



BSI Standards Publication

## Acoustic quality criteria for music rehearsal rooms and spaces

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**Acoustic quality criteria for music  
rehearsal rooms and spaces**

*Critères de qualité acoustique pour les salles et locaux de répétition  
musicale*



Reference number  
ISO 23591:2021(E)



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ISO copyright office  
CP 401 • Ch. de Blandonnet 8  
CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
Website: [www.iso.org](http://www.iso.org)

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

The acoustic properties of a room are crucial for the interaction between the room and the musical instrument. When the acoustic response of a room works well with the instrument, good conditions are achieved for both audience and musicians.

There is a clear connection between the intended use of a music room, the type of music, the ensemble type and the size of the room. It is not possible to achieve satisfactory acoustic conditions for all music types and speech communication in a single room since the acoustic requirements for each use are different.

It is necessary to divide the spaces in accordance with their function and number of musicians or singers (both amateurs and professionals). There are different needs when it comes to the physical size of the room (net volume), timbre, reverberation, net room height and room geometry. The division into types of rooms in this document reflects the practical conditions in musical performance. The musicians play or sing individually (rehearsing or receiving teaching), in small groups (either with the same instruments, voices or in ensembles of three to six persons), in medium size groups/ensembles or in large groups/ensembles (choirs, marching bands, big bands, orchestras and other ensembles), see Reference [22].

The document describes criteria for any kind of rooms and spaces used for music rehearsal. The rooms used for music purposes vary from small practice rooms for one or a few musicians to very large rehearsal rooms and concert halls. In large concert halls, skilled acousticians are engaged for designing and planning the acoustics. In the practice rooms and rooms used for rehearsal or more unformal music performances, the acoustic environment is often not suited for this purpose.

This document is intended for municipalities and county councils, property developers, builders, consultants, architects, contractors, facility owners (public and private) and others who operate or own such buildings. The document may also be used by others, from the individual musician to large groups and associations. A large number of rooms and spaces are used for music rehearsal and performance in municipalities. It is important for property developers to emphasise participation by typical users of the building and the music rooms as early as possible, preferably during the conceptual or planning stages, of which this document should form one of the premises.

[Annex A](#) provides guidelines for determining the sound pressure level at forte applying the sound strength ( $G$ ) of the room and the average sound power level at forte of the musical instruments in question. This leads to favourable range of net room volume and reverberation time for a certain ensemble type. [Annex B](#) provides guidelines concerning user processes for planning of rooms for music rehearsal.



# Acoustic quality criteria for music rehearsal rooms and spaces

## 1 Scope

This document specifies differentiated criteria for acoustic conditions and characteristics for rooms and spaces used for music rehearsal. The criteria are specified for different types of music, regardless of the type of building in which the spaces are located. The document provides criteria for room acoustics in spaces used for music rehearsal, whether this is the primary use of the spaces or they are multi-purpose spaces. Together with the acoustic criteria, requirements are given for net room height, net room volume and net area.

Criteria for acoustic conditions are differentiated on the basis of three music types: amplified music, quiet acoustic music, and loud acoustic music.

This document is applicable to the planning of new buildings and the refurbishment of existing ones. The document can also be used to assess the suitability of existing spaces for different musical purposes. The document can be used for the adjustment of rooms and spaces whose primary purpose is not music rehearsal such as sports halls, classrooms, assembly halls, multi-purpose rooms, etc. Flexible acoustic solutions can be used in order to cover several purposes of use.

The criteria in this document do not apply to large, specialized concert halls, opera venues and similar spaces which are basically designed for concerts and performances, or specialized music recording studios.

The document does not deal with the need for logistics, storage rooms for instruments and other key support functions relating to music rehearsal. Sound insulation criteria are not included in this document.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3382-1, *Acoustics — Measurement of room acoustic parameters — Part 1: Performance spaces*

ISO 3382-2, *Acoustics — Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms*

ISO/PAS 20065, *Acoustics — Objective method for assessing the audibility of tones in noise — Engineering method*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

### 3.1

#### **diffusor**

sound-reflecting surface which spreads the sound in many different directions

### 3.2

#### **rehearsal room**

<music> room for practising individual musical skills, teaching and ensemble rehearsal

### 3.3

#### **individual practise room**

<music> room or studio designed for practising individual musical skills for one to two persons

Note 1 to entry: Individual practise rooms are too small for teaching.

### 3.4

#### **ensemble room**

<music> *rehearsal room* (3.2) for three or more musicians or singers

### 3.5

#### **recital room**

<music> a room where performances or concerts take place

Note 1 to entry: Usually, the performances have relatively few musicians.

### 3.6

#### **reverberation time**

$T$

time that would be required for sound pressure level to decrease by 60 dB after the sound source has stopped

Note 1 to entry: The reverberation time is expressed in seconds.

Note 2 to entry:  $T$  can also be evaluated based on a smaller dynamic range than 60 dB and extrapolated to a decay time of 60 dB. It is then labelled accordingly. Thus, if  $T$  is derived from the time at which the decay curve first reaches 5 dB and 25 dB below the initial level, it is labelled  $T_{20}$ . If decay values of 5 dB to 35 dB below the initial level are used, it is labelled  $T_{30}$ .

Note 3 to entry: The average of reverberation times at the octave bands with the centre frequencies 500 Hz and 1 000 Hz is labelled  $T_{mid}$ .

[SOURCE: ISO 354:2003, 3.2<sup>[3]</sup>, modified - Notes 1 and 2 to entry are added from ISO 3382-1:2009, 3.5, Note 3 to entry is added.]

### 3.7

#### **echo**

a sound wave that has been reflected or returned with sufficient magnitude and delay to be detected as a wave distinct from that directly transmitted and distinguishable as a repetition of it

[SOURCE: ISO 2041:1990, 2.71<sup>[6]</sup>]

### 3.8

#### **flutter echo**

periodic recurrent sound reflections, for example between two parallel sound-reflecting surfaces

Note 1 to entry: In case of short distance between the surfaces, colouration of the sound can be heard. Colouration is an audible accentuation of certain frequencies and may be caused by periodic recurrent sound reflections at short time intervals. In larger rooms, where the distance between the surfaces is large, the phenomenon can be heard as a rustling or rattling sound.

### 3.9

#### **amplified music**

music that is transmitted through an amplifier or sound reinforcement systems

Note 1 to entry: Sound reinforcement systems are often referred to colloquially as "PA equipment". PA is an abbreviation of "public address". PA equipment is normally used for audio reproduction of speech or recorded music.

### 3.10

#### **sound level**

measure for the energy of sound

Note 1 to entry: In this document, sound level is given by the measures A-weighted time-averaged sound pressure level,  $L_{p,A,T}$ , A-weighted maximum sound pressure level,  $L_{p,AFmax}$ , or as octave band levels,  $L_{oct}$ .

