BASICS OF ACOUSTICS

création baumann

CONTENTS

1. PREFACE

Noise or unwanted sounds is perceived as disturbing and annoying in many fields of life. This can be observed in private as well as in working environments. Several studies about room acoustic conditions and annoyance through noise show the relevance of good room acoustic conditions. Decreasing success in school class rooms or affecting efficiency at work is often related to inadequate room acoustic conditions. Research results from class room acoustics have been one of the reasons to revise German standard DIN 18041 on "Acoustic quality of small and medium-sized room" from 1968 and decrease suggested reverberation time values in class rooms with the new 2004 version of the standard. Furthermore the standard gave a detailed range for the frequency dependence of reverberation time and also extended the range of rooms to be considered in room acoustic design of a building.

The acoustic quality of a room, better its acoustic adequacy for each usage, is determined by the sum of all equipment and materials in the rooms. In the sense of good acoustics the rooms should contribute to perceive speech, music or other sounds as not too loud or too quiet and the we can communicate with much effort and feel comfortable.

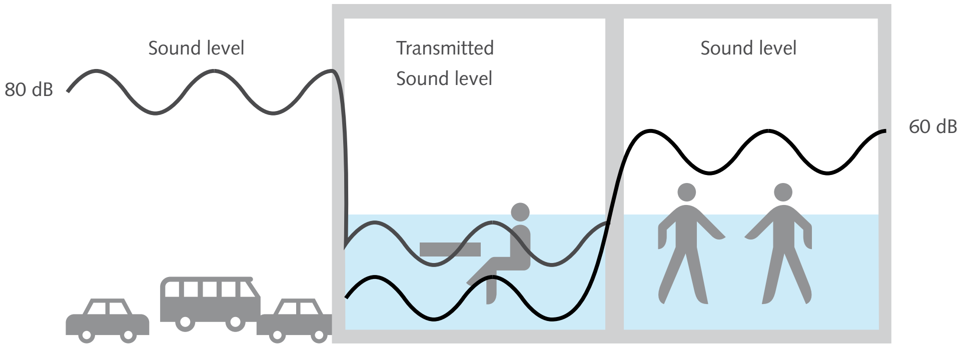
This brochure has been developed by Création Bauman with the intention to give an introduction and professional support in the field of room acoustics that sometimes has the connotation of being confusing or too multi-dimensional. It illuminates important terms and explains basics and interrelationships of room acoustics.

With its palette of creative textiles for rooms Création Baumann delivers acoustically effective as well as artistic attractive solutions for room acoustic questions. The bandwidth of the acoustic efficiency of textile applications is often underestimated. For this Création Baumann offers with its large documentation of acoustic properties for its materials - that is available separately – a great potential in modern solutions for acoustics by textile design in a room.

2. ROOM ACOUSTICS VERSUS BUILDING ACOUSTICS

The difference between the fields of room acoustics and building acoustics becomes obvious only when we take a closer look at acoustical questions. In building acoustics, the question always is:

What portion of the sound reaches the other side of the component in question?
The key property is the sound insulation of the component. Essentially, it is about the ability of components – walls, ceilings, doors, windows, etc. – to minimise the sound transmission between two rooms. A high degree of sound insulation is usually achieved using solid, heavy components which hinder the propagation of sound.



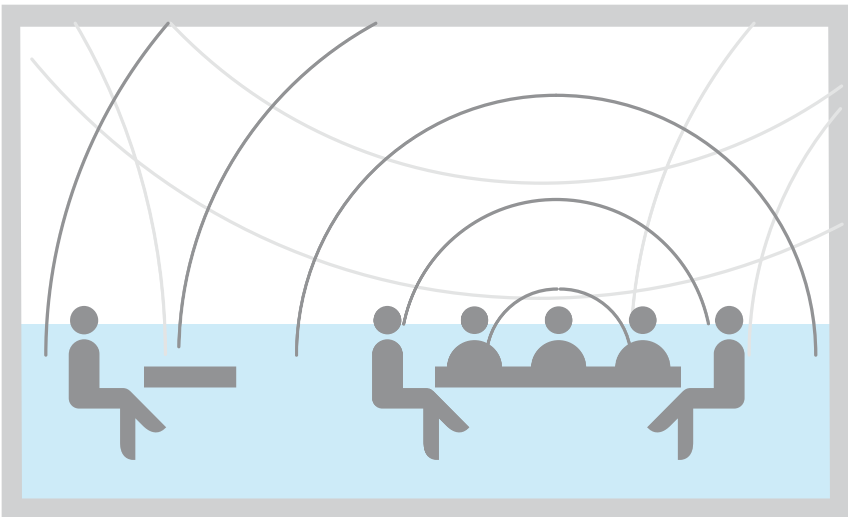
Building acoustics:
Sound transmission between adjacent rooms

Background noise level

The sound insulation of partitions for airborne sound is described by the sound transmission loss or rated sound reduction loss R'_w that can be measured on site or in laboratory or even calculated.

The question in room acoustics, on the other hand, is:

What surfaces help to create optimum listening conditions in a room?
The key property in this case is the sound absorption provided by the materials used in the room. Sound absorption describes the ability of materials to absorb sound or to convert the incident sound energy into other forms of energy. Sound absorption is achieved by means of sound absorbers



Room acoustics:
Acoustic quality within a room

Background noise level

The sound absorption of a surface is described by the frequency dependent sound absorption coefficient or simplified by a average values such as α_w or NRC. The sound absorption coefficient usually is measured in special laboratory room, so-called reverberation chambers.

The terms "sound insulation" and "sound absorption" are well-defined and relate to the fields of building acoustics and room acoustics respectively. If we feel annoyed by noise from an adjacent room, increasing the sound insulation essentially helps to improve this situation.
The sound absorption in a room can generally only decrease the level in room by a small amount. Decreasing sound levels in a room by room acoustic means is in principle much smaller than any optimization of the partion.

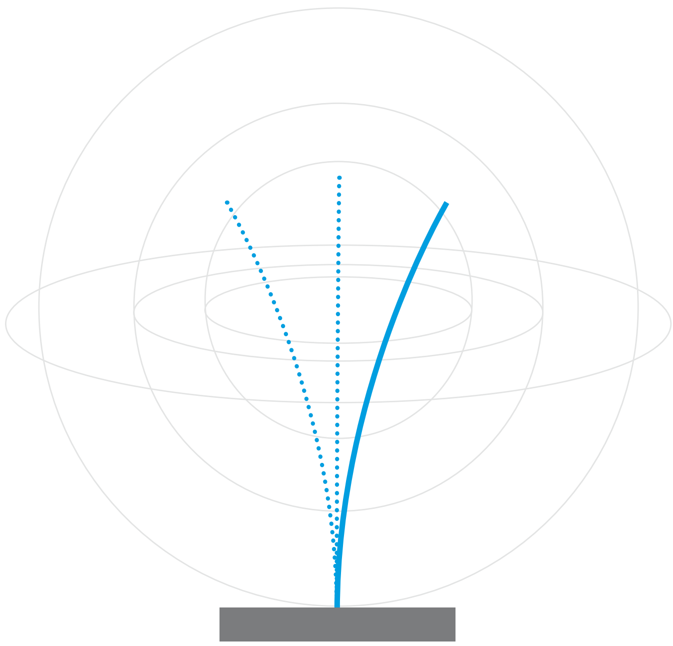
3. FUNDAMENTALS OF ACOUSTICS

3.1 SOUND

Sound can comprise harmonious tones, music, bangs, noise, crackling, but also spoken words. All of these sound events cause a slight variation in air pressure which propagates within the surroundings of its source. We therefore refer to the sound pressure of a tone, of noise, speech or music. The louder the sound event, the heavier is this pressure variation and the higher is the sound pressure.

