

# ETIUDA DPS® MICROSORBER



## BASICS OF ROOM ACOUSTICS

The acoustics of a room is influenced by many factors: Apart from the shape of the room basically other features as floor, wall and ceiling coverings determine the propagation of sound in a room. The size and positioning of sound absorbing as well as sound reflecting surfaces decide whether the acoustics of a room is judged as “good” or “bad”. In this sense “good” acoustics means that the room acoustical conditions correspond to the main usage of the room. A concert hall usually needs another type of acoustics as a telephone centre or an open-plan office. In principle, the acoustics of every room can optimally be adopted to its usage. The shape and size of a room are of equal importance to the room acoustical planning process as well as the choice and positioning of interior materials and furniture. In practice, one very often has only the possibility of changing the ceiling and wall coverings to control the room acoustics. Sound absorbing materials as DPS® Microsorber® serve to precisely adjust the reverberation time of a room. Modern computer software allows the detailed prediction of the acoustic conditions within a room. Especially for rooms with high acoustic demands - like concert halls, auditoria, meeting and conference rooms - an exact planning of the room acoustics should be applied. The acoustics of rooms with lower complexity may also be adjusted by a simple estimation.

To achieve good room acoustics the planning should be carried out within the frequency range between 100Hz and 4000 Hz. Just a reminder: The listening range reaches from about 20 Hz to 20'000 Hz.

Room acoustics covers the frequency range between 100Hz and 4'000 Hz; for measurements and planning this range is split up into 18 one-third octave bands. The following table shows the corresponding 1/3 octave band centre frequencies. A simplified approach may be carried out using the six octave band centre frequencies.



1/3 octave bands	100	200	400	800	1600	3150	octave bands
	<b>125</b>	<b>250</b>	<b>500</b>	<b>1000</b>	<b>2000</b>	<b>4000</b>	
	160	315	630	1250	2500	5000	

## MECHANISMS OF SOUND ABSORBERS

Although there is a large variety of different sound absorbing materials only two basic mechanisms of sound absorption can be distinguished:

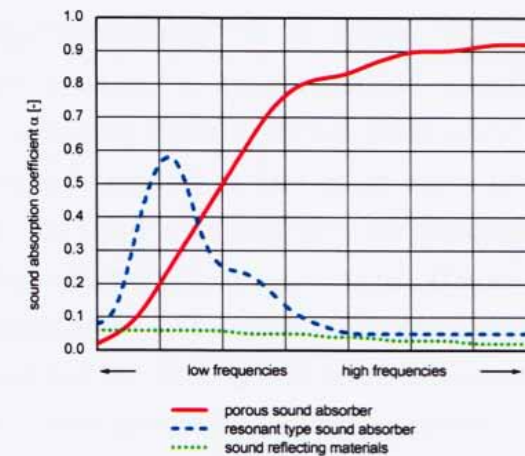
- porous sound absorbers and
- resonant type sound absorbers.

At the surface of a porous sound absorber the incident sound wave enters the material. The sound energy is converted to heat energy by friction in the pores of the material. This mechanism reduces the reflected sound energy. Sound is absorbed.

Resonant type sound absorbers consist of a system that may vibrate, e.g. a wooden plate or a column of air. The excitation works very well at the resonance frequency of the system. The vibration converts incident sound energy to vibrational energy and thus lower the reflection of sound.

The sound absorbing effect of a material or set-up of materials is given by the sound absorption coefficient  $\alpha$ . Roughly spoken the sound absorption coefficient of porous sound absorbers increases with increasing frequency. Resonant type sound absorbers show a maximum sound absorption at a certain, mostly narrow frequency range. The typical sound absorption characteristics of both types are sketched in the following graphic.

In general, the sound absorption coefficient  $\alpha$  strongly depends on the frequency. The value of  $\alpha$  is between 0 (no absorption) and 1 (complete absorption). The frequency dependence of the sound absorption coefficient  $\alpha$  may have any shape over frequency. Some materials like concrete, glass or parquet do not absorb sound and might be referred to as sound reflecting materials. The frequency dependence of the sound absorption coefficient of both types of sound absorbers is depicted in principle in the plot above. However, the absolute values of the sound absorption may be totally different. As presented below the DPS® Microsorber® is a resonant type sound absorber.