### 3.11

#### **sound diffusion**

reflection of sound waves in many different directions

### 3.12

#### **loud acoustic music**

music generated by acoustic instruments (non-amplified) that produce music with sound power levels higher than or equal to 95 dB at forte

Note 1 to entry: Examples of instruments are brass (wind) instruments, percussion, piano, big band, and opera singing.

### 3.13

#### **quiet acoustic music**

music generated by acoustic instrument (non-amplified) that produce music with sound power levels lower than 95 dB at forte

Note 1 to entry: Examples of instruments are such as woodwind instruments, string instruments, and singing.

### 3.14

#### **net average room height**

$\bar{h}$

<music room> average of the interior room height measured from the floor surface to the surface of a ceiling above the net area of a room

Note 1 to entry: If there is an acoustically non-transparent suspended ceiling, for music rooms the net room height is measured up to it. There may be national regulations that have other definitions.

### 3.15

#### **net area**

<music room> net floor area limited by the inner surface of the enclosing walls

### 3.16

#### **net volume**

volume calculated from the inner surfaces of enclosing structures (floor, walls, ceiling) except structural parts, shafts, chimneys, etc.

Note 1 to entry: Recesses, projections of an aesthetic nature, profiles and other secondary structural parts are not taken into account in the net volume. Enclosed volume above the suspended ceiling is not included. The volume under a telescopic stand (also called retractable seating or risers) is not taken into account in the net volume.

**3.17**  
**sound strength**

*G*

acoustic response of a room specified as sound pressure level from an omnidirectional sound source relative to the sound pressure level from the same sound source at a distance of 10 m in a free field

Note 1 to entry: Sound strength is stated in decibels (dB). Sound strength can vary within the room, and the objective is to achieve as even amplification in the room as possible. A more detailed description of the criterion for sound strength is provided in [Annex A](#).

[SOURCE: ISO 3382-1:2009, A.2.1]

**3.18**  
**room resonance**

modal resonance

resonance where the excitation frequency coincides with the natural frequency of one of the room modes

Note 1 to entry: A room has many room resonances which occur at different frequencies. At the first room mode, the largest dimension of the room equals one half the wavelength.

**3.19**  
**variable sound absorber**

sound absorbing curtain, banner, transformable element, or device which can adjust the acoustic absorption within a room

Note 1 to entry: Variable sound absorbers may be used to provide adequate acoustic flexibility. Such elements may also have diffusing or reflecting characteristics.

**3.20**  
**tonal sound**

sound characterized by a single frequency component or narrow-band components that emerge audibly from the total sound

[SOURCE: ISO 1996-1:2016, 3.4.9<sup>[4]</sup>]

**3.21**  
**sound power**

*P*

rate per unit time at which airborne sound energy is radiated by a source

Note 1 to entry: In this document, the sound power is expressed in milliwatts (mW).

Note 2 to entry: This definition is technically in accordance with ISO 80000-8:2020, 8-9<sup>[9]</sup>.

**3.22**  
**sound power level**

*L<sub>W</sub>*

ten times the logarithm to the base 10 of a ratio of the *sound power* ([3.21](#)) radiated by a source to the reference sound power 1 pW

Note 1 to entry: The sound power level is expressed in decibels.

Note 2 to entry: This definition is technically in accordance with ISO 80000-8:2020, 8-15<sup>[9]</sup>.

Note 3 to entry: In this document, no frequency weighting is applied to the sound power levels.

## 4 General criteria

### 4.1 Quiet acoustic music

Quiet music means music that is performed primarily on quiet acoustic music instruments or singing, see 3.12. Typical groups are choirs, vocal ensembles, folk groups, string quartets, string orchestras and groups with string instruments (such as guitars) without amplification.

In rooms for quiet acoustic music, it is generally important to take care of the following:

- appropriate room size (net volume and net area);
- appropriate net room height;
- reverberation adapted to the purpose, the reverberation time as a function of frequency does not vary too much, see 5.7;
- control of repeated reflections, inclining of surfaces, sound diffusion and sound diffusing elements in order to avoid flutter echo;
- sound strength adapted to sound power of the ensemble;
- low background noise level.

Table 1 gives an overview of important properties of rehearsal rooms for quiet acoustic music. Table 4 gives an overview of important properties of recital rooms for rehearsal use for quiet acoustic music.

### 4.2 Loud acoustic music

Loud music means music that is performed on acoustic instruments that generate a powerful sound, see 3.11. Typical groups are brass bands, concert bands, big bands and symphony orchestras with a wind group. Percussion and opera singing belong to this category as well. The number of the musicians affects the need for floor area, net volume and the overall size of a room.

In rooms for loud acoustic music, it is generally important to take care of the following:

- appropriate room size (net volume and net area);
- appropriate net room height;
- reverberation adapted to the purpose, the reverberation time as a function of frequency does not vary too much, see 5.7;
- control of repeated reflections, inclining of surfaces, sound diffusion and sound diffusing elements in order to avoid flutter echo;
- sound strength adapted to the sound power of the ensemble;
- not too high background noise level.

Table 2 gives an overview of important properties of rehearsal rooms for loud acoustic music. Table 4 gives an overview of important properties of recital rooms for rehearsal use for loud acoustic music.

Pipe organs need special consideration although they belong to loud acoustic music instruments. The design of the organ should meet the size of the room. Other instruments, as Japanese drums or percussion ensembles, also need special consideration.

Grand piano belongs to the group of loud acoustic music instruments, but this does not apply if the piano is used for simple accompaniment or other quiet activities.

### 4.3 Amplified music

Amplified music includes all music which is transmitted through amplifying or sound reinforcement system, e.g. pop and rock, electronica, jazz, vocal groups, big bands and musicals or similar, where the sound is mainly transmitted through amplifying equipment.

For rehearsal, quiet acoustic and loud acoustic music groups can also be amplified by using microphones. These are included in amplified music if the majority of the sound volume is transmitted through the loudspeaker system. It should be considered to what extent the sound reinforcement system does create the total sound pressure level in the room.

Big band is normally included in loud acoustic music since the sound production is primarily acoustic. Big band may however be included in amplified music when all the wind instruments are amplified.

In rooms for amplified music, it is generally important to take care of the following:

- appropriate bass absorption;
- short reverberation time, the reverberation time as a function of frequency does not vary too much, see 5.7;
- control of repeated reflections, inclining of surfaces, sound diffusion and sound diffusing elements in order to avoid echo;
- not too prominent room resonance;
- not too high background noise level.