As a rule, sound always propagates into all three directions of space. With many sound sources the sound radiation depends on the orientation of the source; in most cases it is sufficient, however, to assume roughly a uniform, omnidirectional sound radiation. Sound sources of this type are referred to as omnidirectional sound sources. Today it is also possible to select very tightly restricted sound radiation directions by means of special loudspeakers so that the radiated sound can be directed specifically to a particular position. This method is used, for example, when fitting lecture rooms with electroacoustic equipment. Here, it has to be taken into account that the sound energy decreases considerably with increasing distance from the sound source. In the areas occupied by the audience, however, the sound distribution should be as uniform as possible. To achieve this effect, a larger number of loudspeakers may have to be used.

As a rule, sound always propagates into all three directions of space. With many sound sources the sound radiation depends on the orientation of the source; in most cases it is sufficient, however, to assume roughly a uniform, omnidirectional sound radiation. Sound sources of this type are referred to as omnidirectional sound sources.
In principal one has to differentiate between airborne sound, sound in liquids and sound in solid bodies. Generally sound is a propagation of pressure and density variation in an elastic medium. If sound travels through a wall or another partition the airborn sound is converted to vibration of the wall and then radiated from the vibrating wall as airborn sound to the room.

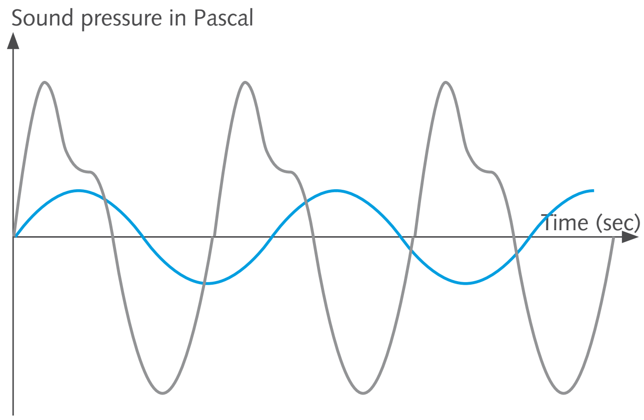


Unwanted sound events can be named as noise. This definition shows that the perception of sounds has strong subjective aspects. Psychoacoustics as a branch of acoustics, or also noise effect research, deals with the relationship between our subjective perception and the sound signals which are objectively present. Often a difference between wanted sound such as music in a concert or a voice of a speaker und unwanted sound like traffic noise or music of the neighbour is made.

3.2 SOUND PRESSURE

Sound can comprise harmonious tones, music, bangs, noise, crackling, but also spoken words. All of these sound events cause a slight variation in air pressure which propagates within the surroundings of its source. We therefore refer to the sound pressure of a tone, of noise, speech or music. The louder the sound event, the heavier is this pressure variation and the higher is the sound pressure.

The minimum sound pressure that a human being can perceive is around 20 μPa = 0.00002 Pascal, a very low value showing high sensitivity of the human auditory system. Sound pressure values of 20 Pascal will damage the hearing system for very short exposure times.

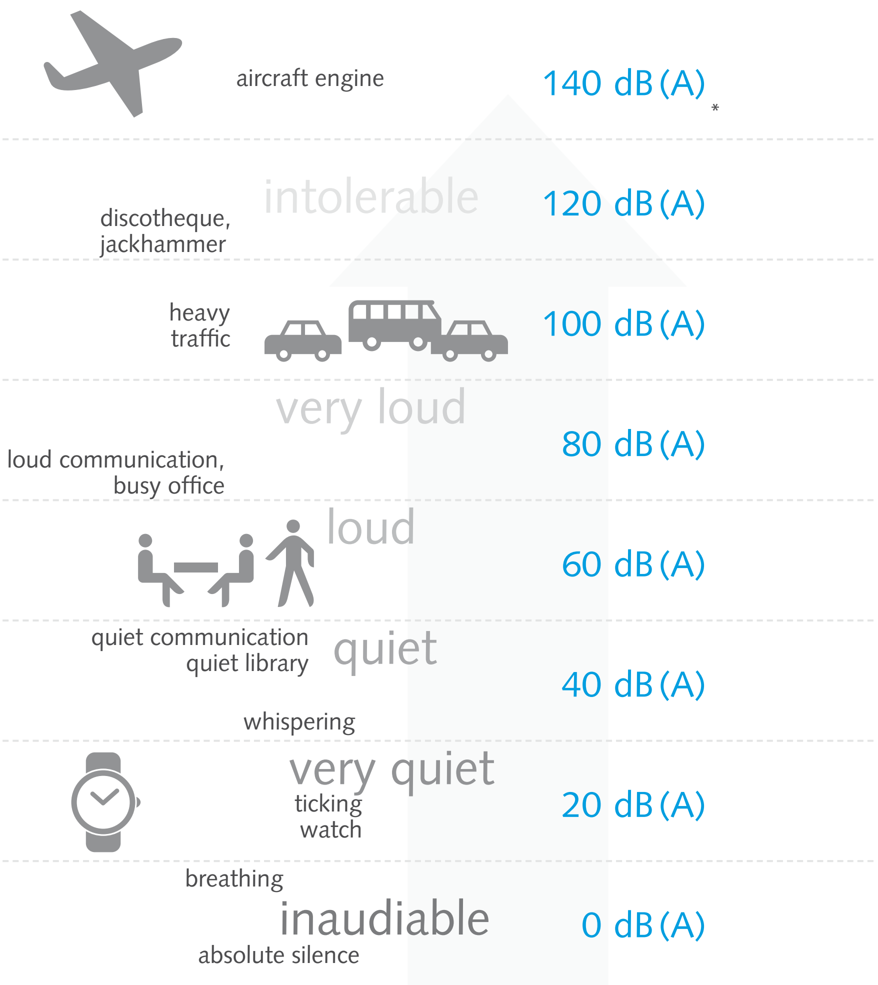


3.3 SOUND PRESSURE LEVEL AND DECIBEL SCALE

The strength of a sound, the sound pressure, usually is given as sound pressure level or sound level. A sound pressure level of 0 decibel refers by definition to the sound pressure level where human perception begins. This definition provides a scale between 0 decibel (abbr.: dB) and about 140 dB.

Constant sound levels of more than 80 dB or very short noises of more than 120 dB can irreversibly damage the auditory system.

Decibel



* Definition see Chapter 5

3.4 SOUND PRESSURE OF SEVERAL SOURCES

An increase in the number of sound sources by a factor of two always results in an increase of the level by 3 dB, a factor of ten in an increase by 10 dB, and a factor of one hundred in an increase by 20 dB.