*Sketch of frequency dependence of the sound absorption coefficient for different materials*

## DPS® MICROSORBER®

The DPS® Microsorber® is a special resonant type sound absorber, more precisely a micro-perforated sound absorber. With respect to the underlying physical principle these sound absorbers might be regarded as a fascinating as well as an highly effective system to absorb sound: The small holes that form the microperforation cause a conversion of sound energy into heat energy. The friction of the air in each single hole is amplified by resonance in the air between the micro-perforated panel and the backing and yields to the impressive acoustic properties of micro-perforated sound absorbers. The acoustic effectiveness of micro-perforated sound absorbers can precisely be predicted from the geometrical set-up applying the theory of the Chinese Acoustician Prof. D.-Y. Maa. The four quantities

- diameter of the holes  $d$  of the microperforation,
- distance between the holes  $b$ ,
- thickness of panel  $t$  and
- thickness of air space between panel and backing  $D$

determine the sound absorption coefficient  $\alpha$  of a micro-perforated sound absorber (see sketch of geometrical set-up). These four quantities allow to tune a micro-perforated sound absorber to various demands.

The microperforation of DPS® stretched ceilings is carried out under the cooperation of Grupa DPS sp. z o.o. and KAEFER Isoliertechnik. The micro-perforated stretched ceiling is named DPS® Microsorber®. KAEFER Microsorber® based on polycarbonate foil instead of DPS® foil is a development of KAEFER Isoliertechnik in collaboration with Fraunhofer-Institut für Bauphysik. The parameters of the DPS® Microsorber® membranes are as follows:

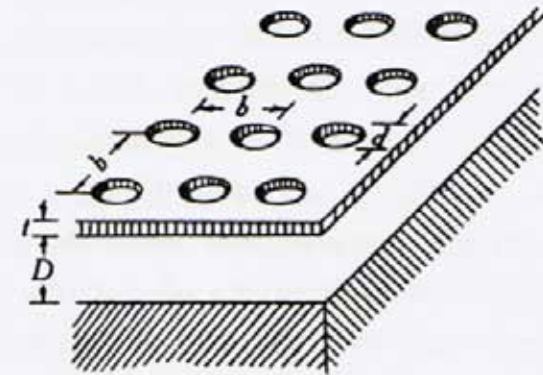
diameter of the holes  $d = 0,2$  mm

distance between the holes  $b = 2,0$  mm

thickness of panel / foil  $t = 0,17$  mm

The distance  $D$  between the foil and the backing may be altered. By changing the distance the sound absorption coefficient can be tuned to the frequency characteristic required.

Each square meter of DPS® Microsorber® shows 250'000 holes on a square grid adding up to about 0,8% of the surface of the DPS® foil. The geometry of the DPS® Microsorber® has been especially developed for the requirements and demands of room acoustics.



*Geometrical set-up of a micro-perforated sound absorber (Source: D.-Y. Maa, Scientia Sinica, Vol. XVIII, 1975)*

## REVERBERATION TIME

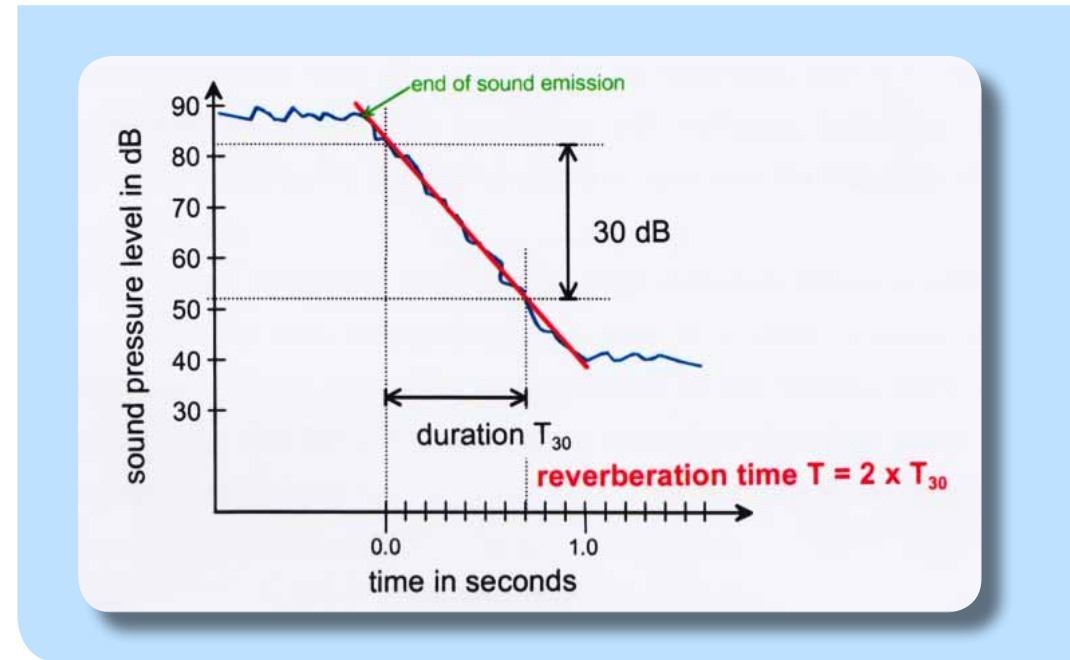
The most important and well known quantity of room acoustics is the reverberation time. Roughly speaking its values gives the duration for an acoustic sensation to become imperceptible in a room. The reverberation time is defined as the time taken by a sound to decrease by 60 dB from its value by termination. The choice of 60 dB decay is entirely arbitrary being embedded in the history of room acoustics. The measurement of the reverberation time is carried out for a 30 dB decay and then doubling this value.