Table 3 gives an overview of important properties of rehearsal rooms for amplified music. Table 4 gives an overview of important properties of recital rooms for rehearsal use for amplified music.

NOTE The criteria for rehearsal spaces, also used for recital, for amplified music are based on Reference [18].

## 5 Criteria for rooms for music rehearsal

### 5.1 General

Rehearsal rooms are divided by type of music (amplified, loud acoustic or quiet acoustic music) and type of ensemble (number of musicians). The division is made into individual practise rooms, small ensemble rooms, medium and large ensemble rooms. These room types are divided in accordance with different requirements as to room size (net volume, net area, net room height, room geometry), room acoustics (reverberation time, sound absorption, sound reflections) and other needs which distinguish the music types. The division relates to whether the musicians play or sing alone (individual rehearsal or teaching), in small groups (either with the same instruments, voices or in ensemble of three to six persons) or in large groups (choir, marching band, big band, orchestra, etc.)

Rehearsal uses of recital rooms are divided according to the music types; amplified, loud acoustic and quiet acoustic music.

Tables 1, 2, 3 and 4 define the criteria for properties of the different room types.

Acoustically, a music room is like an extension to the musical instrument that is being played in the room. This is particularly pronounced for singing and musical instruments without inherent reverberation, like wind instruments. Sound strength,  $G$ , and other acoustic properties of the room are crucial for the interdependence between the room and the musical instrument<sup>[19]</sup>. If the sound strength of the room is too low, the music will sound weak and the musician may try to compensate by forcing the playing, which may lead to harsh sound quality and decreased dynamic range of the music. On the other hand, if the sound strength is too high, the music will sound too loud and the musician may restrain their playing, which in turn will decrease the dynamic range of the music. When acoustic response of the room works well with the instrument, good rehearsal conditions are achieved for the musician. It is

important to consider sound strength,  $G$ , to reduce risk of hearing damage or hearing loss. Appropriate sound strength will assure the right quality of music rehearsal and recital as well. Informative [Annex A](#) describes the relationship between sound strength, reverberation time and net room volume.

Together with sound strength,  $G$ , the main criterion used in this standard is reverberation time (see [5.7](#)), which is a common and easily measurable parameter. However, when designing rooms for music, avoiding several other issues might be equally important; room resonances, colouration due to early reflections, flutter echoes, harshness due to playing directly towards a close, reflecting surface, positions of musicians etc. Such issues tend to be more important in small rooms. Most of these issues can be analysed by inspection of the impulse responses, see ISO 18233<sup>[8]</sup>.

In order to achieve a smooth frequency response in the bass range, it is desirable to have a favourable proportion between room dimensions, especially in rooms smaller than 300 m<sup>3</sup>. Ratios of 1:1 and 1:2 between room dimensions should be avoided. The ratio between width and length of the room should not exceed 1:1,6. See [B.2](#) for more guidance.

Flutter echo and other echo and focusing effects (see [3.6](#) and [3.7](#)) should be avoided. Within each main category of music rooms, variable acoustics may be needed. Some control of low frequency sound, either in the form of absorption, sound diffusion or scattering is necessary as well. For music rooms, the requirements to background noise given in the tables, apply. For other types of rooms and spaces whose primary purpose is not music rehearsal, requirements to background noise from service equipment stated for the different spaces or room types apply. In such rooms and spaces, every effort should be made to achieve equally good acoustic conditions as in music rooms.

**NOTE 1** Flutter echo is often perceived in rooms where two parallel surfaces are reflective, with all other surfaces more absorbing. This often gives a high frequency tail of the sound decay, especially for impulsive sounds. For small distance between surfaces, this can be audible as a sound coloration. For large distance between reflective surfaces, a periodic series of echoes can be heard.

The background noise from service equipment shall not exceed the tabled values for the different room types. Tonal sound of the noise, as defined in ISO/PAS 20065, shall be avoided because it is especially critical in music rooms. Background noise from other service equipment and from outside noise sources shall be subjected to special assessment. See [6.2](#) for requirements for background noise level.

Good sound insulation between rooms is recommended, in addition to requirements for room acoustical conditions. The aim is to avoid disturbing noise from adjacent rooms and to ensure suitability and flexibility of the rooms for their desired purpose.

**NOTE 2** National regulations or standards can give limit values for sound insulation, see for example References [\[10\]](#), [\[11\]](#) and [\[12\]](#).

Good ventilation, good lighting and appropriate storage capacity are important in buildings for music purposes. The need for increased ventilation depends on the level of exertion required by the type of music.

Requirements for other important conditions such as ventilation, lighting and storage are not directly dealt with in this document. Requirements for ventilation and ventilation rate are given for example in EN 15251<sup>[2]</sup> or in national regulations. In a number of situations, there may however be a need for increased ventilation.

Ventilation rate often relate to sedentary work. For other situations, the ventilation rate per person is calculated in accordance with the metabolic rate. Music playing and singing can be comparable with different degrees of light or heavy physical work. Therefore, the ventilation rate may be dimensioned by using values averaged over time and number of musicians.

Requirements for level of illumination and the design of illumination installations (including for music rooms) are given for example in EN 12464-1<sup>[1]</sup>. The aim should be to have variable positional lighting as a supplement to the general level of illumination in the room. The selected solution for illumination should take into account the possibility of light being reflected from instruments and other objects.

For assessments relating to universal design, additional measures may be necessary. Illumination installations should not give rattling sounds when music is played.

NOTE 3 The need for storage capacity can be described in other documents e.g. from national music organizations.

## 5.2 Individual practise rooms

Individual practise rooms are designed for practise for one to two persons, see 3.3. The acoustic requirements for individual practise rooms are relatively similar for the individual musical instruments or singing, except for rooms for percussion. In practise, it will often be appropriate to incorporate solutions for variable acoustics to make the room suitable for several types of music. Individual practise rooms will then be able to be used for both quiet acoustic and loud acoustic instruments.

## 5.3 Ensemble rooms

In this document, ensemble rooms are divided by size as small, medium and large. Small ensemble rooms are intended for three to twelve musicians for acoustic music and three to six musicians for amplified music. Medium size ensemble rooms are for thirteen to twenty-four musicians playing loud acoustic music and for up to thirty musicians for quiet acoustic music or for seven to twelve musicians for amplified music. If there are more musicians, the room size shall be increased, and such rooms are referred to as large ensemble rooms.

Many music groups playing acoustical music have between three and twelve musicians, such as chamber music ensembles, small jazz groups etc., and they will use small ensemble rooms. The same concerns small groups between three and six musicians playing amplified music such as pop bands, rock groups, etc. Medium size rooms may also be suited to group rehearsals and vocal exercises, such as brass instrument rehearsals, soprano voice exercising in choirs, first violin rehearsals for orchestras, large rhythmic groups (salsa bands, large jazz groups etc.), clarinet rehearsals for marching bands, and so forth. Such groups require a larger net area and net volume than smaller groups.