SOUND PRESSURE INCREASE FOR IDENTICAL SOUND SOURCES

Example Alarm clock	Increase of dB value
1	62 dB
2	62 + 3 = 65 dB
3	62 + 5 = 67 dB
4	62 + 6 = 68 dB
5	62 + 7 = 69 dB
10	62 + 10 = 72 dB
15	62 + 12 = 74 dB
20	62 + 13 = 75 dB
50	62 + 17 = 79 dB
100	62 + 20 = 82 dB

Number of identical sound sources	Sound power	Sound pressure	Sound pressure level
	× 100	× 10	+ 20 dB
	× 10	× 3,2	+ 10 dB
	× 4	× 2	+ 6 dB
	× 2	× 1,4	+ 3 dB
	× 1	× 1	0 dB

The following table gives a simple rule of thumb for the addition of two sound levels. First of all the difference between the two levels should be calculated.

Sound pressure level difference	0 to 1	2 to 3	4 to 9	more than 10
Level increase (to be added to the higher value)	+ 3 dB	+ 2 dB	+ 1 dB	+ 0 dB

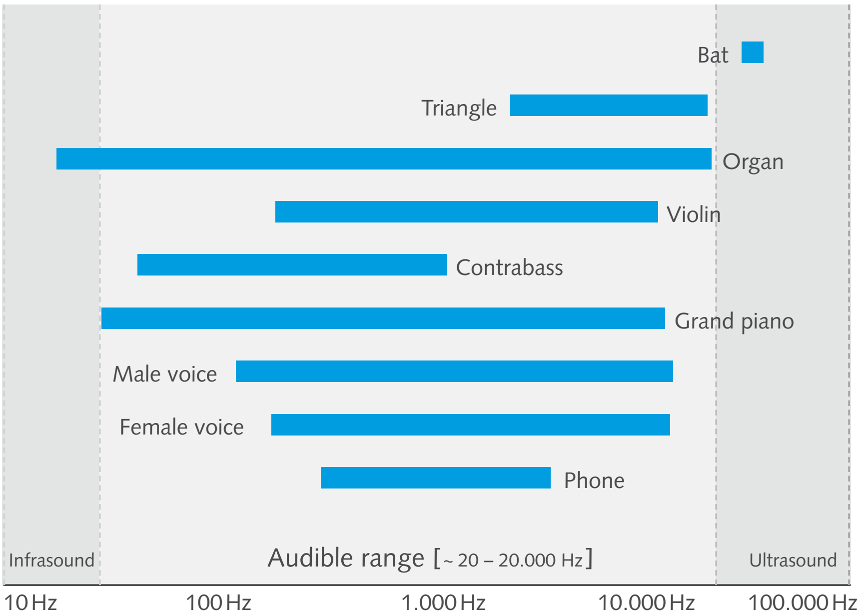
Example:
For two sources of 45 dB and 52 dB, respectively, the difference of 7 dB means an increase by 1 dB, which is added to 52 dB and thus results in a total level of 53 dB.

3.5 FREQUENCY

The frequency of a sound wave describes the number if pressure changes or oscillations per second. It is often abbreviated by the letter f and has the unit 1 Hertz (short: Hz). A frequency of 1000 Hz means 1000 oscillations per second. The sound pressure or sound level is perceived as loudness and is one important dimension for the perception of sound. Equally important is the frequency content of the sound or spectrum. Pure tones are sound with only one frequency.

The sensitivity of the human auditory system is highly dependent on frequency. It is particularly pronounced in the frequency range of human speech between 250 Hz and 2000 Hz. This is very useful when we listen to someone speak, but disruptions in this frequency range are perceived as particularly annoying and can strongly affect communication. With too high or low frequencies, our hearing ability decreases.

Frequencies – measured in Hertz (Hz)



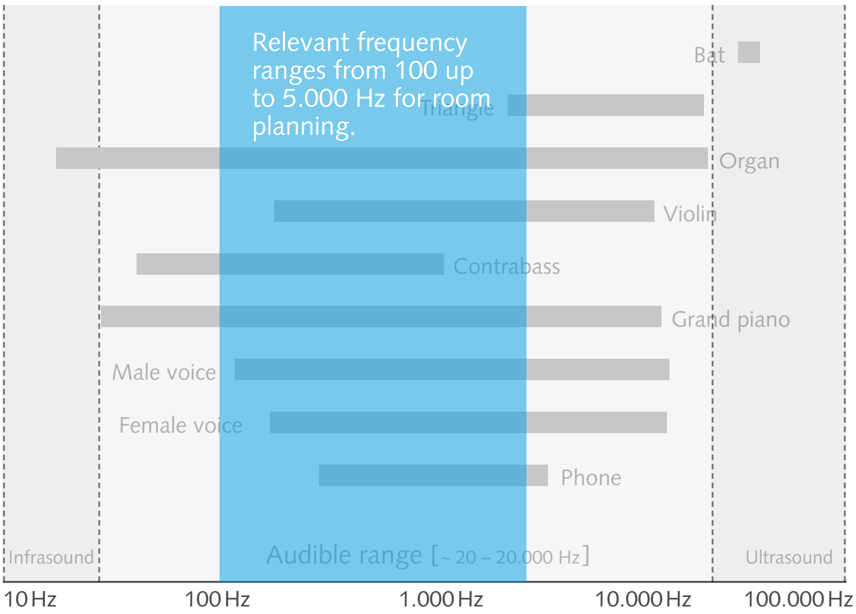
A noise loudness rating which is to meet the demands of the human auditory system needs to take into account the frequency characteristic of the human auditory system. The medium frequencies, at which the human auditory system is particularly sensitive, are weighted more heavily than the high and low frequencies. This weighting results in the term dB(A) for sound pressure levels, i.e. the so-called A-weighted sound pressure level. Nearly all regulations, guidelines, standard values, limit values, recommendations and references to sound pressure levels use values expressed in dB(A).

3.6 FREQUENCY RANGES RELEVANT FOR ROOM PLANNING

The frequency range to be taken into account when planning a room is based on the human auditory system on the one hand and what is technically sensible and feasible on the other. Frequencies above 5000 Hz are attenuated by the air to such a degree that it is not sensible to take them into account when planning the acoustics of a room. Below 100 Hz, other physical implications of sound propagation need to be taken into account.

The internationally standardised test methods for determining the sound absorption by particular materials are based on the frequency range from 100 Hz to 5000 Hz. Correspondingly it has been decided to focus room acoustic planning on the frequency range between 100 Hz and 5000 Hz, as a rule.

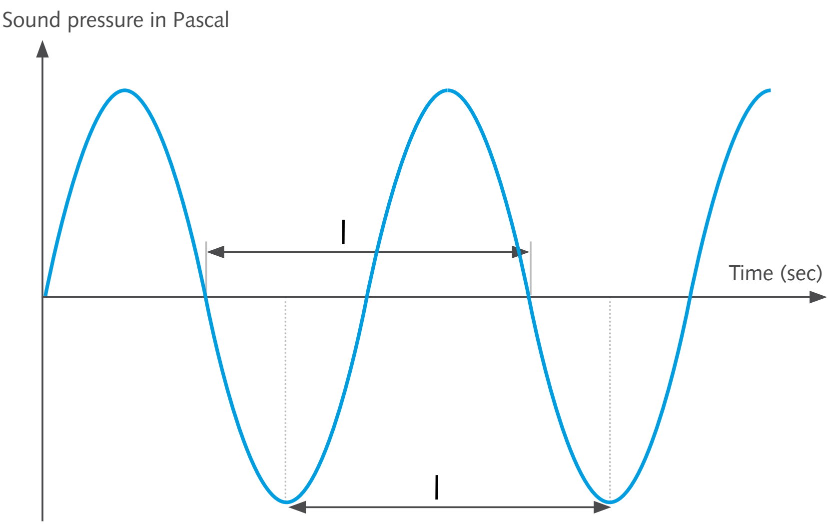
Relevant frequency ranges



3.7 WAVELENGTHS OF SOUND

Each frequency of sound is associated with a sound wave of a particular wavelength. In air, a 100 Hz wave has an extension of 3.40 meters, whereas a 5000 Hz wave has an extension of only about 7 centimeters. Accordingly, the sound waves relevant for room acoustics have a length of between 0.07 m and 3.40 m. As we can see, the dimensions of sound waves are well within the range of the dimensions of rooms and furnishings. The following figure shows the range of all sound wavelengths relevant for room acoustics.

