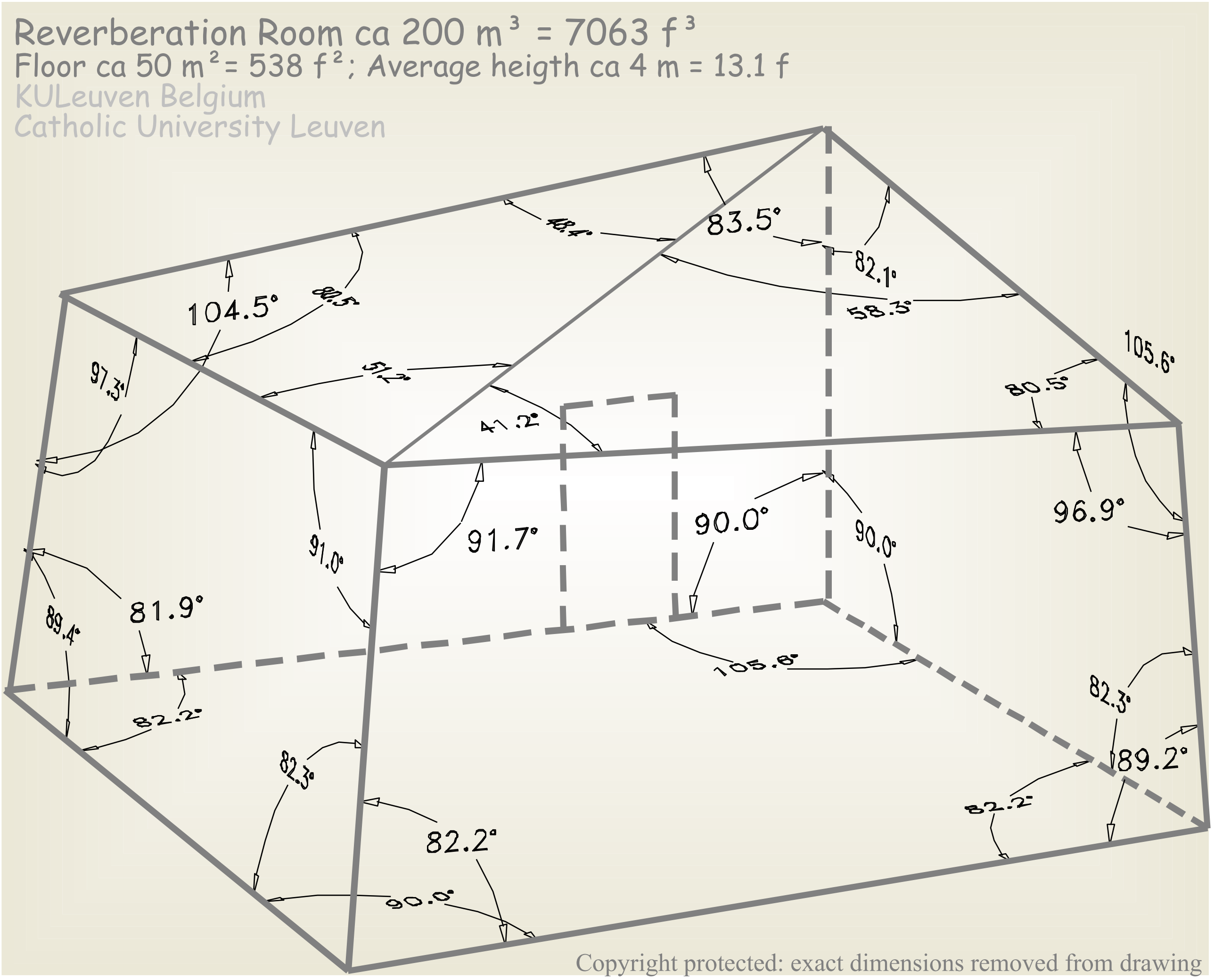
Playing with Sabines for baffles, diagonal absorption & plain panels



This document covers some acoustic measurements, executed in the Reverberation Room of the Catholic University of Leuven - Belgium. ALL included data is copyright protected and can not be distributed, neither complete nor partly, nor direct or indirect, via hard copy or on-line without the written consent of the author.

While not meant to give a complete oversight, nor an in-depth approach, this document can give some practical insight in different acoustic phenomena or often referred topics.

None of the materials included in this document are standard commercial products, but discrete objects specially produced or prepared (using standard commercial available material if applicable) in function of those measurement sessions, or custom made products for specific projects.

The included measurements are executed by either the author of this document himself (with aid of assistants), or University students accompanied by lab technicians/assistants. All measurements and studies included in this document are initiated by the author and executed under the supervision of, with the co-operation or assistance or interest shown by:

Prof. Dr. Ir. Gerrit Vermeir - Catholic University Leuven - Department Building physics - Laboratory Acoustics.