Large ensemble rooms are suited for ensemble playing, tutti rehearsals and tutti practises for larger music ensembles. Typical music groups are, for example, brass bands (25 musicians to 35 musicians), concert bands (35 musicians to 70 musicians), choirs (30 singers to 80 singers), amateur orchestras (40 musicians to 70 musicians) and professional orchestras (70 musicians to 110 musicians).

For amplified music, large ensemble rooms should have their own sound reinforcement system, and they should be suitable for preproduction. To some extent, such rooms may also be usable for public concerts.

Large ensemble rooms shall have a large net volume adapted to the different music groups. The distinction between large ensemble rooms and rehearsal use of recital rooms (see 5.4) is due to the musicians' need for greater clarity and somewhat shorter reverberation time.

For string ensembles, the floor should be able to vibrate in order to amplify the sound from the double bass and cello which have contact with the floor. The same applies for the harp, see also 5.5.

## 5.4 Rehearsal use of recital rooms

Many recital rooms with audience, are used for rehearsals without audience as well. Rooms with seating for an audience of up to 500 persons, or for amplified music, with a standing audience of up to 1 000 persons, maybe considered according to Table 4. These rooms could for example be rooms for large music groups (marching bands, choirs, big bands) or for smaller groups (performing arts school groups, jazz groups, stage bands, brass ensembles and vocal ensembles).

These rooms shall have satisfactory acoustic conditions for both performers (in the stage area) and the audience. If there is a separate stage area, this shall be in the same acoustic space as the public area, i.e. without fixed boundaries to the sides or above the edge of the stage.

NOTE 1 Partially recessed stages with small stage openings, so-called "peep-show stages", are unsuited to musical purposes.

NOTE 2 The maximum number of musicians and audience or seats is a dimensioning criterion (see Table 4, footnote <sup>a</sup>).

## 5.5 Multi-purpose rooms

Multi-purpose rooms can be rooms for music and other purposes (theatre, dance, sports, etc.) or rooms for different types of music. For rooms used for music rehearsal and music performance (with or without audience present), see 5.4 and Table 4.

Multi-purpose rooms can be adapted to several types of music. In such rooms, various purposes shall be clearly defined and prioritised. The main intended use and other uses should be specified and made known to all users, in order to avoid conflicts concerning suitability of the spaces for various applications.

Differentiated criteria for acoustic conditions and characteristics for spaces used for music rehearsal and recital are similar regardless of the type of building in which the spaces are located. The room acoustics should be similar whether music rehearsal is the primary use, or if the room is a multi-purpose room.

In multi-purpose rooms and spaces, it is necessary to have solutions with variable acoustics in order to facilitate the distinct needs of different music types and music groups. The different requirements that apply to the different music types in Tables 1 to 4 of this document shall also be taken care of in multi-purpose rooms, based on the prioritised applications of the individual room. In practical use, it will often be appropriate to incorporate solutions for variable acoustics to make the room suitable for several types of music.

Particular emphasis shall be given to the stage conditions in order to adapt the stage to different music types. For example, for string ensembles the stage floor should be able to vibrate in order to amplify the sound from the double bass and cello which have contact with the floor. The same applies for the harp and some Asian and African types of instruments with direct contact to the floor.

## 5.6 Criteria for rooms for different types of music

Table 1 specifies properties for rehearsal rooms for quiet acoustic music.

**Table 1 — Properties for rehearsal rooms for quiet acoustic music**

Rehearsal rooms for quiet acoustic music				
Property	Individual practise room	Small ensemble room <sup>a</sup>	Medium ensemble room	Large ensemble room
Number of musicians/singers ( <i>N</i> )	1 to 2	3 to 12	13 to 30	20 to 35 (string orchestras)
Ensemble type	See 4.1	See 4.1	See 4.2	30 to 80/100 (choirs) See 4.1
Net volume (see NOTE)	≥35 m <sup>3</sup>	>25 × <i>N</i> m <sup>3</sup>	>25 × <i>N</i> m <sup>3</sup>	>25 × <i>N</i> m <sup>3</sup>
Net area	≥13 m <sup>2</sup> <sup>a</sup>	≥20 m <sup>2</sup> to 40 m <sup>2</sup> (rel. to number of musicians/singers)	≥40 m <sup>2</sup> to 70 m <sup>2</sup> (rel. to number of musicians/singers)	≥50 m <sup>2</sup> + 1,5 × <i>N</i> m <sup>2</sup>
Net average room height, $\bar{h}$	≥2,7 m	≥3,5 m	≥4,5 m	≥5 m <sup>e</sup>
Room geometry <sup>b</sup>	Adequate room ratios	Adequate room ratios	Adequate room ratios	Adequate room ratios
Acoustic treatment <sup>c</sup>	(WA), CA, BA, D	(WA), CA, BA, D	WA, CA, BA, D	WA, CA, BA, D
Reverberation time, <i>T</i>	See Figures 1 and 2			
Background noise level <sup>d</sup>	See national standard, or use recommended level $L_{p,A,T} = 25$ dB.			
NOTE The sound strength is related to net volume and reverberation time. For assessments of sound strength and sound power level from different musical instruments, see 5.1 and Annex A.				
<b>Key</b>				
CA = Ceiling absorbers, WA = Wall absorbers, BA = Bass absorbers, D = Diffusors.				
<sup>a</sup> Includes teaching for one to two persons.				
<sup>b</sup> B.2 (see also Reference [21]) shows room ratios that are recommended to be used, for large rooms see B.2.2. The wall may be angled at 5° to 7° or more or the wall may be convex curved.				
<sup>c</sup> Variable absorption is used for rooms where singing occurs and/or several types of instrument are played.				
<sup>d</sup> Tonal sound of the noise is especially disturbing for music rehearsal and should not occur in rehearsal rooms. It is recommended that the background noise level should not exceed 45 dB at 63 Hz.				
<sup>e</sup> For larger ensembles, there may be a need for greater net average room height.				

Table 2 specifies properties for rehearsal rooms for loud acoustic music.