Wavelengths l

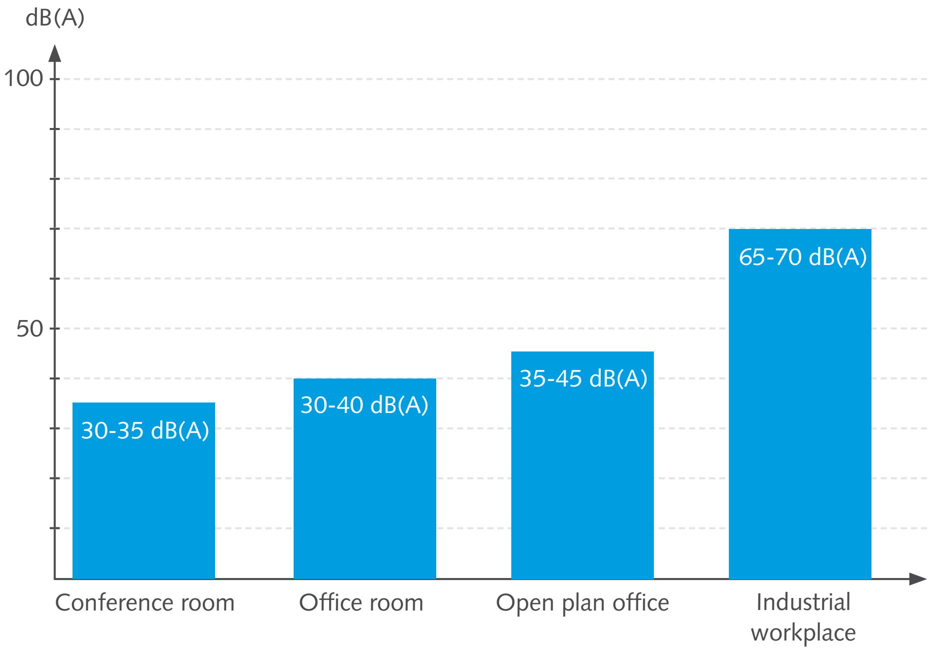


3.8 LEVEL VALUES

The relevant parameter for an objective assessment of the noise impact at a work station is the so-called rating level, which consists, on the one hand, of the measured, time-averaged sound pressure level in a room and, on the other hand, of adjustments in accordance with the characteristic of the noise as well as its duration of impact.

The rating level is usually based on a rating period of 8 hours.
High background noise levels in office rooms will likely affect the intellectual efficiency. For this reason, several regulations and standards contain recommendations regarding the maximum permissible background sound pressure level.

The following table shows the values of the recommended background noise level in accordance with DIN EN 11690:

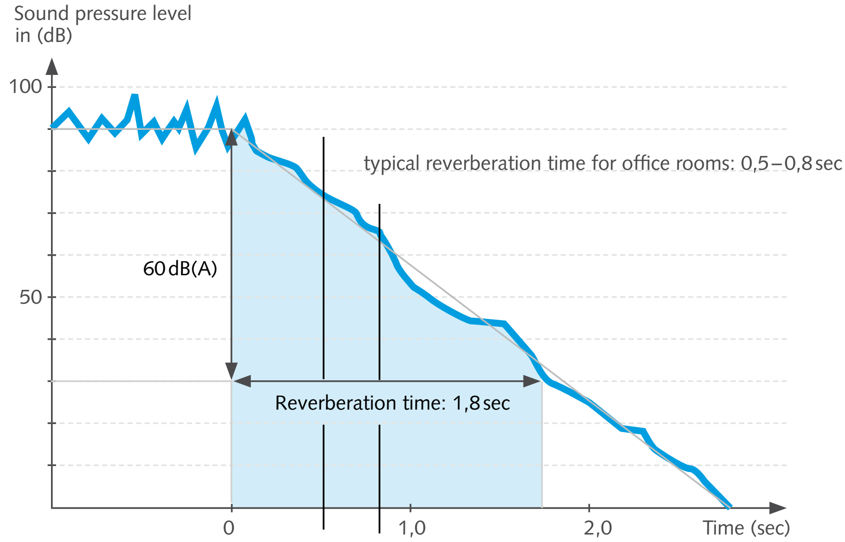


4. ROOM ACOUSTIC PARAMETERS

4.1 REVERBERATION TIME

The reverberation time is the basis for ratings of room acoustic quality. Put simply, the reverberation time indicates the period of time it takes for a sound event to become inaudible. Technically, the reverberation time T has been defined as the time required for the sound pressure level in space to decay by 60 dB. This means that, if a room is excited with a bang of 95 dB, the reverberation time indicates the period of time within which the noise level drops to 35 dB. This can be a few tenths of a second up to several seconds.
The reverberation time can be determined for each enclosed space.

Reverberation time



This objectively measurable quantity allows different rooms to be compared with each other and their room acoustic quality to be assessed. While a reverberation of 4 to 8 seconds is quite normal for a church, the values aimed at for the reverberation time in conference or office rooms are quite different. The following table provides an overview of the typical reverberation times of different room types.

Type of room	Reverberation time (exemplary)
Church	approx. 4 – 8 seconds
Class room – medium sized	0,6 seconds
Office room – depending on size	0,5 – 0,8 seconds
Concert hall for classical music	approx. 1,5 seconds

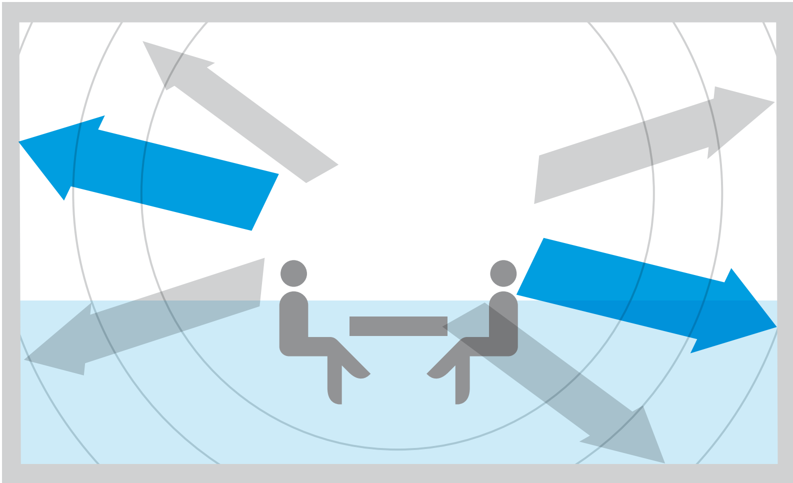
It has a direct effect on speech intelligibility in a room. In general, speech intelligibility in a room decreases with increasing reverberation time. This does not mean, however, that the shortest possible reverberation time is always the best solution! Very poor speech intelligibility usually does suggest, though, that the reverberation time is too long.