Some of the measurements are done just for the know-how and/or know-why, others where related to a TV-studio in excess of 14000 m³ (500,000 cf) acoustically designed by the author.

Possibly this document will be extended in the future with more (existing) data covering similar and other acoustic absorption topics.

The author: Eric Desart
DESART acoustics
ANTWERP BELGIUM

Interpreting α_{Sabine} values:

The table below is not meant to explain the measurement of Sabine values in a certified laboratory in-depth. Much more is calculated than is shown here. Statistics are often involved to calculate the best straight line fitting, in function of predefined minimum correlation factors. Literally applying the -5 dB to -35 dB rule can sometimes cause some strange results.

However it is meant to show that there are tolerances, which can be influenced by numerous factors, as there are the diffusity, modal behavior etc. which can be influenced by the 'to be measured' absorptive material itself.

Positioning of the material in the room, even when applied within the boundaries of the related standards, can cause more or less deviations.

Can such measurements then not be trusted? **YES THEY CAN BE TRUSTED.**

Certified laboratories will do the utmost to fine-tune their rooms. Often they will compare similar material measurements between labs as some kind of calibration. He standards prescribe rules in function of repeatability etc.

Only one should take the complexity of the influencing physical factors into account. This means that one NEVER should worry too much about minor differences between measurements of comparable materials.

Different labs can measure minor differences. Measured absorptive material is only a sample that can deviate a bit from another sample. Even the same material measured in the same lab can show minor differences.

Experienced producers of specific acoustic materials, mostly do understand the boundaries and flexibility within the specifications of the related standards. It can be temping to publish the most attractive measurement data. Certainly when discrete large 3-D objects are involved, one must be careful to understand the acoustic boundaries of the published measurement data.

	Polyester 32 kg/m³ - 65 mm + air cavity 35 mm (Tot 100 mm)								**Empty** Reference Reverberation Room								**Sabine** & Stand. Dev.				
		Reverb Time in sec.				Standard deviation				Reverb Time in seconds				Standard deviation			αSabine values				
Fre quency	Dynamic Range in dB	T_{dyn}	T_{10}	T_{20}	T_{30}	σ in sec.	σ in - α	σ in + α	Dynamic Range in dB	T_{dyn}	T_{10}	T_{20}	T_{30}	σ in sec.	σ in - α	σ in + α	α_{dyn}	α_{10}	α_{20}	α_{30}	σ_{30} in α_S
