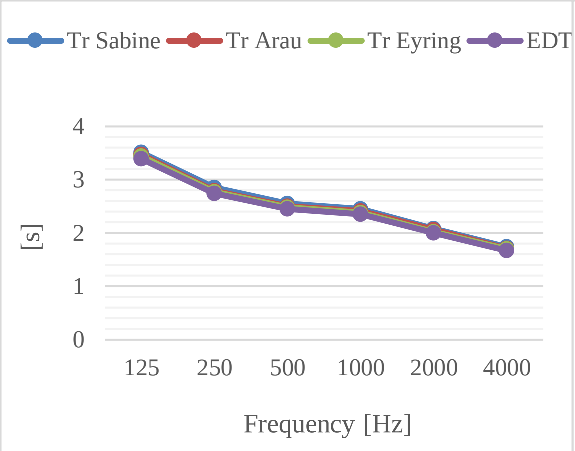
Frequency (Hz)	125	250	500	1000	2000	4000
ΔT = EDT – RT Arau (s)	-0.08	-0.05	-0.05	-0.06	-0.06	-0.04

Table 9

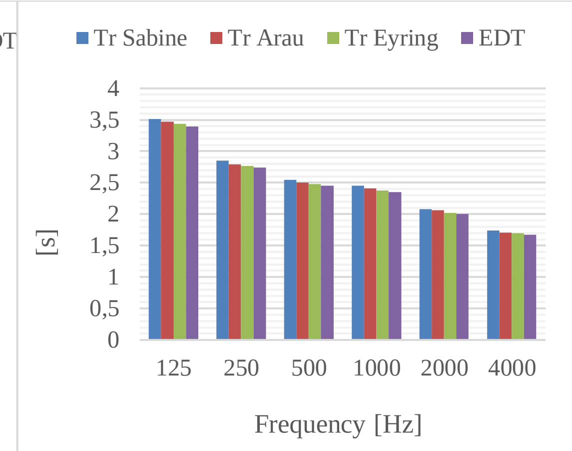
Frequency (Hz)	125	250	500	1000	2000	4000
Dispersion factor d	1.02	1.02	1.02	1.03	1.03	1.03

Table 10

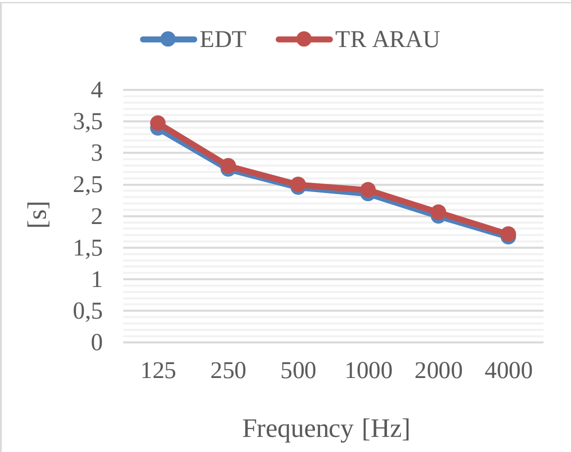
Frequency (Hz)	125	250	500	1000	2000	4000	T_{mid}	T_{low}	T_{high}	I_{war}	I_{br}
EDT (s)	3.39	2.74	2.45	2.35	2.00	1.67	2.40	3.07	1.84	1.28	0.76
RT Arau (s)	3.47	2.79	2.50	2.41	2.06	1.71	2.46	3.13	1.89	1.27	0.77
LDT (s)	3.56	2.84	2.55	2.48	2.12	1.77	2.52	3.20	1.95	1.27	0.77