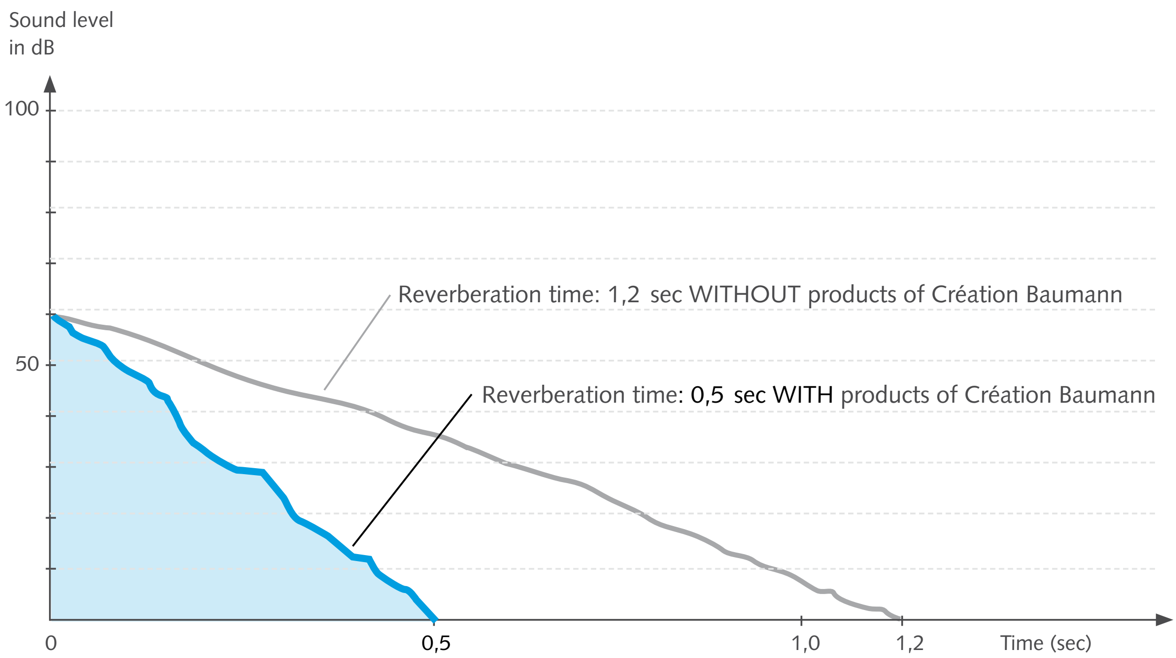
The subjective impression of the sound quality of a room allows even the non-expert to draw conclusions as to how the reverberation time progresses within the different frequency ranges. If, for example, speech in a room sounds blurred, and if it is very difficult to understand each other, it can be assumed that the reverberation time is too long. Acoustically "dry" in this context means that the sound is absorbed unnaturally fast. If this happens only at high frequencies, the room sounds "hollow" or "booming", whereas at low frequencies it sounds "piercing" and "sharp".

Performance	Reverberation time at low frequencies	Reverberation time at high frequencies	Subjective impression
speech	too long too long too short too short	too long too short too long too short	blurred, difficult to understand hollow, but easy to understand piercing, clanking, sharp, difficult to understand dry, but easy to understand

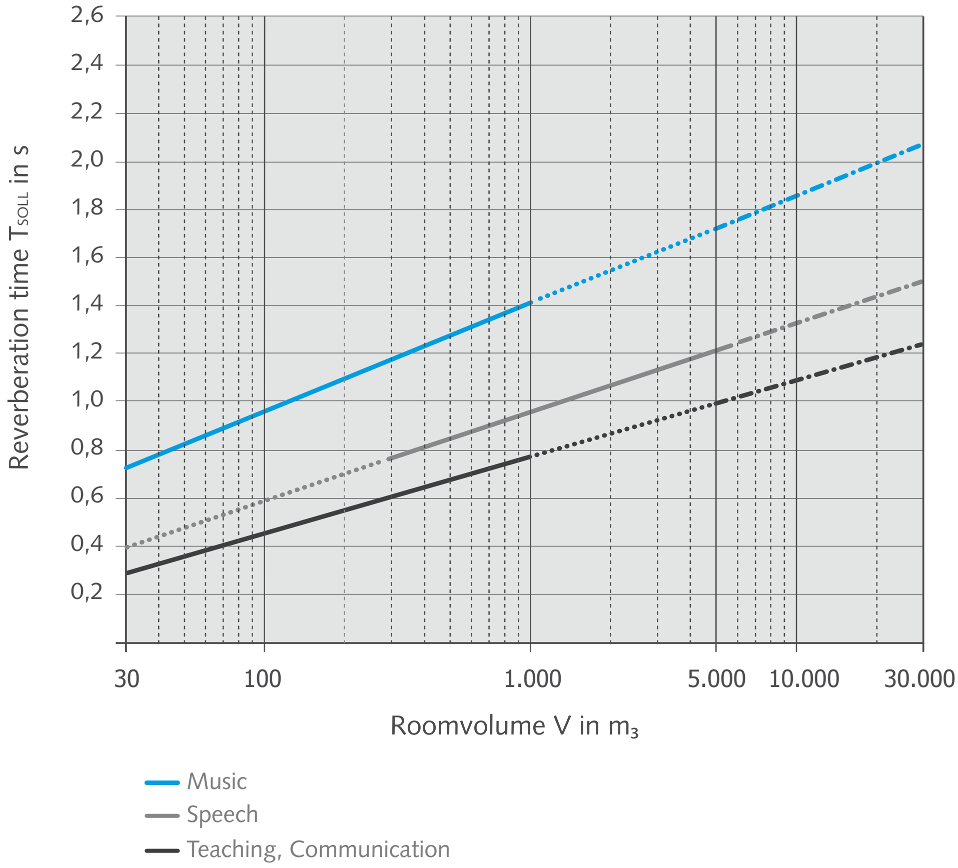
On which factors does the reverberation time depend?
The reverberation time depends mainly on three factors:
- the volume of the room,
- the surfaces of the room and
- the furniture in the room.

A room usually becomes more reverberant with increasing height. Absorbing surfaces – such as carpets, curtains and sound absorbing ceilings, but also furniture or people present in the room – reduce the reverberation time.





The shape of a room is usually of minor importance for the reverberation time. Only if the room acoustic requirements are very high (e.g. in concert halls) or if the shape is very unusual, e.g. vaulted surfaces or heavily varying room heights, does shape become an essential factor.
The recommendations given in DIN 18041 should always form the basis for any room acoustic planning. DIN 18041 "Acoustic quality in small to medium-sized rooms" forms the basis for the recommendations regarding the acoustic design of small to medium-sized rooms.
With regard to the optimum reverberation time, DIN 18041 distinguishes between three different room categories: "music", "speech" and "communication and teaching". Rooms of the usage type "music" are music class rooms and halls for music presentations.
"Speech" in the broadest sense comprises all rooms where a speaker speaks in front of an audience.
"Communication and teaching" comprises all types where several people speak at the same time, i.e. teaching rooms as well as conference rooms, multiple occupancy offices, service points, call centers and rooms with audiovisual presentations or electroacoustic uses.