Table 2 — Properties for rehearsal rooms for loud acoustic music

Rehearsal rooms for acoustical loud acoustic music				
Property	Individual practise room	Small ensemble room <sup>a</sup>	Medium ensemble room	Large ensemble room
Number of musicians ( $N$ )	1 to 2	3 to 12	13 to 24	>25
Ensemble type	See 4.2	See 4.2	See 4.2	See 4.2
Net volume (see NOTE)	$\geq 50 \text{ m}^3$	$> 30 \times N \text{ m}^3$ $> 50 \times N \text{ m}^3$ for extra loud groups	$> 30 \times N \text{ m}^3$ $> 50 \times N \text{ m}^3$ for extra loud groups	$> 50 \times N \text{ m}^3$ $> 60 \times N \text{ m}^3$ for extra loud groups
Net area <sup>b</sup>	$\geq 15 \text{ m}^2$	<sup>c</sup>	<sup>c</sup>	$\geq 120 \text{ m}^2$ $+ 2 \times N \text{ m}^2$
Net average room height, $\bar{h}$	$\geq 3,0 \text{ m}$	$\geq 3,5 \text{ m}$	$\geq 4,5 \text{ m}$	$\geq 5,0 \text{ m}^{\text{e}}$
Room geometry <sup>d</sup>	Adequate room ratios	Adequate room ratios	Adequate room ratios	Adequate room ratios
Acoustic treatment <sup>e</sup>	WA, CA, BA	CA, BA, D	CA, BA, D, R	CA, BA, D, R
Reverberation time, $T$	See Figures 1 and 2			
Background noise level <sup>f</sup>	See national standard/criteria, or use recommended level $L_{p,A,T} = 25 \text{ dB}$ .			
NOTE Extra loud groups can for instance be professional symphony orchestras, brass bands, percussion ensembles or groups playing instruments with sound power levels above 100 dB. The sound strength is related to net volume and reverberation time. For assessments of sound strength and sound power levels from different musical instruments, see 5.1 and Annex A.				
<b>Key</b>				
CA = Ceiling absorbers, WA = Wall absorbers, BA = Bass absorbers, D = Diffusors, R = reflectors.				
<sup>a</sup> Includes teaching for one to two persons.				
<sup>b</sup> For some instruments, for example percussion and piano, there is a need for a greater area than for other musical instruments. This should be taken into account in the planning of rooms for this purpose.				
<sup>c</sup> The net area will be determined by the net volume and net average room height.				
<sup>d</sup> B.2 (see also Reference [21]) shows room ratios that are recommended to be used, for large rooms see B.2.2. The wall may be angled at 5° to 7° or more or the wall may be convex curved.				
<sup>e</sup> Variable absorption is used for rooms where several types of instrument are played.				
<sup>f</sup> Tonal sound of the noise is especially disturbing for music rehearsal and should not occur in rehearsal rooms. See also 6.2. It is recommended that the background noise level should not exceed 45 dB at 63 Hz.				
<sup>g</sup> For larger ensembles, there may be a need to increase the net average room height.				

Table 3 specifies properties for rehearsal rooms for amplified music.

**Table 3 — Properties for rehearsal rooms for amplified music**

Rehearsal room for amplified music				
Property	Individual practise room	Small ensemble room	Medium <sup>a</sup> ensemble room	Large <sup>a</sup> ensemble room
Number of musicians ( <i>N</i> )	1 to 2	3 to 6	7 to 12	>12
Ensemble type	See 4.1	See 4.1	See 4.1	See 4.1
Net volume	>35 m <sup>3</sup>	≥60 m <sup>3</sup>	≥200 m <sup>3</sup>	≥400 m <sup>3</sup>
Net area	≥13 m <sup>2</sup> <sup>c</sup>	≥20 m <sup>2</sup>	≥60 m <sup>2</sup>	≥100 m <sup>2</sup>
Net average room height, $\bar{h}$	≥2,7 m <sup>b</sup>	≥3,0 m <sup>b</sup>	≥3,5 m	≥4 m
Room geometry <sup>d</sup>	Adequate room ratios	Adequate room ratios		
Acoustic treatment <sup>e</sup>	WA, CA, BA, D	WA, CA, BA, D	WA, CA, BA (D if necessary)	WA, CA, BA (D if necessary)
Reverberation time, <i>T</i>	See Figures 1 and 2 <sup>f</sup>			
Background noise level <sup>g</sup>	See national standard, or use recommended level $L_{p,A,T} = 30$ dB.			
<b>Key</b>				
CA = Ceiling absorbers, WA = Wall absorbers, BA = Bass absorbers, D = Diffusors.				
<sup>a</sup> Acoustical requirements for medium and large ensemble rooms may be the same for amplified music and preproduction.				
<sup>b</sup> National regulation may have other criteria.				
<sup>c</sup> For some instruments, there is a need for a greater area than for other musical instruments. This should be taken into account in the planning of rooms for this purpose.				
<sup>d</sup> B.2 (see also Reference [21]) shows room ratios that are recommended to be used, for large rooms see B.2.2. The wall may be angled at 5° to 7° or more or the wall may be convex curved. If inclining is not possible, diffusors should be used.				
<sup>e</sup> Some control of low-frequency sound is necessary. The smallest dimension of the room will often be a reason for pronounced standing waves at low-frequencies and potential ceiling absorption should be considered.				
<sup>f</sup> For the 1/1 octave bands 63 Hz and 125 Hz in rooms with a net volume of <100 m <sup>3</sup> , the thresholds for reverberation time may differ somewhat due to room modes. See Figure 2.				
<sup>g</sup> The background noise level is not as critical for amplified music as for other types of music. It is recommended that the background noise level should not exceed 50 dB at 63 Hz.				

Table 4 specifies properties for rehearsal use of recital rooms with audience up to 500 seated (1 000 standing) persons. The rooms should be considered with and without audience, and with appropriate variable absorption.

