# How to improve the accuracy of the absorption measurement in the reverberation chamber ?

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## Introduction

Sound absorption measurements of building materials such as suspended ceilings and other products are performed in a reverberation chamber according to ISO 354.

It is known that the inter laboratory reproducibility of these measurements is not very well. At this moment the differences of results between laboratories are much larger than can be accepted, e.g. from a jurisdictional viewpoint in case of building contracts and liability. Actions should be taken to reduce the spread. An ISO working group has started to investigate possibilities to improve the method.

Due to the insufficient diffuse sound field in a reverberation chamber with the test sample, the shape of the reverberation room and the placing of diffusers will influence the result.

A round robin research containing 13 laboratories is performed to get information on the spread and if it is possible to reduce this by correcting for the mean free path or by application of a reference material.

## Requirements

The property to be determined in the laboratory should fulfil two basic requirements:

1. It should correspond to the basic concept of absorption, representing what is actually happening.
2. It should be determined with a certain level of accuracy. Since basically different products have differences in absorption around 0,1, it would be desirable that the reproducibility is not more than 0,05.

When we look into the results of laboratory sound absorption measurements we often find data with an absorption coefficient higher than 100%. This does not fulfil the first requirement. It is not clear how to determine the 'right' absorption coefficient. The spread between data from different labs is also significant (see further). And Manufacturers may 'shop' for the laboratory with the highest values.

So it seems that both requirements are not fulfilled. We will give some results of a recent wound robin, a short overview of possible causes of the aforementioned problems and some possibilities to improve the results.

## Round Robin

The absorption of four samples has been tested:

1. 15 elements of mineral wool (Rockwool type 211, thickness 100 mm and density of ca. 44 kg/m3) in a wooden casing (1,2*0,6m), covered with a non-woven fleece (Lantor type 3103HO) and an open wire mesh for protection. The back is made of a 3 mm hardboard.
2. A mixture of 8 panels type 1 and 7 panels type 3, in a checkerboard lay out.
3. As type 1, mounted up side down, with the 3 mm hardboard exposed.
4. 18 elements of 25 mm thick foam (Mappypell SP 25B) with one side foil, glued to 8 mm mdf panels. The dimensions of each panel are 1000 x 600 x 33 mm.

The following laboratories participated: CSTB (Paris), Delta (Hoersholm), IAB (Oberursel), ITA (Achen), ITA (Wiesbaden), KUL (Leuven), Peutz (Mook), PTB (Braunschweig, 2 halls), SP (Borås), SRL (London), TNO (Delft) ,WTCB (Limelette).

The laboratories did the measurements and submitted the measured reverberation data. The calculation of absorption data and further analysis was done by Peutz.

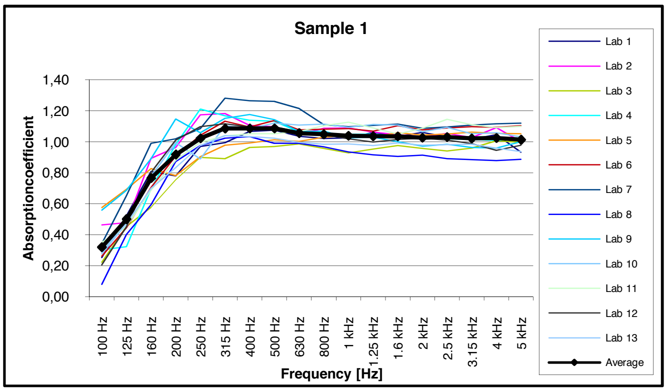



**Figure 1:** Measurement results of the sound absorption in 13 labs. The black solid line gives the average result.

Figure 1 shows the data and the average of the results of sample 1. This figure shows that the average absorption is more than 1,0, especially around 400 Hz. It also shows a significant spread and some data that are clearly outliers, with result over 1,2 or under 0,9.

The calculated Reproducibility according to [1b] is given in Figure 2. For the middle frequencies the reproducibility is in the order of 0,2, this corresponds to the values given in [1a] and corresponds to earlier investigations by [2],[3],[4].