Two examples:

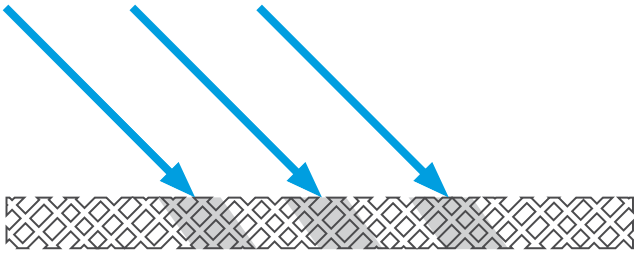
Example 1:
A conference room (usage type: "communication and teaching") with a volume of 250 m3 should have a reverberation time of 0.60 s.

Example 2:
A chamber music hall (usage type: "music") with a volume o 550 m3 should have a reverberation time of 1.30 s.

4.2 SOUND ABSORPTION

The sound absorption coefficient α describes the property of a material to convert incident sound into other forms of energy – e.g. thermal or kinetic energy – and thus to absorb it.

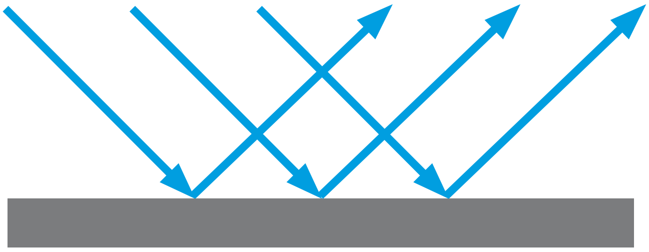
Case 1: Sound completely absorbed (sound absorption coefficient α = 1) no reflection



Sound completely absorbed

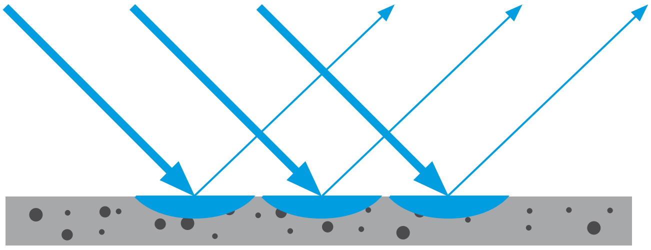
The other extreme is full sound reflection. All the incident sound is reflected.

Case 2: Sound completely reflected (sound absorption coefficient α = 0)



Sound completely reflected

Case 3: Sound partly absorbed (sound absorption coefficient α = between 0 and 1)

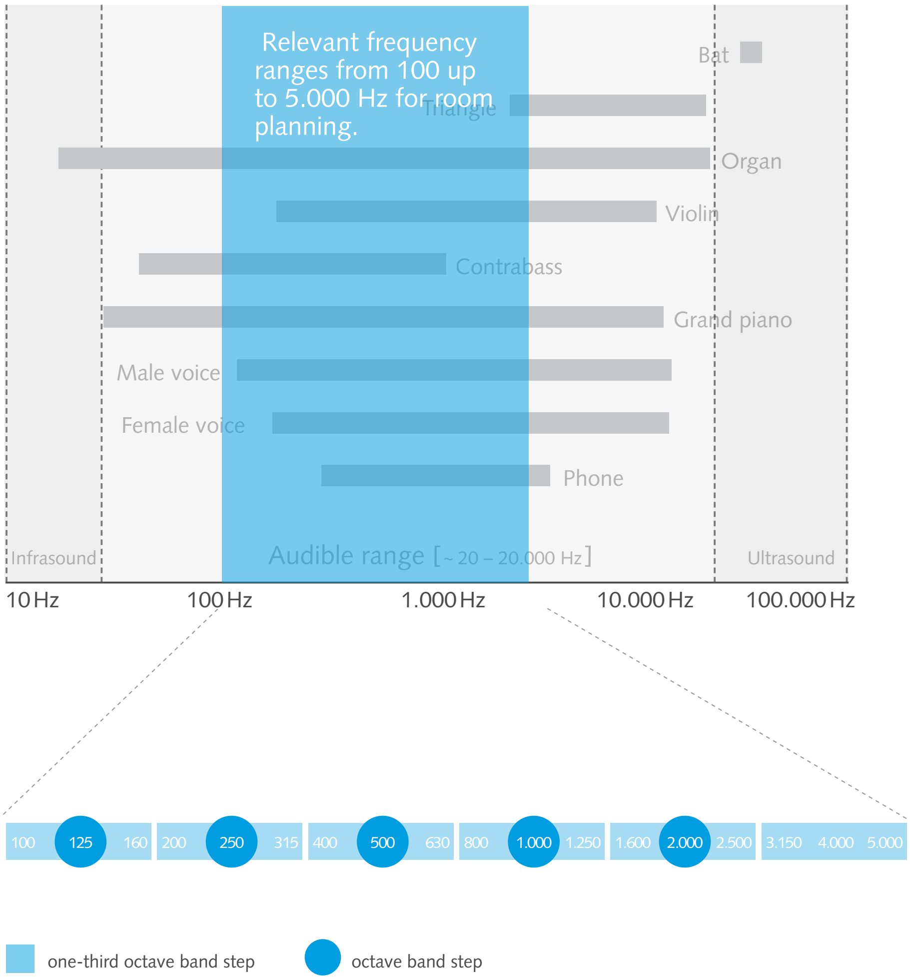


Sound partially absorbed

The frequency-dependent sound absorption coefficient of a material is determined by means of a special acoustic material test method – the so-called reverberation room method. For this test, a material sample is placed into the reverberation room, whose reverberation time has been determined previously without the sample. From the change in the reverberation time with the sample present in the room, the sound absorption coefficient α_S can be determined for each one-third octave between 100 Hz and 5000 Hz.
This yields 18 one-third octave values which uniquely describe the absorption behavior of the material, i.e. to what extent and at what frequencies the material absorbs the sound.

Solving room acoustic problems with measurements should always use on-third octave band resolution in frequency as many problems occur in small frequency bands and require adequate solutions.

Octave average frequency



It is not only the choice of material, however, which is responsible for the sound absorption in a room. What is most important is the total area of this material present in the room. The equivalent sound absorption area has been introduced to provide a measure for the sound absorbing performance of a sound absorber actually present in the room. It is defined as the product of the sound absorption coefficient α_s of a material and the surface of this material.

Calculation of the equivalent sound absorption of surfaces in a room:

$A = s_1\, \alpha_1 + s_2\, \alpha_2 + s_3\, \alpha_3 + \ldots + s_n + \alpha_n + A_1 + A_2 + \ldots + A_n$
A – total equivalent sound absorption area in a room
s_1 – surface size of material 1, e.g. acoustic ceiling
α_1 – sound absorption coefficient of material 1
s_2 – surface size of material 2, e.g. carpet
α_2 – sound absorption coefficient of material 2
…
S_n – surface size of material n
α_n – sound absorption coefficient of material n

4.3 SOUND ABSORPTION COEFFICIENT AND REVERBERATION TIME

In a fully furnished room with different surfaces, for example, each material (e.g. carpets, plaster, acoustic ceiling, curtains, windows, shelves, etc.) can be allocated a sound absorption coefficient, and by multiplying this coefficient by the surface of this material, the equivalent sound absorption area can be calculated. The equivalent sound absorption areas of all materials are then added to determine the total equivalent sound absorption area of the room. The reverberation time of a room can be derived from the calculated total equivalent sound absorption area using the Sabine formula.