The reverberation time depends on the air volume of a room. The larger a room the longer is its reverberation time. Just as the volume the total absorption in a room influences the reverberation time. The greater the sound absorption in the room is the more rapid the decay of sound takes place. This relationship has been found by extensive and ingenious experiments by the acoustician W. C. Sabine. A simple equation, known as Sabine equation, links the reverberation time T, the volume V, and the total sound absorption area A<sub>total</sub> of room as follows:

$$T = 0.163 \frac{V}{A_{total}}$$

The total sound absorption area A<sub>total</sub> is given by the product of the sound absorption coefficient a and the surface area S of the sound absorber. The calculation may refer to the average sound absorption coefficient a of all surfaces. The total sound absorption area A<sub>total</sub> can also be calculated as the sum of the singles surfaces S<sub>1</sub> to S<sub>n</sub> with the corresponding sound absorption coefficients a<sub>1</sub> to a<sub>n</sub>, hence:

$$A_{total} = \alpha S = a_1 S_1 + a_2 S_2 + a_3 S_3 + \dots + a_n S_n$$

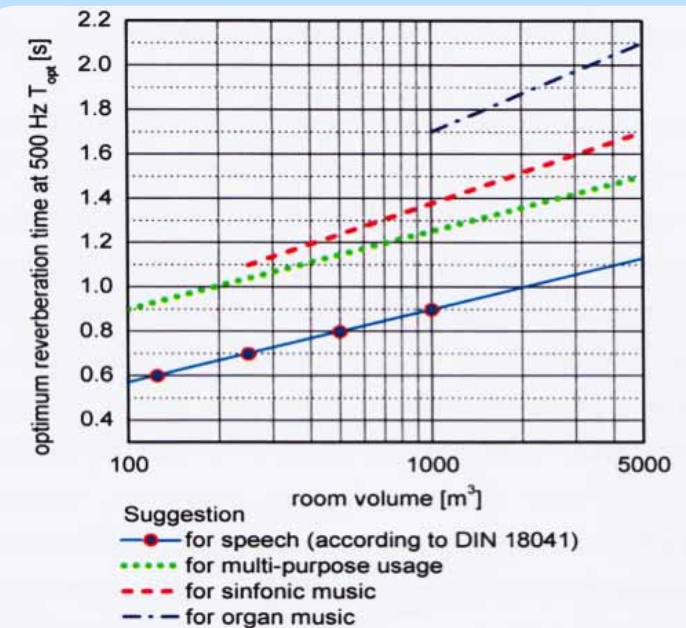


Apart from the sound absorption given by the surfaces of a room the absorption of furniture, audience and damping in the air might be added. The reverberation time of a room might be estimated from information concerning room size and furnishing with sufficient accuracy. This estimation requires the description of the volume and the materials of the room surfaces.

As the sound absorption coefficient of most materials shows a variation with frequency also the reverberation time of a room changes over frequency. A room acoustical measurement of the reverberation time according to ISO 3382 and also room acoustical plannings cover the frequency range from 100 Hz to 5000 Hz. This range might be extended to start at 63 Hz up to 8000 Hz for special demands.