**Table 4 — Properties for rehearsal use of recital rooms with audience up to 500 seated (1 000 standing) persons**

Rooms with audience up to 500 seated (1 000 standing) persons <sup>b</sup>				
Property	Amplified music		Loud acoustic music	Quiet acoustic music
	Club venue	Room		
Net volume <sup>a</sup>	300 m <sup>3</sup> to 800 m <sup>3</sup> (rel. to number of audience)	≥600 m <sup>3</sup>	≥10 m <sup>3</sup> /person incl. musicians <sup>c</sup> and at least ≥2 000 m <sup>3 a</sup>	≥12 m <sup>3</sup> /10 m <sup>3</sup> / person incl. musicians <sup>c</sup> and at least ≥600 m <sup>3</sup>
Net area	100 m <sup>2</sup> to 300 m <sup>2</sup> (rel. no. of audience)	≥150 m <sup>2</sup>		
Net average room height, $\bar{h}$ <sup>d</sup>	4 m to 6 m <sup>c</sup>	≥5 m	≥8 m	≥6 m
Number of audience	100 to 500	≥200	≥150 <sup>b</sup>	≥50
Ensemble type <sup>a</sup>	See 4.3	See 4.3	See 4.2	See 4.1
Stage area (net rig area)	≥30 m <sup>2</sup>	≥50 m <sup>2</sup>	≥100 m <sup>2 f</sup>	≥75 m <sup>2 f</sup>
Room geometry <sup>d</sup>			Adequate room ratios <sup>e</sup> Avoid concave room surfaces and triangular/fan-shaped layouts	Adequate room ratios <sup>e</sup> Flat floors or slightly sloping gallery <sup>f</sup> Avoid concave room surfaces and triangular/fan-shaped layouts
Acoustic treatment <sup>a</sup>	D, CA, BA WA	D, CA, BA	D, R	D, R
Reverberation time, $T$	See Figures 1 and 2			
Background noise level from service equipment <sup>hi</sup>	See national standard/criteria, or use recommended level $L_{p,A,T} = 28$ dB		See national standard/criteria, or use recommended level $L_{p,A,T} = 23$ dB	
Background noise level <sup>hi</sup> from outdoor sound sources	See national standard/criteria, or use recommended level $L_{p,A,T} = 30$ dB		See national standard/criteria, or use recommended level $L_{p,A,T} = 25$ dB	
Stage <sup>h</sup>	D $T \approx$ as in the room Check the sound level on small stages		D $T \approx$ as in the room <sup>i</sup> Partially absorbing rear wall Large room height, at least the same as the room Stage floor <sup>k</sup>	D $T \approx$ as in the room <sup>l</sup> Partially absorbing rear wall Large room height, at least the same as the room Stage floor <sup>k</sup>

NOTE Intimate club venues with lower net room heights can also work if proper acoustic treatment of the room is taken care of.

**Key**

CA = Ceiling absorbers, WA = Wall absorbers, BA = Bass absorbers, D = Diffusors, R = Reflectors.

<sup>a</sup> The number of audience or seats is a dimensional criterion, together with the maximum number of musicians that is desirable to be placed in the room.

<sup>b</sup> There may be up to 500 seated or 1 000 standing persons in the audience, depending on type of music. See also 5.4 and 5.5.

<sup>c</sup> The number of musicians is determined on the basis of the largest relevant ensemble.

<sup>d</sup> There are often problems with too low net room heights. The lowest net room height in the table corresponds with the lowest number of audience. These values are indicative for the lowest net room heights and the room height should be planned more precisely on basis of the prioritised application of the room.

<sup>e</sup> Full equipped symphony orchestra requires a larger area. Rooms for rehearsal use where a choir and orchestra/ marching band perform simultaneously require a larger stage area. The same is true for stages in multi-purpose rooms with theatre and dance.

<sup>f</sup> Telescopic stand (also called retractable seating or risers) has usually a too steep incline and should be avoided, because too much of the sound energy is directed towards the audience that acts as a sound-absorbing surface.

<sup>g</sup> B.2.2 shows recommended room ratios that are to be used. There should be at least 3,0 m of room height above the rearmost row under any reflecting surface, for instance a balcony. The room height should be at least 4 m at back row of the gallery.

<sup>h</sup> Requirements for background noise from service equipment and outdoor noise sources are in Tables 1 to 3. Stricter requirements should be considered based on the prioritised use of the room. In practise, noise from stage equipment such as lighting rigs etc. is often the dominant sound source during concerts. It is important to take this in to consideration during detailed project planning.

<sup>i</sup> For rehabilitation of existing rooms, 5 dB higher sound level is acceptable.

<sup>j</sup> There shall be a good acoustic coupling between the stage and the rest of the room, so that the total space can be considered as the same acoustic space; see 5.4.

<sup>k</sup> The stage floor should be elevated over the audience floor when there is no raked seating.