Sabine formula:

$$T = 0{,}163 \times \frac{V}{A}$$

T – Reverberation time
V – Volume of the room
A – Total equivalent sound absorption area

A sound absorber of 10 m^2 with a sound absorption coefficient of 0.50 has an equivalent sound absorption area of 5 m^2 and thus has the same effect as a sound absorber of 20 m^2 with a sound absorption coefficient of 0.25 or a sound absorber of 5 m^2 with a sound absorption coefficient of 1.00.
In a fully furnished room with different surfaces, for example, each material (e.g. carpets, plaster, acoustic ceiling, curtains, windows, shelves, etc.) can be allocated a sound absorption coefficient, and by multiplying this coefficient by the surface of this material, the equivalent sound absorption area can be calculated. The equivalent sound absorption areas of all materials are then added to determine the total equivalent sound absorption area of the room.

4.4 RATING OF SOUND ABSORPTION

In the previous sections the advantages of looking at the sound, the reverberation time and the sound absorption coefficient in a frequency-dependent context have been explained in great detail. Several interested parties have, however, expressed their desire for simplified values, which might not permit differentiated planning, but would allow rough comparisons to be made between different sound absorbers or preliminary statements regarding the basic suitability of products for particular applications. Such values should also enable a simplified planning of rooms with low requirements regarding their acoustic quality.
Against this backdrop, single values of sound absorption have been defined in Europe and the US which differ slightly. The most common single value of sound absorption in Europe is the so-called weighted sound absorption coefficient α_w, whereas in the English-speaking world it is the Noise Reduction Coefficient (NRC) or the Sound Absorption Average (SAA).

All procedures to determine of single number ratings rely on tests in the reverberation chamber with on-third octave band resolution.

Weighted sound absorption coefficient α_w (DIN EN ISO 11654): In order to determine the weighted sound absorption coefficient αw, the mean value for the octave centre frequency between 125 Hz and 4000 Hz is determined from three one-third octave values. 18 one-third octave values are thus converted into 6 octave values.
The mean value of the respective octave is then rounded to the nearest 0.05; it is referred to as the practical sound absorption coefficient α_p. The practical sound absorption coefficient αp between 250 Hz and 4000 Hz is compared to the reference curve given in DIN EN 11654. This comparison gives a single value of the weighted sound absorption coefficient α_w.
Deviations by more than 0.25 between the curve and the reference curve are indicated by means of the shape indicators L, M or H, depending on whether they occur at 250 Hz (L), at 500 Hz or 1000 Hz (M), or at 2000 Hz or 4000 Hz (H).
The resulting values are, for example, $\alpha_w = 0.65$ (H), $\alpha_w = 0.20$ or $\alpha_w = 0.80$ (LM).

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Based on the α_w value, sound absorbers can be classified into different sound absorber classes. α_w values of more than 0.90, for example, belong to sound absorber class A, values of between 0.15 and 0.25 belong to class E.

Sound absorber class	α_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

Single-number values commonly used in the US

NRC (ASTM 423):
The NRC (Noise Reduction Coefficient), which is widely used in the US, is determined by calculating the mean value from four one-third octave values of the sound absorption coefficient (250 Hz, 500 Hz, 1000 Hz and 2000 Hz) and rounding the result to the nearest 0.05. If the number is at the exact mid-point of the numbers divisible by 0.05, the value is always rounded up (example: 0.625 => 0.65; 0.675 => 0.70).

SAA (ASTM 423):
Another value used in the US is the SAA (Sound Absorption Average). It is determined by calculating the mean value from twelve one-third octave values of the sound absorption coefficient between 200 Hz and 2500 Hz and then rounding the result to the nearest 0.01.

ADVANTAGE OF SINGLE-NUMBER VALUES:
Sound absorbers can be roughly classified and thus compared with one another.

DISADVANTAGE OF SINGLE-NUMBER VALUES:
A single-number sound absorption value is always an extremely simplified value. Sound absorbers with very different absorption spectra can have identical single-number values. This may sometimes result in the use of a sound absorber which is not suitable for the existing conditions. Frequencies below 200 Hz are not taken into account.

5. INDEX

A-WEIGHTED SOUND PRESSURE LEVEL – dB(A)

The A-weighted sound pressure level is the weighted average value of the sound pressure level (dB) as a function of the frequency of a sound. The weighting takes into account the ability of the human auditory system to perceive sound pressure levels or tones of different frequencies to a different degree. This sensitivity is particularly pronounced in the medium frequency range, i.e. the range of human speech. Nearly all regulations and guidelines indicate values expressed in dB(A).

EQUIVALENT SOUND ABSORPTION AREA

The equivalent sound absorption area A is defined as the product of the sound absorption coefficient α of a material and the surface S of this material.

AURALISATION

Auralisation is a method for simulating the acoustic properties of a room. With this method, the effects of certain acoustic treatments can be “auralised” as early as the design stage.

BUILDING ACOUSTICS

Building acoustics is a branch of building physics, or acoustics, which deals with the effect of the structural conditions on the propagation of sound between the rooms of a building or between the interior of a room and the outside of the building.

RATING LEVEL (L_r)

The rating level L_r (L for “level”, r for “rating”) is the relevant parameter for objectively assessing the noise impact at a workplace. Apart from weighting the sound pressure level as a function of the frequency (see A-weighted sound pressure level), a determination of the sound pressure level takes into account certain adjustments which depend on the characteristic of the sound (e.g. impulsiveness or clear prominence of individual tones) and its duration of impact. The rating level is also expressed in dB(A).

DECIBEL (dB)

Logarithmically defined unit of measurement which expresses the sound pressure level. The relevant scale for human beings is 0 dB to 140 dB. 0 dB refers to a sound pressure of 20 μPa.

SINGLE NUMBER VALUES OF SOUND ABSORPTION

So-called “single number values” are used for a simplified representation of the frequency-dependent parameter of the sound absorption coefficient as well as for a rough comparison of different sound absorbers. In Europe, the “weighted sound absorption coefficient” αw in accordance with DIN EN ISO 11654 is commonly used. In the US, the NRC and SAA values are widely used. All of the above values are based on measurements of the sound absorption in one-third octave and octave increments.
For a detailed acoustic planning of a room it is necessary to know these sound absorption values precisely in one-third octave or at least in octave increments (see “octaves”).

FREQUENCY

Frequency indicates the number of sound pressure changes per second. Sound events with a high frequency are perceived by the human ear as high-pitched tones, sound events with a low frequency as low-pitched tones. Sounds such as noise, road traffic, etc., normally comprise a great number of frequencies. The measurement unit of frequency is hertz (Hz), 1 Hz = 1/s. Human speech is in the range between 250 Hz and 2000 Hz. The audible range of human beings is between 20 Hz and 20000 Hz.

REVERBERATION ROOM

Reverberation rooms are special laboratory rooms with walls which reflect the incident sound waves to a very high degree. Reverberation rooms have particularly long reverberation times across the entire frequency range.

REVERBERATION ROOM METHOD

The reverberation room method is used for determining the frequency-dependent sound absorption coefficient.
A sample of the material to be tested is placed into the reverberation room. The sound absorption of a material can then be calculated from the change in the reverberation time of the room.

BACKGROUND NOISE LEVEL

Usually, sounds which do not contain any meaningful information are referred to as background noise (e.g. noise from air conditioning or traffic). The background noise level is measured in dB or, by weighting its frequencies in accordance with the human auditory system, in dB(A).
The background noise level indicates the sound pressure level which has been exceeded during 95 % of the measurement period. It has a direct effect on speech intelligibility.