The optimum reverberation time of a room depends on its main usage. This is the reason why one can find various suggestions for the appropriate reverberation times. Often these suggestions for the reverberation time are specified by the volume and kind of usages of the rooms. As an example, a German standard (DIN 18041) first shows suggestions for the reverberation time at medium frequencies (500 Hz to 1000 Hz) in dependence of the room volume and usage and second the optimum frequency characteristics.

Especially for music there is a large number of suggestions for the optimum reverberation time that might even vary with the kind of music and the personal taste of the audience. In general, rooms meant for speech require the shortest values for the reverberation time. A short value for the reverberation time improves speech intelligibility.

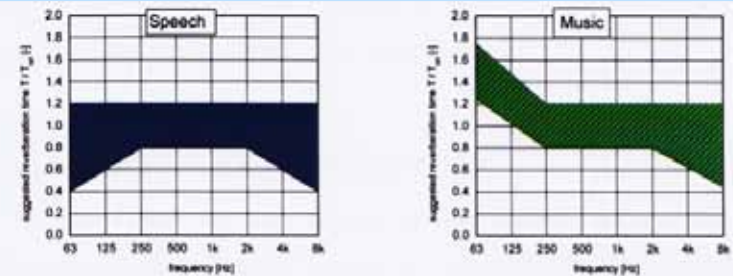


*Optimum reverberation time at mid-frequencies*

As important as the value of the reverberation time is its frequency dependence. The following graphics show suggestions for rooms intended for music and for speech. Rooms used for speech or communication should have no variation over frequency. A tolerance of  $\pm 20\%$  might be accepted. For music a slight increase towards low frequencies is acceptable or even judged as favourable by many people.

Too long reverberation times of rooms at low frequencies are often experienced as dull or even booming. By contrast, excessive high frequency reverberation gives a shrill or sharp impression in a room. These subjectively perceived properties of timbre in a room are often the reason for complaints about loudness as too little sound absorption or too long reverberation also disturb a good intelligibility. The deficits are compensated by raising the voice hence increasing the sound level. Other acoustical defects of a room are the false positioning or wrong tuning of sound absorbers. A typical result that can be found in measurements is a very irregular reverberation time over frequency. Known acoustical problems in a room can easily be revealed objectively by a measurement of the reverberation time. The results then clearly indicate how the refurbishment should be carried out. Detailed proposals about the needed sound absorbers, the surface areas, and the positioning of the sound absorption can be worked out from the measured values.

In principle, it can not be claimed that a material with a high sound absorption coefficient is more advantageous compared to material with a lower value for the sound absorption. As shown above only the product of the surface area and the sound absorption coefficient defines the total sound absorption area  $A_{total}$  of a room. A larger area with a lower sound absorption coefficient may be more suitable for the achievement of good room acoustics than a small, highly absorbing area.



*Suggestions for the frequency dependence of the reverberation time*



## MEASUREMENT OF SOUND ABSORPTION

The measurement of the frequency dependent sound absorption coefficient as of a material is carried out according to standard ISO 354 in a reverberation chamber. The reverberation chamber is a testing laboratory built up according to the standard with sound reflecting surfaces (usually concrete or tiles) and some diffusing plates for a high degree of sound scattering in the room. In the reverberation chamber all materials to be tested (floors, walls, ceilings coverings) are usually placed on the floor. Only practical considerations lead to this handling which has no influence on the measured result.

An empty reverberation chamber shows an extremely long reverberation time. By building up the test material under consideration the reverberation time will be lowered. The difference in reverberation without and with the sample is then taken to calculate the frequency dependent sound absorption coefficient as applying the Sabine equation stated above.  $\alpha_s$  is deduced for 18 one-third (1/3) octave bands between 100 Hz and 5000 Hz. The 1/3 octave band values are the basis for the calculation of single number ratings as the NRC-value or the weighted sound absorption coefficient QW (see following pages on single number ratings).

## SINGLE NUMBER RATINGS FOR SOUND ABSORPTION

For certain demands and far more comfortable handling when comparing different acoustical products single number ratings for sound absorption have been introduced. Indeed, as the sound absorption Coefficient generally shows a strong variation over frequency this simplification is hardly helpful for room acoustical planning but rather serves as a first assessment. It might be used as a guideline to describe the requirements of a needed sound absorber.