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
80 Hz	36.0	5.40	5.3	4.7	**4.99**	0.8 s	-0.07	0.10	37.6	8.00	6.4	6.7	**7.34**	1.2 s	-0.05	0.07	0.16	0.09	0.17	**0.17**	0.10
100 Hz	39.0	6.20	4.2	4.6	**5.51**	1.1 s	-0.08	0.12	33.1	13.90	9.8	11.6	**11.64**	3.0 s	-0.05	0.08	0.24	0.36	0.35	**0.25**	0.11
125 Hz	37.3	4.20	2.8	3.9	**3.96**	0.5 s	-0.07	0.09	36.9	12.20	10.4	11.2	**11.79**	1.8 s	-0.03	0.04	0.41	0.69	0.44	**0.44**	0.09
160 Hz	33.4	3.60	2.7	3.1	**3.41**	0.4 s	-0.08	0.11	35.9	11.40	10.1	10.1	**10.76**	1.8 s	-0.04	0.05	0.50	0.72	0.59	**0.53**	0.10
200 Hz	34.6	2.20	2.3	2.1	**2.10**	0.2 s	-0.09	0.11	38.1	9.50	9.1	8.8	**8.98**	0.7 s	-0.02	0.02	0.92	0.86	0.96	**0.96**	0.10
250 Hz	37.9	2.00	2.2	1.9	**1.92**	0.1 s	-0.07	0.08	38.4	8.20	8.1	7.5	**7.79**	0.5 s	-0.02	0.02	1.00	0.88	1.04	**1.04**	0.08
315 Hz	36.3	2.10	2.1	2.0	**2.01**	0.1 s	-0.09	0.10	37.5	7.50	8.0	7.3	**7.38**	0.4 s	-0.02	0.02	0.91	0.93	0.96	**0.96**	0.09
400 Hz	35.8	2.40	2.2	2.3	**2.36**	0.1 s	-0.05	0.05	37.3	7.30	7.4	7.5	**7.27**	0.3 s	-0.01	0.02	0.74	0.84	0.80	**0.76**	0.05
500 Hz	36.8	2.40	2.4	2.3	**2.32**	0.1 s	-0.04	0.05	37.4	7.00	6.9	7.0	**6.92**	0.2 s	-0.01	0.01	0.72	0.72	0.77	**0.76**	0.05
630 Hz	36.1	2.30	2.3	2.3	**2.30**	0.1 s	-0.07	0.07	37.9	6.60	6.6	6.5	**6.51**	0.2 s	-0.01	0.01	0.75	0.75	0.74	**0.74**	0.07
800 Hz	37.5	2.30	2.2	2.3	**2.30**	0.1 s	-0.04	0.04	36.8	6.70	6.5	6.6	**6.58**	0.2 s	-0.01	0.01	0.75	0.79	0.75	**0.75**	0.04
1000 Hz	37.9	2.30	2.2	2.2	**2.23**	0.1 s	-0.05	0.05	37.9	6.90	6.9	6.8	**6.82**	0.2 s	-0.01	0.01	0.77	0.82	0.81	**0.80**	0.05
1250 Hz	37.2	2.20	2.2	2.2	**2.20**	0.1 s	-0.03	0.03	38.8	7.20	7.3	7.2	**7.18**	0.1 s	-0.01	0.01	0.83	0.84	0.83	**0.83**	0.03
1600 Hz	37.0	2.00	2.0	2.0	**2.03**	0.1 s	-0.03	0.03	37.7	6.70	6.7	6.6	**6.65**	0.1 s	-0.01	0.01	0.93	0.93	0.92	**0.90**	0.03
2000 Hz	36.6	1.90	2.0	1.9	**1.90**	0.1 s	-0.04	0.04	37.6	5.60	5.6	5.5	**5.54**	0.1 s	-0.01	0.01	0.92	0.85	0.91	**0.91**	0.04
2500 Hz	36.9	1.80	1.8	1.8	**1.82**	0.1 s	-0.04	0.04	37.8	4.60	4.6	4.5	**4.50**	0.1 s	-0.01	0.01	0.89	0.89	0.88	**0.86**	0.04
3150 Hz	36.6	1.70	1.7	1.7	**1.71**	0.0 s	-0.03	0.03	38.7	3.80	3.8	3.8	**3.78**	0.1 s	-0.01	0.01	0.86	0.86	0.86	**0.85**	0.03
4000 Hz	36.8	1.50	1.5	1.5	**1.49**	0.0 s	-0.02	0.02	38.3	3.00	2.9	2.9	**2.95**	0.1 s	-0.01	0.02	0.88	0.85	0.85	**0.88**	0.03
5000 Hz	34.8	1.30	1.3	1.3	**1.31**	0.0 s	-0.03	0.03	36.6	2.30	2.3	2.3	**2.31**	0.0 s	-0.01	0.01	0.88	0.88	0.88	**0.87**	0.03
6300 Hz	36.0	1.10	1.1	1.1	**1.09**	0.0 s	-0.04	0.05	36.6	1.70	1.6	1.6	**1.66**	0.0 s	-0.03	0.03	0.85	0.75	0.75	**0.83**	0.05