By removing 4 of the 13 results a significant reduction in Reproducibility at the middle and high frequencies can be achieved. So it seems that a few laboratories are responsible for a large part of the deviations.

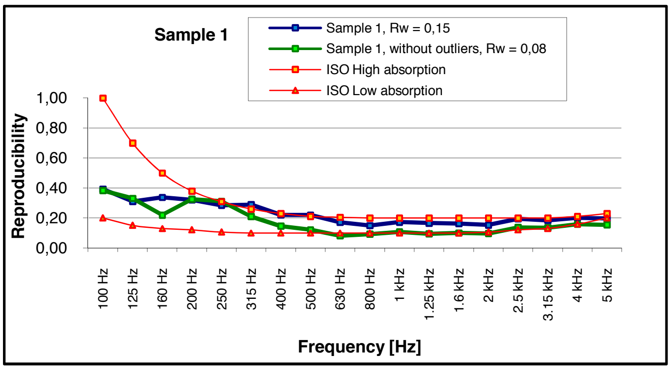



**Figure 2:** Reproducibility of sample 1 according to [1b]. For 13 labs (blue line) and for 9 labs (green line). Also indicated are the indications for the Reproducibility of a high and a low absorptive sample [1a].

From the measurement data we can conclude that the absorption data can be (significantly) above 1,0 and the Reproducibility is much more than 0,05.

The average absorption data and Reproducibility data of sample 1 to 4 are given in Figure 3.

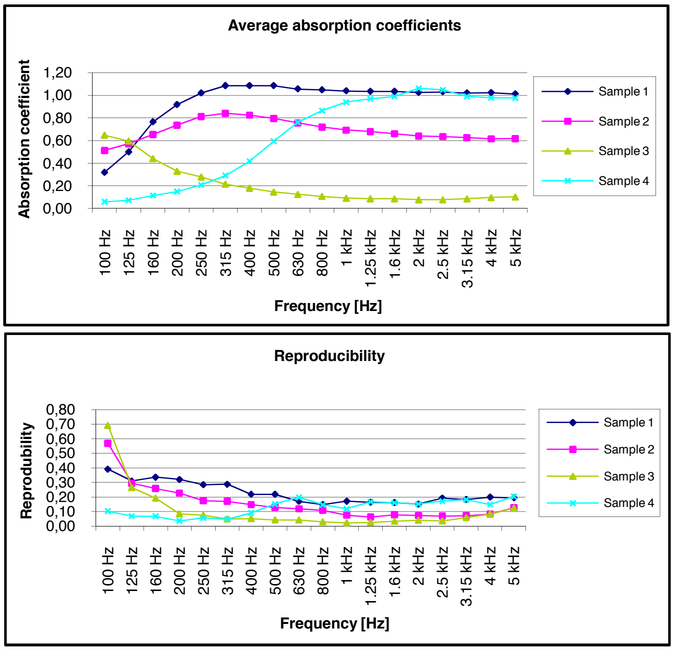


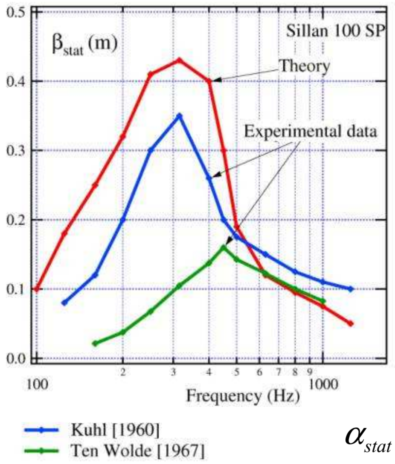

**Figure 3:** Average measured absorption (upper graph) and Reproducibility (lower graph) of sample 1 to 4.

## Reasons for high absorption

There are several (potential) reasons for the high absorption:

1. One of the reasons for $\alpha > 1{,}0$ is the well known edge effect. This is related to the wavelength relative to the dimensions of the sample, see [5]. Figure 4 illustrates the edge effect as a linear function of the relative edge length. The edge occurs mainly at the lower frequencies from 200-500 Hz. For small wavelength the edge effect is very small.