Apart from just averaging all 18 one-third octave band values some other single number ratings are widely known.

The American standards ASTM C 423 defines the Noise Reduction Coefficient (NRC). This is the arithmetic average of four measured one-third octave band values at 250 Hz, 500 Hz, 1000 Hz and 2000 Hz,

$$\text{NRC} = \frac{\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000}}{4}$$

This average is round to the nearest multiple of 0.05. For DPS® Microsorber® with 100 mm air cavity depth behind a NRC-value of 0.45 is obtained.

Furthermore, the standard ASTM C 423 describes the procedure to calculate the Sound Absorption Average (SAA) as the average value of the sound absorption coefficient as between 200 Hz and 2500 Hz.

For DPS® Microsorber® with 100 mm air cavity depth a SAA value of 0.45 is deduced. The European standard EN ISO 11654 introduces the weighted sound absorption coefficient  $a_w$  as a single number rating for sound absorbing materials. The deduction of this value requires as a first step the calculation of the practical sound absorption coefficient  $a_p$ . For  $a_p$  the three measured one-third octave band values in one octave band are arithmetically averaged and rounded to the nearest multiple of 0.05. The six octave values for the practical sound absorption coefficients  $a_p$  are needed for a comparison with a reference curve given in EN ISO 11654. For this comparison, the initial reference curve is shifted downwards in steps of 0.05 until the sum of unfavourable differences is smaller or equal than 0.10. An unfavourable difference means that  $a_p$  is smaller than the reference value at that frequency. The weighted sound absorption coefficient  $a_w$  is given by the shifted reference curve at 500 Hz. This procedure is depicted for the DPS® Microsorber® with 100 mm air cavity depth in the following two plots.

If the value of  $a_p$  exceeds the shifted reference curve by more than 0.25 in one or more octave bands then a so-called form indicator must be added to the weighted sound absorption coefficient  $a_w$ . If the difference is larger than 0.25 at 250 Hz then the form indicator is L (low), at 500 Hz or 1000 Hz it is M (middle) or at 2000 Hz or 4000 Hz it is H (high). For DPS® Microsorber® a  $a_w$ -value of 0.45 without form indicator is obtained.

The informative appendix B of standard EN ISO 11654 finally defines so-called sound absorption classes according to the value of  $a_w$ .

Sound absorber class	$a_w$ - value
A	0,90 - 1,00
B	0,80 - 0,85
C	0,60 - 0,75
D	0,30 - 0,55
E	0,15 - 0,25
not classified	0,00 - 0,10

Definition of sound absorber classes according to EN ISO 11654

From the point of room acoustics it is not always sensible to judge the quality of a acoustically effective material by a single number. That is the reason why DE EN ISO 1 1654 states:

*„The single number rating .... may be used to formulate demands and to describe acoustical properties of sound absorbing properties that are intended for routine applications in usual offices, corridors, class rooms, hospitals etc. The rating is not suitable if the products should be used in a demanding environment that needs a careful acoustic outline. For such cases on/y the full frequency dependent sound absorption coefficients are suitable. “*

Nevertheless, single number ratings give a first hint on the ability of a material to absorb sound. A detailed room acoustical planning will need the full set of one-third octave values from the test reports. The data sheets at the end of this brochure show all information for developers, architects, room acousticians and other people interested in different set-ups of DPS® and DPS® Microsorber®.

## VALUES OF SOUND ABSORPTION FOR DPS® AND DPS® MICROSORBER®

The following pages contain the data sheets for different set-ups of DPS® and DPS® Microsorber® with and without mineral wool in the air cavity behind. All measurements of the frequency dependent sound absorption coefficient  $a_s$  have been carried out according to ISO 354.

The traditional DPS® has a sound absorption coefficient near smaller than 0.15 over the whole frequency range. There is hardly any difference between the lacquer velour version of DPS®. A big change in absorption takes place if some porous sound absorbing material like mineral wool is installed behind the foil. The results for different set-ups are shown below.

Most of the set-ups use micro-perforated DPS® Microsorber®. The differences between the set-ups are the version of DPS®, the air cavity depth and the presence of extra mineral wool. The following table gives a survey of the data sheets and lists the single number values for NRC, SAA and  $a_w$ .