Problem is that often the needed info to judge or interpret the published Sabine values isn't published at all.

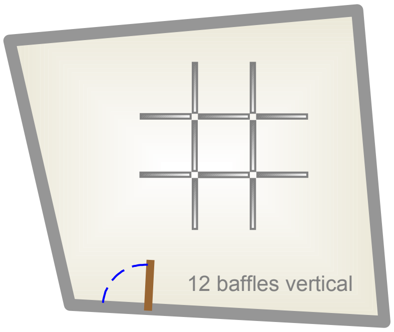
The table shows a typical measurement of a flat acoustic polyester foam (32 kg/m³) mounted on a cavity of 35 mm. Reverberation time measurements are made from the room with (including edge screening) and without the absorptive objects or lining. The difference between both, results in the added total absorption, which than can be recalculated per unit of discrete objects (in US known as Sabines, in Europe often expressed as α_S per unit), or per surface unit recalculated versus the total lined surface. The latter then results for both ASTM and ISO standards in the well-known α_S. The unit (imperial, metric) doesn't matter here since this can roughly be (as a matter of speech = not complete exact) interpreted as a percentage of equivalent absorption per surface unit.

For the ones less familiar with such measurement procedures, but yet still interested to get the picture) a small explanation of the content of the above table.

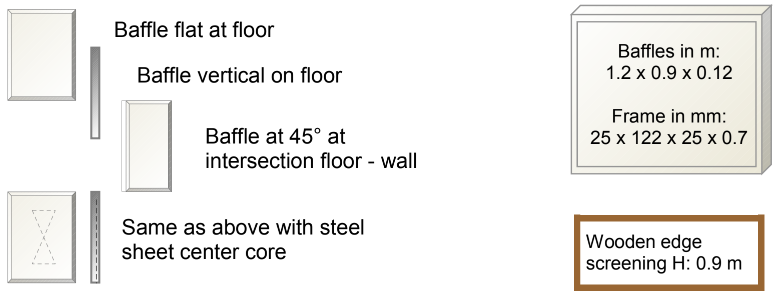
<u>Columns:</u>

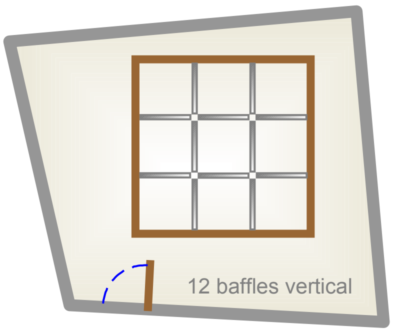
- Column 1: Frequency bands in 1/3 octave bands
- Columns 2 & 10:
  The total available dynamic range of the lab, based on the sound pressure level in the room resulting from the noise source versus the background noise, measured per frequency band.
  - ✓ In order to have a valid measurement, one should try to measure a decay of 30 dB (exceptions are allowed but should be avoided).
  - ✓ In order to make sure that there is a maximum sound distribution (diffusity) and to exclude early reflections, the decaying noise is taken into account starting from the maximum level minus 5 dB.
  - ✓ In order to make sure that the background noise will not influence the tale of the reverberation decay, the specific noise pressure at it lowest level integrated in the measurement must still exceed the background noise with ca 10 dB.
  - ✓ In the table, the level difference between noise source and background noise, as such is 15 dB higher than the above mentioned, for the measurement available dynamic range figures.
  - ✓ The standards tell that the Maximum pressure minus 5 dB towards -35 dB, is the standard range. However laboratories often introduce some additional algorithms to optimize the straight line fitting, which can make the method more complicated then a simple averaged subtraction.
  - ✓ Note that a published laboratory value is NEVER the result of a single measurement. The standards define the number of measurements, source and microphone positions. Roughly one could say that with nowadays real time equipment and fixed microphone positions, a published measurement is calculated from 12 measurements.
- Columns 3 to 6 & 11 to 14:
  This are the respective reverberation times over the diverse dynamic ranges:
  - ✓ T_{dyn}: Reverberation time calculated based on total VALID dynamic range (is the total dynamic range -15 dB).
  - ✓ T_{10}: Reverberation time calculated based on first 10 dB decay (-5 to -15 dB). This is also often referred to as EDT or Early Decay Time and is in room acoustics an often used parameter in function of speech intelligibility.
  - ✓ T_{20}: Reverberation time based on first 20 dB decay (-5 to -25 dB). This parameter is mostly used as an alternative for the T_{30}, when not enough dynamics is available. Some norms for in situ measurements (building and industrial acoustics), define this as a standard parameter, since too often the conditions aren't fulfilled to calculate a valid T_{30}.
  - ✓ T_{30}: Reverberation time based on first 30 dB decay (-5 to -35 dB). This is the most used standard approach, also mentioned in lots of norms as THE standard or preferable approach.
  - ✓ Note that all the above are in fact real reverberation times expressed as the time in seconds for a decay of 60 dB. The difference is only to be found in the dynamic decay range this T is calculated from.
- Columns 18 to 21:
  This are the respective Sabine values calculated for the above different dynamic noise decay ranges. Here one can notice that noise decay and absorption isn't such a nice linear process, as one should imagine at a first glance. It also shows the uncertainties and physical phenomena (often difficult to study) influencing those results.
  NOTE THAT IN AN OFFICIAL LABORATORY MEASUREMENT REPORT ONLY THE T30 WILL BE SHOWN (exceptionally a T_{20} will be used to compensate for lacking dynamics. The author assumes this will seldom occur).
- Columns 7 to 9 & 15 to 17:
  The standard deviations calculated for both, the measurements with the absorptive sample, and the empty reference room, with the effect on the related absorption values (minus and plus) (only shown for T30 values).
- Column 23:
  The standard deviation calculated on the final published T_{30} Sabine values, taking both the uncertainties of the empty room and the sample measurements into account. While containing interesting additional

information, even most acousticians will only see minor part of the information included in the above table.