2. The calculation by Sabine's formula may overestimate the absorption. Eyrings formula gives lower results. The effect is




$$\alpha_{stat} = \alpha_S + \beta \cdot E$$

**Figure 4:** The edge effect: the absorption of a finite sample is composed of the absorption of an infinite sample $(\alpha_s)$ and a factor $\beta$ multiplied with the relative edge length E. The graph show the $\beta$ from experimental and theoretical studies [5].

around 0,03. It is noted that the average absorption of sample 1 (see figure 1) is around 1,03 for the high frequencies.

3. The diffusers in reverberation chambers will reduce the path length and thus the mean free path. This effect is not accounted for in the calculation of the absorption from the measured reverberation times.

## Reasons for large spread

The main reason for the large spread in results is expected to be the lack of a diffuse field in the reverberation chamber. On can think of the sound field consisting out of a horizontal sound field and a vertical sound field. Especially for high absorptive samples the vertical field will be strongly damped, while the horizontal sound field is much less affected by the absorption. If the horizontal sound field dominates, the absorption will be underestimated. With wall diffusion one can redirect the horizontal sound field into the vertical sound field and thus increase the absorption. The procedure in [1b], to increase diffusion until the absorption does not increase anymore does not always give an optimum. The absorption may not be beyond the maximum with maximum number of diffusers [6],[7]. The absorption may be increased even further by wall diffusion.

So, although an attempt has been made with the qualification procedure in [1b], the sound field in a reverberation chamber, with high absorptive sample, is not clearly defined so the conditions for application of Sabines equation are not met.

## Possibilities to reduce the absorption and the spread

The result of the absorption measurement can be reduced by:

1. Correcting for the edge effect, thus obtaining the absorption for the infinite sample. This was proposed in the 60's but did not make it into the standard. It requires the

measurement of many different configurations with different Edge length and therefore it is not practical. That means that the edge effect has to be accepted. By giving the range for the dimensions of the sample, the relative edge length is automatically fixed within a range.

2. One may use Eyrings formula in stead of Sabine. Without going into the theoretical background we can see that this might prevent the high frequency excess. It will not reduce the spread (there will be a small effect though on Reproducibility since the Reproducibility is lower for low absorption values).

3. One may correct for the shorter mean free path in the reverberation chamber with free suspended diffusing panels. The mean free path $\bar{l}$ can be calculated from:

$$\bar{l} = \frac{4V}{S} \qquad [\mathrm{m}] \qquad (1)$$

If we determine the actual mean free path *MFP* from ray tracing calculations the corrected volume for the free hanging diffusers can be calculated by:

$$V_c = MFP\frac{S}{4} \qquad [\mathrm{m}^3] \qquad (2)$$

A calculation for one of the reverberation chambers shows 12% lower absorption results using this reduced volume. However the problem remains, since it has to be determined what surface to use: the surface of the walls or the surface including the surface of the diffusers.

4. Use volume diffusers in stead of free hanging diffusers. In this case the volume behind the diffuser can be subtracted, see figure 5. This might also influence the diffusion of the room, especially when applied to the walls.

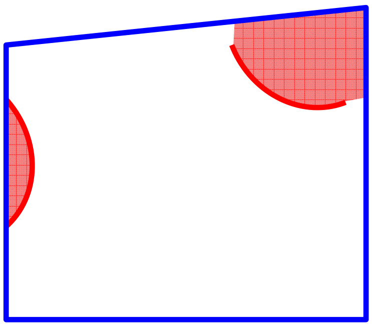


**Figure 5:** Illustration of the shielding by a suspended diffuser (upper right) and the more defined situation for volume diffusers (left).

5. A more strict qualification procedure for laboratories, for example with a reference absorber and a defined bandwidth. Figure 6 shows the average absorption of sample 1 and the bandwidth (±½R) of 9 out of 13 laboratories. In case the result is within the bandwidth the Lab is 'qualified'.