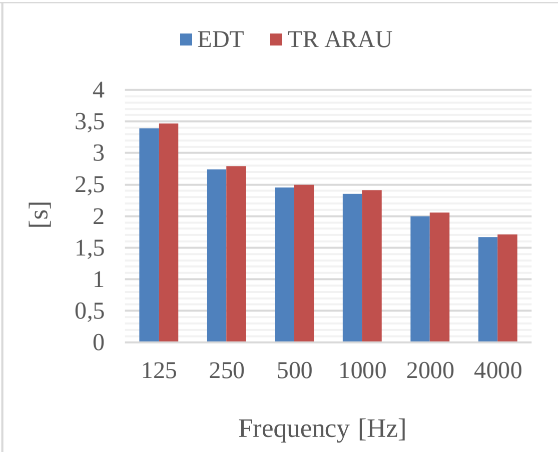
Graph 7



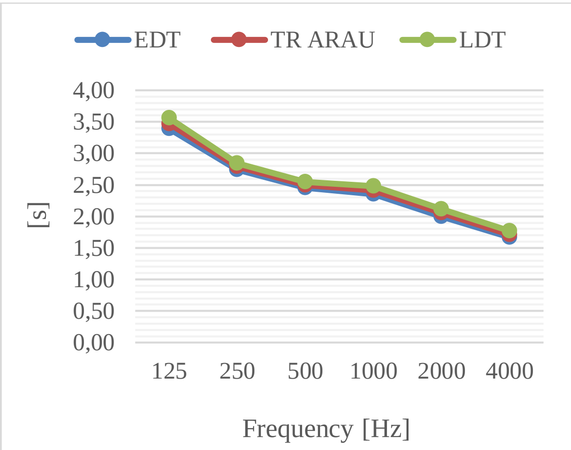
Graph 8



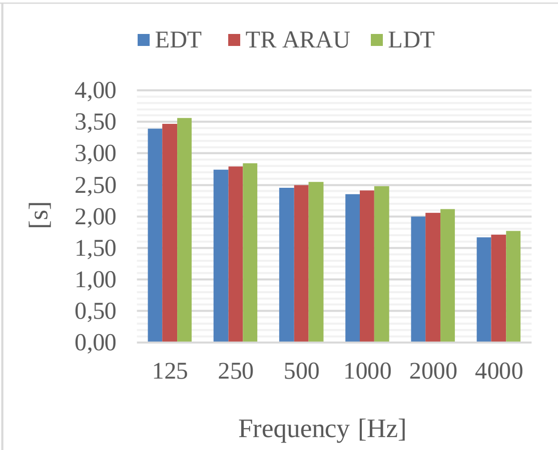
Graph 9



Graph 10



Graph 11



Graph 12

Firstly, as you can see in the comparative tables (Graph 7 and Graph 8) of the calculated reverberation times, the results of the three theories almost match, in particular that of Sabine and Arau in the frequency of 500 Hz and the of Eyring and Arau in the frequencies 250 Hz and 4000 Hz.

Comparing the values of the T_{mid}, we make evident that the values calculated by Arau and Eyring are closer with a minimum discrepancy of 0.03 s. Furthermore, all the values obtained with Arau's theory are placed in the middle of the values obtained with the other two theories. All the values of the *EDT* are placed below the values calculated by Eyring, approaching a lot, almost to coincide, with them.

Secondly, in Graph 9 and Graph 10 the results of the *EDT* and the *RT* of Arau are compared. We can demonstrate that, although they never coincide, the two values are much closer than the previous case in all frequencies, with an average discrepancy of -0.056 s (Table 8). In this case, more than the previous one, it is possible to observe that the uniformity of the sound distribution is achieved practically by the equality of the values of the *EDT* and the *RT*. It can be said that this is the situation in which the theory of Arau, theory devised for no-uniformity, also achieves the uniformity of the sound distribution by the equality of the values of the *EDT* and the *RT*.

Thirdly, you can see very well in Table 9 how all the values of the normal logarithmic dispersion factor for all frequencies almost coincide with the value of the unit with a mean value of 1.025 and a minimum value of 1.02 in the first three frequency bands.

Finally, in Graph 11 and Graph 12, we have compared the values of the *EDT*, *RT* of Arau and *LDT*, and we observe how the three are always growing, as they should be, but they are very close in all the frequencies: this is another verification of the uniformity achieved in the reverberant room by Arau's theory.

4. CONCLUSIONS

Based on the comparison made in the work, it is possible to extrapolate the following conclusions.

First, in the case of empty room with absorption of 10 m^2 area placed on the floor, we note that the results achieved with the formulas of Sabine and Eyring almost coincide, while those of Arau differ considerably in the low frequencies with higher values. This happens because Arau's theory takes into account the no-uniformity of the absorption of an enclosure and the spatial directionality of the absorption.

Secondly, case b2), in the case of an empty room with absorption placed between two mutually collateral walls and the floor, an almost equivalence of the results achieved with the three theories is presented.

This depends on the fact that there is more uniformity of absorption in the room compared to the case analyzed above, case b1), and there is a congruence of the results between the two classical theories that contemplate the uniformity of the rooms and the Arau theory validates when there is no uniformity. In fact, we can affirm that in a situation in which there is very well distributed absorption in a room, the theory of Arau, theory devised for no-uniformity in an enclosure, achieves the uniformity of the sound distribution by the equality of the values of the *EDT* and the *RT*. In this case, the uniformity has been checked with the calculations of the normal logarithmic dispersion factor d, which, for all frequencies, is very close to 1.

Finally, it can be said that Arau's theory pursues "uniformity from no-uniformity" in an enclosure. Therefore, in order to achieve maximum accuracy in the measurements of a material in a reverberating room, please make a change to the ISO 354 standard concerning the subject by explaining here , so that the test sample is divided into three aerial areas, which we have indicated and its sum is equal to 10 m^2.

With which we would get a prediction of the absorption coefficient of the material much more accurate (*A. Ratto – H. Arau, Bibliografía General).