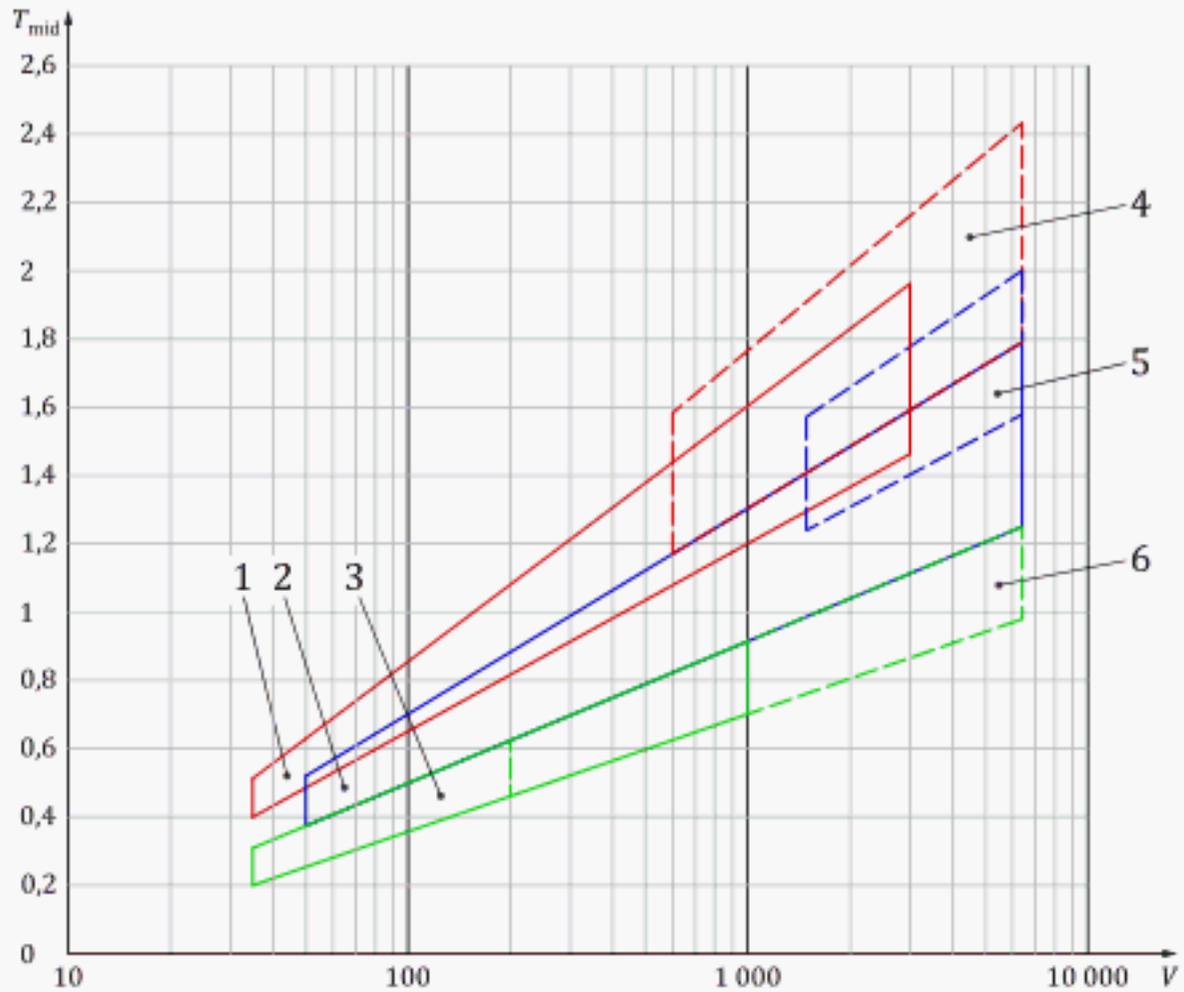
## 5.7 Criteria for reverberation time

Depending on net volume,  $V$ , and type of music, the reverberation time,  $T_{mid}$ , is given in Figure 1. The reverberation time is the average value of the octave bands 500 Hz and 1 000 Hz (the mid-frequency range). The reverberation times are given for normal furnishing (with or without seats), but without persons. The graphs in Figure 1 are in accordance with the formula:

$$T_{mid} = a \cdot \lg(V) - b \text{ (s)} \quad (1)$$

where the constants  $a$  and  $b$  are given in Table 5.

For rehearsal use of recital rooms, the reverberation time shall satisfy the criteria given in Figure 1 for each area of application. If seating for audience is not normally set out for rehearsals, it shall be taken into consideration when calculating reverberation time. It will often be necessary to use variable sound absorbers to ensure good conditions for rehearsal use of recital rooms.



**Key**

$V$  volume, expressed in cubic metre

$T_{mid}$  average of mid-frequency reverberation time, expressed in seconds

1 upper and lower limit for quiet acoustic music in rehearsal rooms (solid lines)

2 upper and lower limit for loud acoustic music in rehearsal rooms (solid lines)

3 upper and lower limit for amplified music in rehearsal rooms (solid lines)

4 upper and lower limit for quiet acoustic music for rehearsal use of recital rooms (dashed lines)

5 upper and lower limit for loud acoustic music for rehearsal use of recital rooms (dashed lines)

6 upper and lower limit for amplified music for rehearsal use of recital rooms (dashed lines)

Solid lines apply to rehearsal rooms, dashed lines apply to rehearsal use of recital rooms.

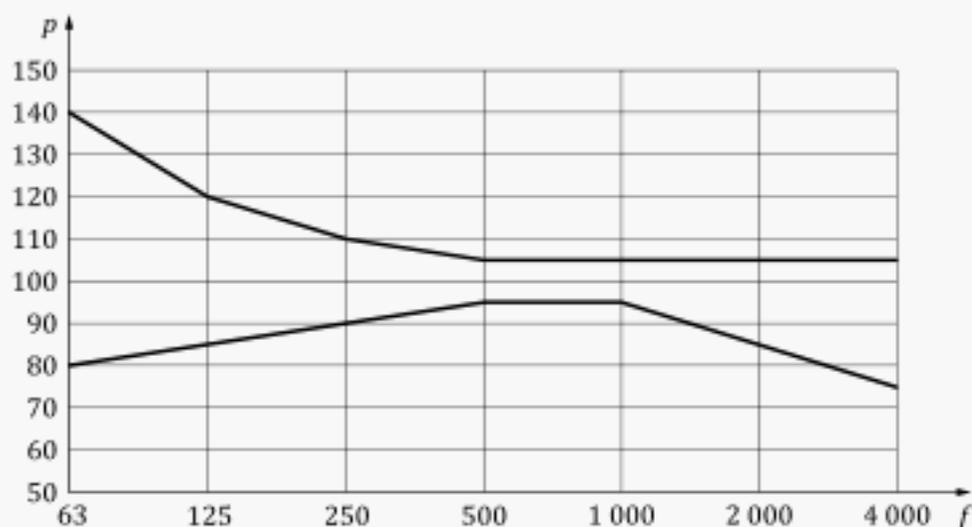
**Figure 1 — Reverberation time,  $T_{mid}$ , relative to net volume,  $V$ , for different types of music**

**Table 5 — Values for constants in [Formula \(1\)](#) related to reverberation time as a function of net volume in [Figure 1](#)**

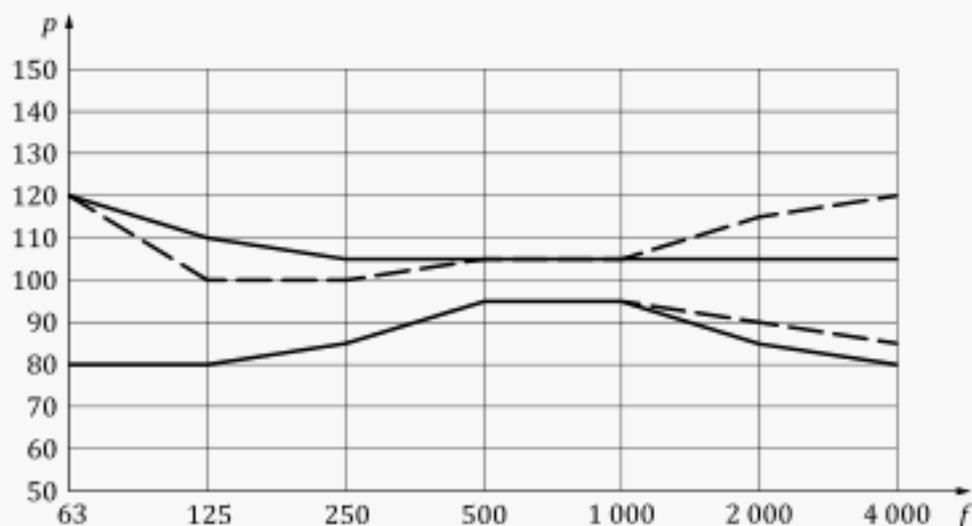
Rehearsal rooms	<i>a</i>	<i>b</i>	Minimum volume <i>V</i> m <sup>3</sup>	Maximum volume <i>V</i> m <sup>3</sup>
Amplified music, lower limit	0,325	0,335	35	1 000
Amplified music, upper limit	0,415	0,335	35	1 000
Loud acoustic music, lower limit	0,415	0,335	50	6 500
Loud acoustic music, upper limit	0,600	0,500	50	6 500
Quiet acoustic music, lower limit	0,550	0,450	35	3 000
Quiet acoustic music, upper limit	0,750	0,650	35	3 000
<b>Rehearsal use of recital rooms</b>				
Amplified music, lower limit	0,345	0,335	200	6 500
Amplified music, upper limit	0,415	0,335	200	6 500
Loud acoustic music, lower limit	0,525	0,425	1 500	6 500
Loud acoustic music, upper limit	0,675	0,575	1 500	6 500
Quiet acoustic music, lower limit	0,600	0,500	600	6 500
Quiet acoustic music, upper limit	0,830	0,730	600	6 500

Once the average value of the mid-frequency reverberation time,  $T_{mid}$ , is found, it is important to achieve suitable reverberation times for the entire frequency range.