ACOUSTIC QUALITY

The acoustic quality of a room refers to its suitability for a particular use.
It is influenced by the properties of the boundary surfaces (walls, ceiling, floor) and the furnishings and by persons present in the room.

NOISE

Noise comprises all sounds which, due to their loudness and structure, are considered as harmful or annoying or stressful for human beings and the environment. It depends on the condition, preferences and mood of a person whether sounds are perceived as noise or not. The perception of sounds as noise and the way in which people are affected by it depend, on the one hand, on physically measurable quantities such as the sound pressure level, pitch of a tone, tonality and impulsiveness. On the other hand, certain subjective factors also play a role: at bedtime noise is perceived as extremely annoying. The same is true for activities which require a high level of concentration. If we like certain sounds, we will not perceive them as annoying even at high volumes; sounds which we do not like are annoying to us even at low volumes (e.g. certain types of music). Furthermore, how we feel at a particular time also influences our sensitivity to noise. If an activity is disrupted or disturbed by one or more sounds, this is referred to as noise pollution. We are particularly sensitive to noise if verbal communication is affected, e.g. if a loud conversation at the neighboring table makes it difficult for us to listen, and if we have to concentrate or want to sleep.

REVERBERATION TIME

Put simply, the reverberation time indicates the period of time it takes for a sound event to become inaudible. Technically, the reverberation time T has been defined as the time required for the sound pressure level in space to decay by 60 dB.

OCTAVE BANDS

Acoustic parameters such as the sound pressure level or the sound absorption coefficient are usually expressed in increments of octaves and one-third octaves. The precise knowledge of acoustic properties in the smallest possible frequency steps of sound is a prerequisite for a detailed acoustic design. For room acoustics the relevant octave frequencies are 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. The octave increments are obtained by doubling the previous frequency. Each octave comprises three one-third octave values (see also “single values”).

POROUS ABSORBERS

Porous absorbers comprise, for example, mineral fibres, foams, carpets, fabrics, etc. The effect of the porous absorbers is due to the fact that sound is able to enter the open structures of the material where, by the friction of air particles, the sound energy is converted into thermal energy at the surface of the pores. Porous absorbers achieve their best effect at medium and high frequencies.

PSYCHOACOUSTICS

Branch of acoustics or noise effect research which deals with the subjective perception of objectively present sound signals. Furthermore, psychoacoustics studies the influence of a listener’s personal attitudes and expectations on the perception of sound events.

RESONANCE ABSORBER

This term comprises all types of absorbers using a resonance mechanism such as an enclosed air volume or a vibrating surface. Resonance absorbers are mainly suitable for absorbing sound of medium to low frequencies. The maximum effect of resonance absorbers is usually restricted to a certain frequency range (see also “porous absorbers”).

SOUND ABSORBER

Sound absorbers are materials which attenuate incident sound or convert it into other forms of energy. A distinction has to be made between porous absorbers and resonance absorbers or combinations of these absorber types.

SABINE FORMULA

If the volume and the total equivalent sound absorption area of a room are known, the reverberation time can be estimated using the Sabine formula, where “T” is the reverberation time, “V” is the volume of the room and “A” is the total equivalent sound absorption area.
The close relationship between the volume of a room, the sound absorption of the surfaces of this room, and the reverberation time was discovered the physicist Wallace Clement Sabine (1868 - 1919). He found out that the reverberation time T is proportional to the room volume V and inversely proportional to the equivalent sound absorption area A:
$T = 0{,}163 \times V / A$
The equivalent sound absorption area A is the sum of all surfaces S present in the room, each multiplied by its corresponding sound absorption coefficient α:
$A = \alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + \ldots + \alpha_n S_n$

SOUND ABSORPTION COEFFICIENT α

The sound absorption coefficient α of a material indicates the amount of the absorbed portion of the total incident sound. $\alpha = 0$ means that no absorption occurs; the entire incident sound is reflected. If $\alpha = 0{,}5$, 50 % of the sound energy is absorbed and 50 % is reflected. If $\alpha = 1$, the entire incident sound is absorbed, there is no longer any reflection.

SOUND ATTENUATION

Sound attenuation describes the ability of materials to absorb sound or to convert the sound energy present into other forms of energy, i.e. ultimately into thermal energy (see also “sound insulation”).

SOUND INSULATION

Sound insulation refers to the restriction of the propagation of sound through the boundaries of a room. Sound insulation is, therefore, a measure to separate rooms acoustically from unwanted sound from adjacent rooms or the outside. This has nothing to do, however, with the required acoustic sound attenuation within a room (see also “sound absorption”). Sound insulation is a fundamental parameter of building acoustics. A distinction has to be made between airborne sound insulation and impact sound insulation. Airborne sound is created by sound sources present in the room which are not immediately connected to the boundary surfaces, e.g. people who are talking. Impact sound, on the other hand, results from structure-borne sound (footfalls, knocking), which in turn excites the walls or ceilings to radiate airborne sound. Airborne sound insulation and impact sound insulation both have to fulfil the requirements established in relevant building laws.

SOUND PRESSURE

All sound events have in common the fact that they cause slight variations in air pressure which can propagate in elastic media such as air or water. We therefore refer to the sound pressure of a tone. The heavier the pressure variations are, the louder is the sound event. The faster the variations occur, the higher is the frequency.

SOUND PRESSURE LEVEL (LP)

The sound pressure level (L for level and p for pressure) is a logarithmic quantity for describing the intensity of a sound event. The sound pressure level is often also referred to as “sound level”, which is actually not quite correct. The sound pressure level is expressed in decibels (abbreviated as dB). Sound pressures are measured using microphones. The measurable level range starts at just below 0 dB and ends at approximately 150 to 160 dB.

SOUND EVENTS

General term for tones, music, bangs, noise, crackling, etc.

SOUND SHIELDING

A sound shield is basically an obstacle which interrupts the direct propagation of sound from a source to a receiver. It can consist in a movable partition or an attachment to be placed on top of a desk. Cabinets and other large-surface pieces of furniture can also function as sound shields. Sound shields can be provided with a sound absorbing surface which additionally reduces the propagation of sound.

SOUND SPECTRUM

The sound spectrum describes the frequency composition of the sound. Pure tones are sound events of a single frequency. A superposition of tones of different frequencies is referred to as noise or sound.

SOUND WAVES

Variations in air pressure which are caused by sound events are referred to as sound waves. The length of the sound waves defines the frequency and their height defines the level. Long sound waves have a low frequency and are perceived as low-pitched tones. Short sound waves have a high frequency and are perceived as high-pitched tones.
In air, a 100 Hz wave has an extension of 3.40 meters, whereas a 5000 Hz wave has an extension of approximately 7 centimeters.

SOUND MASKING

Sound masking specifically uses natural (e.g. birds’ twittering) or artificial (e.g. noise) sounds in order to blanket other sounds. This method can be used, for example, to drown out information-containing sounds if the other background noise is too weak to mask them.

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The physicists Dr. Catja Hilge and Dr. Christian Nocke founded an acoustic consulting company in Oldenburg (Germany) in 2001. They work as specialized engineers for architects, expert witnesses for courts and consultants in the field of acoustics. Architectural acoustics for class rooms, offices and other facilities has become one major focus of the company.

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