5. REFERENCIAS

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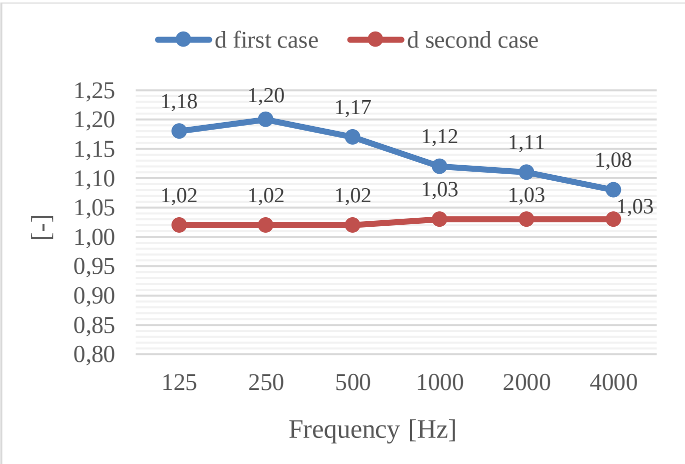
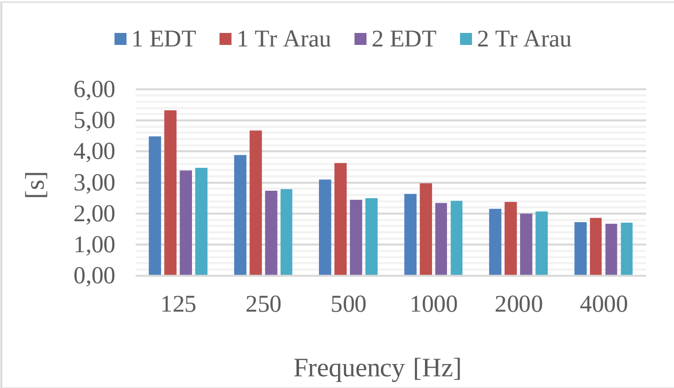
6. ANNEXED

As a first comparison, the values of the normal logarithmic dispersion factor can be compared in the first and the second case. As can be seen from the comparative table (Graph 13) in the second case, where there is a more uniform distribution of the absorbent material, all the values of the factor *d* come close to the unit while the other values of the first case stand out considerably from the unit and from the other values. A large difference can be seen in the low frequency values.



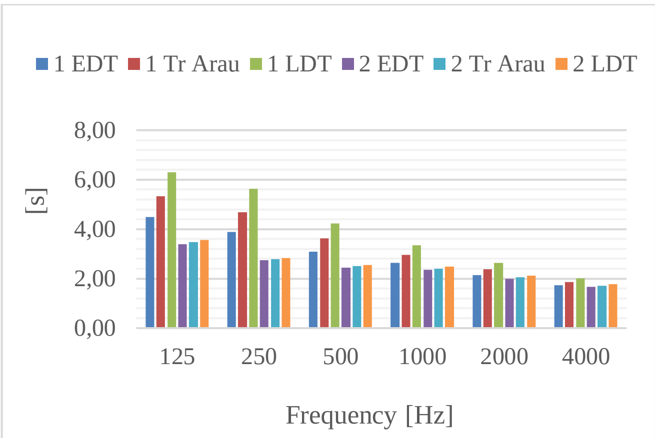
Graph 13

As a second comparison, we have compared the values of the *RT* of Arau and the *EDT* and, as seen in Graph 14, in the second case the uniformity has been better achieved by the almost coinciding values of the *EDT* and the *RT* of Arau.



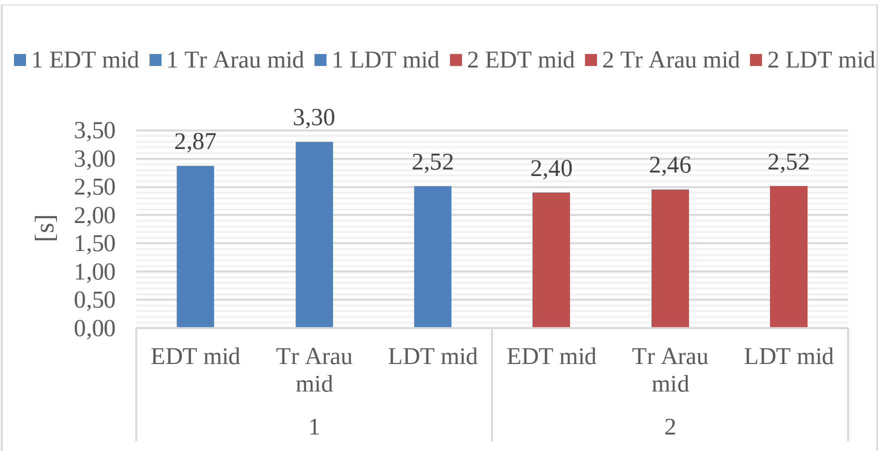
Graph 14

The same consideration can be made as regards to the comparison between the values of the *EDT*, *RT* of Arau and *LDT*, where always in the second case, there is almost the coincidence between the three values. In the first case they stand out a lot among them (Graph 15).



Graph 15

Finally, the comparison table (Graph 16) of EDT_{mid}, Arau's RT_{mid} and LDT_{mid} in both cases is shown.



Graph 16