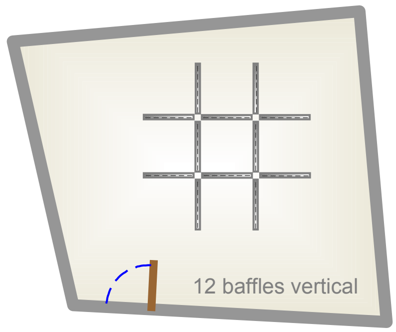


Measurement 01

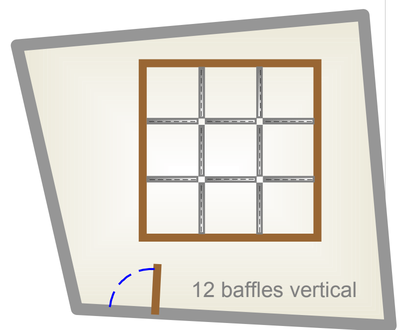




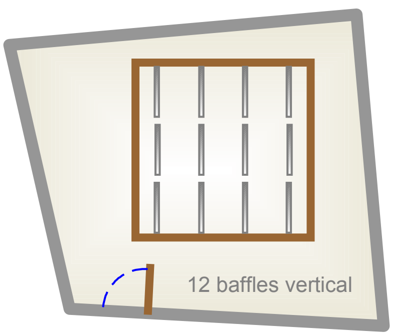
Measurement 02



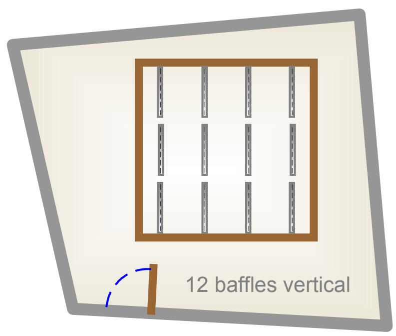
Measurement 03



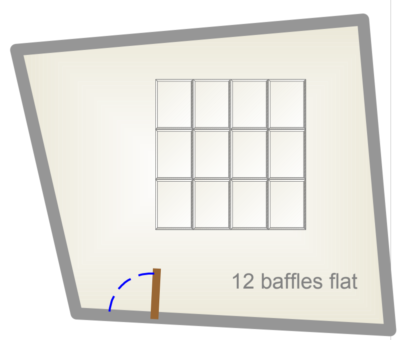
Measurement 04



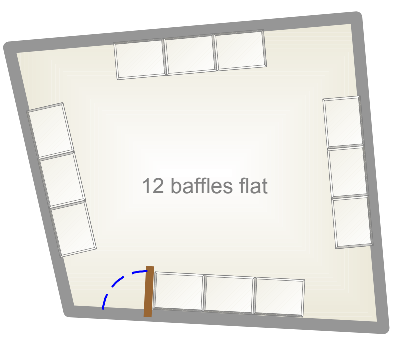
Measurement 05



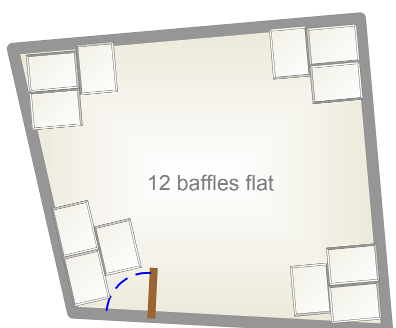
Measurement 06



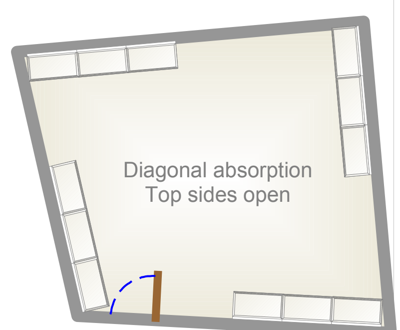
Measurement 07



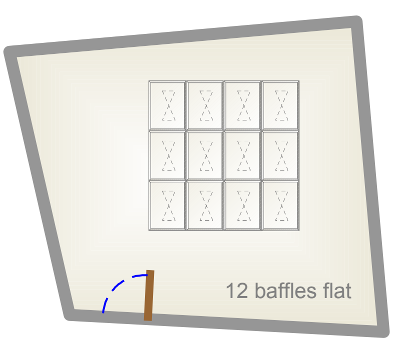
Measurement 08



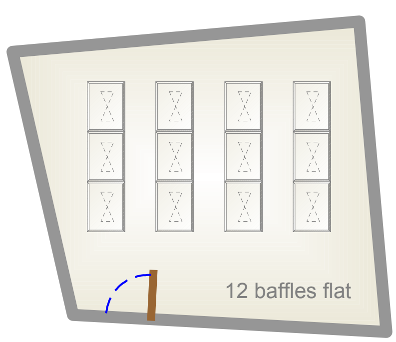
Measurement 09



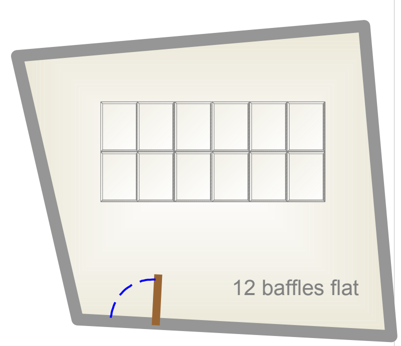
Measurement 10



Measurement 11



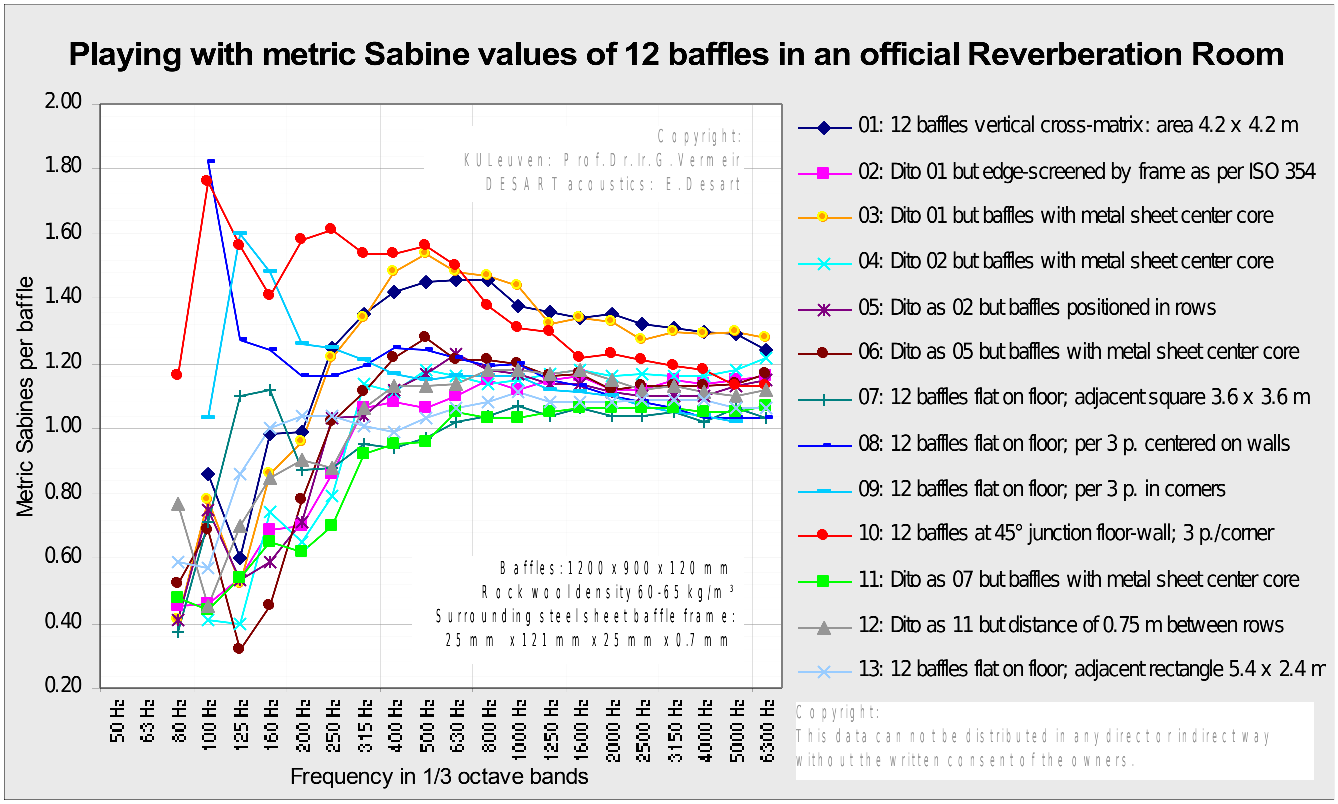
Measurement 12



Measurement 13

All graphs together:

While this graph is very difficult to read or interpret in detail, one conclusion stands out from the pack:



All detailed measurements to be found in Appendix A of this document

A Sabine value is NO constant material property.

All the above measurements are executed with THESAME Baffles. The only material difference are the baffles where a metal sheet center core was integrated. However this center core (as to be expected) has negligible impact.

As such one can notice that measurement technique, positioning in the room, and numerous other phenomena can influence the resulting data. As such it has little sense to compare Sabine data from one supplier to the other, in senseless detail.

Even repeated measurements on the same material in the same laboratory, will show some deviation. Different laboratories, can show larger deviations.

When measuring discrete objects as baffles, chairs, people, tube traps and other kinds of discrete absorbers the difference can become much larger, since the related standards do allow a lot of interpretation in the way they should be measured, and how the results are presented.

The slightly different approach between the standard sample size as defined by the ASTM (US) standard (72sf - 6.7 m²) versus the ISO (European) standard (ca 129sf = 12 m²) can contribute a lot to this confusion. Based on a floor surface of ca 50 m² (538 sf) this different sample size equals respectively a floor coverage of 13.4% versus 24 %, having significant impact on the diffusity of the room, causing the US standard almost systematically to result in somewhat higher Sabine values for plain (and other) materials. This different sample size also contribute to the higher ASTM edge effect (ratio perimeter versus surface, also contributing to those higher values.