6. Calibration of the reverberation chamber by a reference absorber. This will be discussed in the next paragraph.

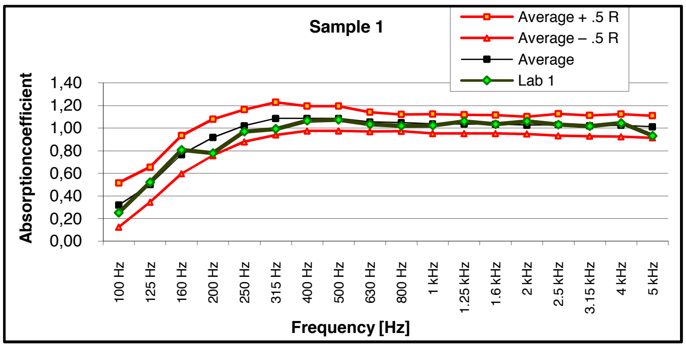



**Figure 5:** Illustration of the average and spread (±½R) of sample 1 and the individual result of one laboratory (green).

## Calibration by a reference absorber

When using a standard absorber the average result may be used as a reference for correcting measurement results of other samples, based on the difference of the measured absorption of the reference absorber and the average absorption of this absorber. The results of sample 1 will be used as reference absorber, to correct the measurement results of sample 2 and 4.

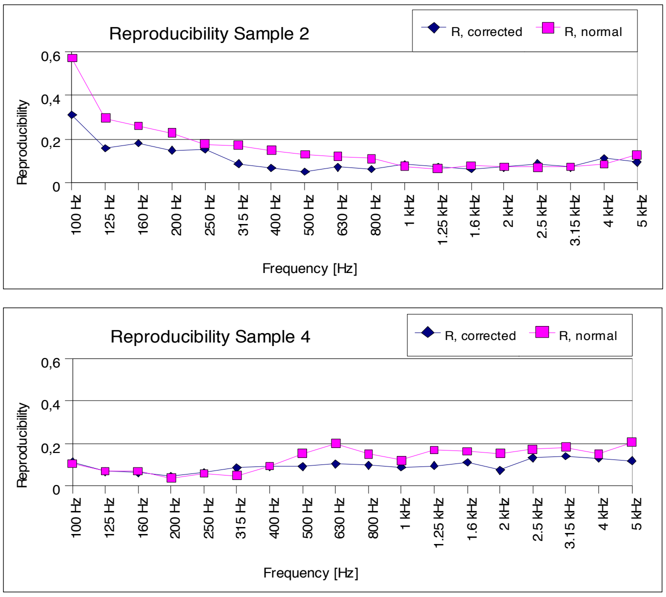



**Figure 7:** The effect of correcting for the reference absorber (sample 1) on the Reproducibility of sample 2 (upper graph) and sample 4 (lower graph).

Figure 7 shows the Reproducibility of sample 2 and 4. It shows that especially when the Reproducibility exceeds 0,1, the use of the reference absorber reduces the spread significantly. When the Reproducibility is already below 0,1, no further improvements are found. This indicates that, assuming the spread consist of a statistical variation and a systematical variation due to the sound field properties in the reverberation chamber, the systematical variation can be filtered out to some extend by using the reference absorber. Especially the outliers that are responsible for a large part of the spread (see figure 2), are consistent, also for the other samples. By using the correction based on the reference absorption, mainly these outliers are corrected.

# Conclusions

A Round Robin test for the sound absorption using the reverberation chamber method is performed. From the measurements it can be concluded that:

- the measured sound absorption of a high absorbing material is larger than 1,0, both for the lower frequency range, where this can be attributed to the edge effect, as for the higher frequencies
- the Reproducibility of the absorption measurement is rather poor
- a limited number of 'outliers' is responsible for this Reproducibility

Additional analysis of the data showed that:

- the high frequency excess of 1,0 can be reduced by:
    - using Eyrings formula in stead of Sabine, and/or
    - correcting for the effect of diffusers
- the spread can be reduced by:
    - qualification of laboratories using a reference absorber, or
    - correcting the laboratory result for the difference of the measured value of the reference absorber and the average value

The use of volume diffusers in stead of free suspended diffusers may create a more defined situation, the volume of the diffusers can be subtracted from the volume of the room and applying these on the walls may give a better diffuse field situation. This needs further research.

# References

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