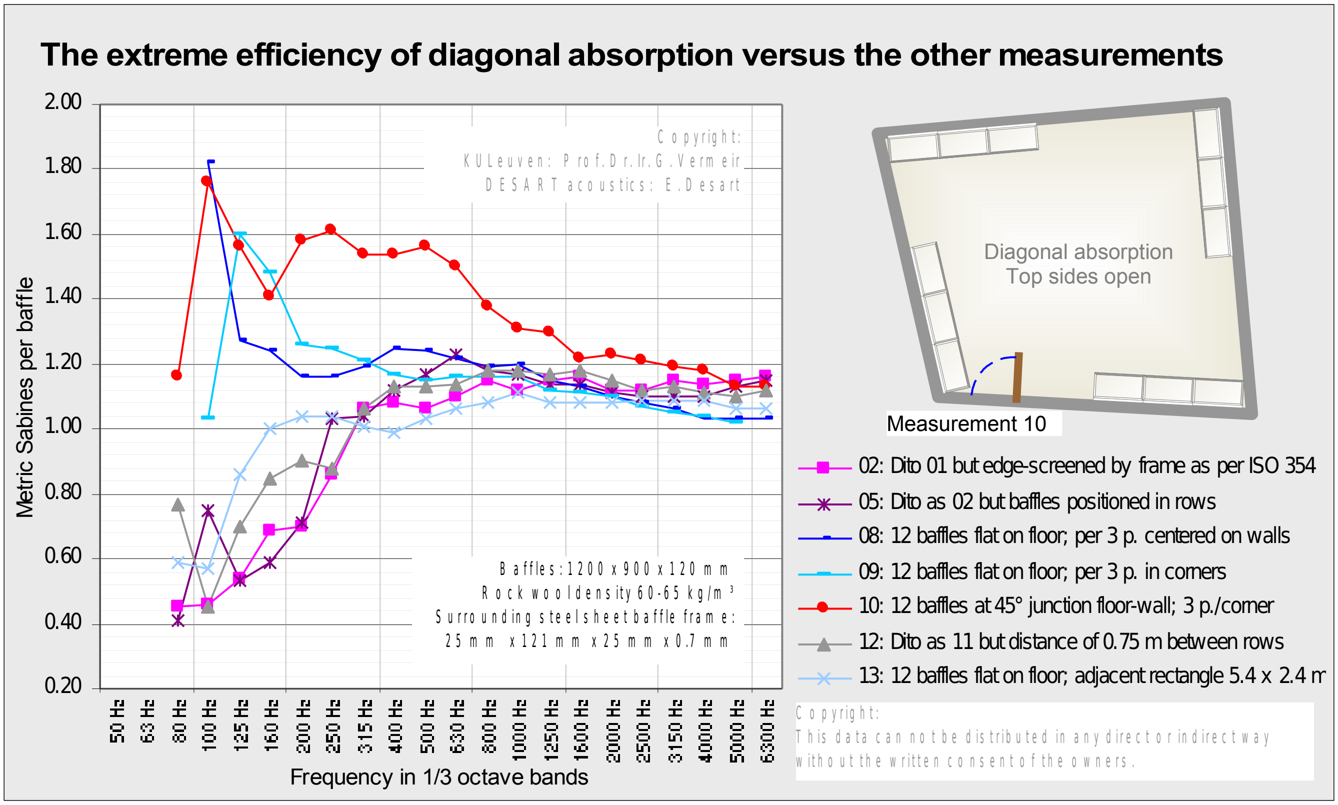
It should also be clear that producers have great interest in showing as high as possible Sabine values. By not describing the exact used measurement method, in fact the user is prevented to picture the exact content the presented Sabine values stand for. As such some discrete objects are presented in such a way that the layman or even acoustician with less lab measurement experience can STRONGLY be mislead. Certainly discrete objects allow for such confusion which can sometimes be presented as values with a factor 3 too high versus the same discrete object used as part of an array.

While for plain materials as foam or mineral wool panels measured as per the related standards, the comparison between the resulting values can give a good representation of acoustic quality differences. However for discrete object the measurement method is too great an influence, to interpret resulting values without any further description of the used method.

Note that the results in this study are NOT meant for publication as official values, but to study some acoustic phenomena.

A Sabine value represents the sound absorption of materials or discrete objects within, and related to, certain boundary conditions.

The extreme efficiency of Diagonal absorption:



In the above graph a selection is made of the other measurements in order to be compared with the principle of diagonal absorption.

Excluded are:

1. All baffles with a metal sheet center core since the shown diagonal absorption also does not include the center core.
2. The baffles without screening, since they are basically measurements presenting a wrong absorption picture. They are included in this study to measure and show this non-screened edge effect.
3. Measurement 7, since this measurement shows an increased absorption in the 125 Hz and 160 Hz band, which is clearly related to the specific layout/arrangement of the measurement in the reverberation room, and as such not really representative for the behavior of a 120 mm thick absorptive cladding.

It should be clear that diagonal absorption (panels mounted at 45° in corners) in a 2-wall intersection, and even more in a 3-wall intersection is an extremely efficient absorptive approach.

Unlike standard absorption, where with increased thickness or increased cavity width behind the absorptive panels, the absorption curve becomes flatter and flatter (increased low frequent absorption with increased thickness = relation with wavelength), with diagonal absorption, one gets a reverse absorption curve, where the low frequent absorption becomes higher than the higher frequency range (curve declines rather than rises).

While doing so, this positive low frequent effect is not at the expense of the mid and high frequencies still exceeding the absorption values of other object or panel arrangements.

This phenomenon is confirmed by several other measurements executed by the author.

While the principle is familiar and used a lot in practice in the studio world, elsewhere it seems not a common or well-known approach.

However in function of speech intelligibility it is a very efficient approach to be used in classrooms, and certainly in rooms where to limited height, one does not prefer to use suspended ceilings etc.

The spectral absorption behavior of diagonal absorption is about an optimum in function of such applications.

Often one checks reverberation curves in function of the energetic spectral distribution of speech.

The low frequent absorption is often wrongly ignored as well in function of speech, music as technical equipment.

This is also related to the asymmetric behavior of the basilar membrane in the human ear causing the relative higher low frequent masking of disturbing noise.

The principle was described in a US and International Patents:

In Sweden the principle (licensed) was promoted by Rockwool AB for primary use in Classroom acoustics, boardrooms, offices and the like.

The patent (8 pages) discusses different versions and deviated designs and applications.

Patent Number: 04362222 Section: Front Page 1 of 8 pages

United States Patent [19] **Hellström**

[11] **4,362,222**
[45] **Dec. 7, 1982**

[54] **ARRANGEMENT FOR DAMPING AND ABSORPTION OF SOUND IN ROOMS**

[75] Inventor: **Per A. Hellström**, Gothenburg, Sweden

[73] Assignee: **Byggnadsfysik A & K AB**, Gothenburg, Sweden

[21] Appl. No.: **250,254**

[22] Filed: **Apr. 2, 1981**

[30] **Foreign Application Priority Data**

Apr. 9, 1980 [SE] Sweden 8002653

[51] **Int. Cl.**[3] **E04B 1/82**; E04B 1/99

[52] **U.S. Cl.** **181/30**; 181/287; 181/295

[58] **Field of Search** 181/30, 198, 284, 287, 181/295, 286; 52/144-145

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,020,430 11/1935 Oed .... 181/284 X
2,224,651 12/1940 Jacobs 181/30

FOREIGN PATENT DOCUMENTS

786503 9/1935 France 181/30

OTHER PUBLICATIONS

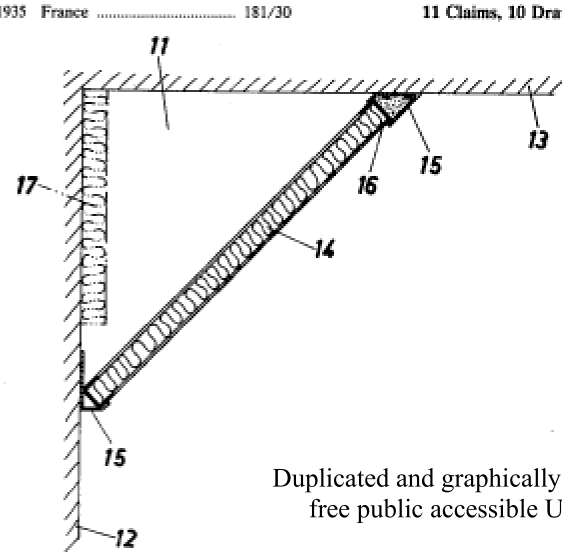
Carson et al., "Broadcast Studio," *Architectual Forum*, Feb. 1946, pp. 98-100.
Rettinger, Scoring-Stage Design, *Journal of the Society of Motion Picture Engineers*, May 1938, pp. 519-534.

Primary Examiner—L. T. Hix
Assistant Examiner—Thomas H. Tarcza
Attorney, Agent, or Firm—Holman & Stern

[57] **ABSTRACT**

An acoustical system for damping and absorption of sound in rooms to provide a sound damping even at very low frequencies, e.g. 50 Hz, and simultaneously improve speech comprehension in the entire room by reduction of the resonance time. The acoustic absorption can be varied to vary the resonance time over the entire part of the frequency area. The sound absorbents **14** in the form of plates, mats or similar constructions, are arranged at an angle in at least one corner area **11** formed by the walls **12** and ceiling **13** of the room. In the corner area **11** behind the absorbent **14**, an air volume is trapped so that the absorbent due to the sound influence has a membrane effect. The inclination and position of each absorbent **14** can be varied individually or in groups.

11 Claims, 10 Drawing Figures



Duplicated and graphically optimized from free public accessible US on-line patent database.