Figures 2a and 2b specify frequency-dependent tolerance limits for the highest and lowest reverberation times  $T$  at a given frequency in octave bands from 63 Hz to 4 000 Hz. The figures show the relation in percentage of the reverberation time  $T$  at a frequency relative to the mid-frequency reverberation time,  $T_{\text{mid}}$ . This percentage should lie within the lines shown in Figures 2a and 2b. When evaluating measured reverberation times, another  $\pm 10$  %-points tolerance in each octave band may be acceptable, see Clause 6 and ISO 3382-2.



a) Quiet acoustic music and loud acoustic music for rehearsal use and for recital use (solid lines)



b) Amplified music for rehearsal use (solid lines) and recital use (dashed lines)

#### Key

$f$  centre frequency of octave band, expressed in hertz

$p$  percentage of reverberation time  $T$  relative to the average value of mid-frequency reverberation time  $T_{\text{mid}}$  in %

Figure 2 — Frequency-dependent tolerance limits in percentage relative to average value of mid-frequency reverberation time,  $T_{\text{mid}}$ , at the frequency bands 500 Hz and 1 000 Hz

## EXAMPLE

An example on application of the frequency-dependent tolerance limits in Figure 2a is presented in Table 6. The selected room is a rehearsal room for quiet acoustic music with the volume 1 000 m<sup>3</sup> and the mid-frequency reverberation time  $T_{\text{mid}} = 1,4$  s. The percentages  $p_{\text{min}}$  and  $p_{\text{max}}$  in the table are taken from Figure 2a. The lowest and highest reverberation times in each octave band are shown in the Table 6.

**Table 6 — An example of lowest and highest reverberation times in octave bands from 63 Hz to 4 000 Hz for a rehearsal room for quiet acoustic music when  $T_{\text{mid}} = 1,4$  s**

$f$ Hz	$p_{\text{min}}$ %	$p_{\text{max}}$ %	$T_{\text{min}}$ s	$T_{\text{max}}$ s
63	80	140	1,12	1,96
125	85	120	1,19	1,68
250	90	110	1,26	1,54
500	95	105	1,33	1,47
1 000	95	105	1,33	1,47
2 000	85	105	1,19	1,47
4 000	75	105	1,05	1,47

## 6 Measurement

### 6.1 Reverberation time

Reverberation time shall be determined in accordance with ISO 3382-1 or ISO 3382-2, depending on the room size and use. ISO 3382-1 applies to performance rooms with stage and audience area. ISO 3382-2 applies to all other spaces, including individual practise rooms (3.3) and ensemble rooms (3.4). The main difference between these two methods is position of the sound source and microphone.

ISO 3382-1 defines a series of room acoustic parameters which can be measured in addition to the reverberation time, including sound strength,  $G$ . In ISO 3382-2, there are several degrees of precision for measuring reverberation time with different numbers of measurement positions. For simple checks of reverberation, survey measurement method can be used. For meeting the requirements set out in the architect's plans or which are contractual, the engineering degree of precision in ISO 3382-2 for measuring reverberation time is used.

### 6.2 Background noise level

The background noise shall be measured in octave noise bands and assessed. The A-weighted sound pressure level,  $L_{p,A,T}$  is determined accordingly. The average background noise level of all the measured positions is determined.

Sound level from fixed service equipment in a building can be measured in accordance with ISO 16032[2] and evaluated in relation to limit values for the type of space, unless otherwise required in national criteria. If the noise contains tonal sound, this shall be determined and reported. Background noise levels from outdoor sound sources can be measured by using ISO 1996-2[5] or other relevant standards.

## 7 Information to be recorded and reported

For rooms with variable acoustics, instructions for operation and maintenance shall be incorporated in the general facility management documentation of the building, in the facility management documentation for the technical facilities of the stage or as a separate document. The documentation shall include operating instructions with safety assessments, maintenance routines and supplier information with contact details. Where the operation and setting of acoustic measures are not self-explanatory, a separate user manual shall be prepared and made available to the users.

Reporting of measured reverberation time shall be performed as stated in ISO 3382-1 or ISO 3382-2.

Reporting of measured background noise level can be performed as stated in ISO 16032<sup>[2]</sup>, ISO 1996-2<sup>[5]</sup> or other relevant standards as given in [Clause 6](#).

## Annex A (informative)

### Determination of sound strength and sound power level from musical instruments

#### A.1 General

For musical instruments which are not electrically amplified, the sound pressure level in the space is determined by the following factors:

- the type and number of the musical instruments;
- the style of playing, dynamic expression;
- the net room volume;
- the reverberation time of the room.

The musical instrument may be a string instrument, a woodwind instrument, a brass instrument, percussion, a keyboard instrument or singing. The instruments may be played solo or in small or large ensembles. Electronically amplified music is not relevant in this context.

Musical instruments can be played at different sound power. The most common dynamic designations are pianissimo - piano - mezzoforte - forte - fortissimo (*pp* - *p* - *mf* - *f* - *ff*). Pianissimo specifies that the sound is very quiet but still with timbre; fortissimo is very loud, but without the timbre being distorted. There are also *ppp* (extremely quiet) and *fff* (extremely loud).

The dynamic range from *pp* to *ff* for solo musical instruments is typically around 25 dB to 30 dB, somewhat less for the flute and the oboe, somewhat more for the clarinet and the horn. An orchestra may have a dynamic range between 50 dB and 60 dB. This dynamic range also depends on the musician's proficiency. Novices do not master as great a dynamic range as experienced for professional musicians. To characterise the sound level using a single figure, in the following, the sound level at forte (*f*) is used, i.e. when played consistently loud. The typical sound power level at forte for a range of different musical instruments is given in [Table A.1](#). The sound power levels are the time-averaged energy equivalent levels without frequency-weighting.

Sound strength specifies how many decibels the sound level in a space is above the sound level which a given sound source would produce outdoors at a distance of 10 m. This assumes a sound source which emits the sound evenly in all directions. "Outdoors" in this context means a free sound field without sound reflections. Sound strength depends on the net volume and reverberation time of the room, see [Figure A.1](#). The plotted curves for sound strength show that different combinations of net volume and reverberation time will produce the same sound level for a given ensemble.

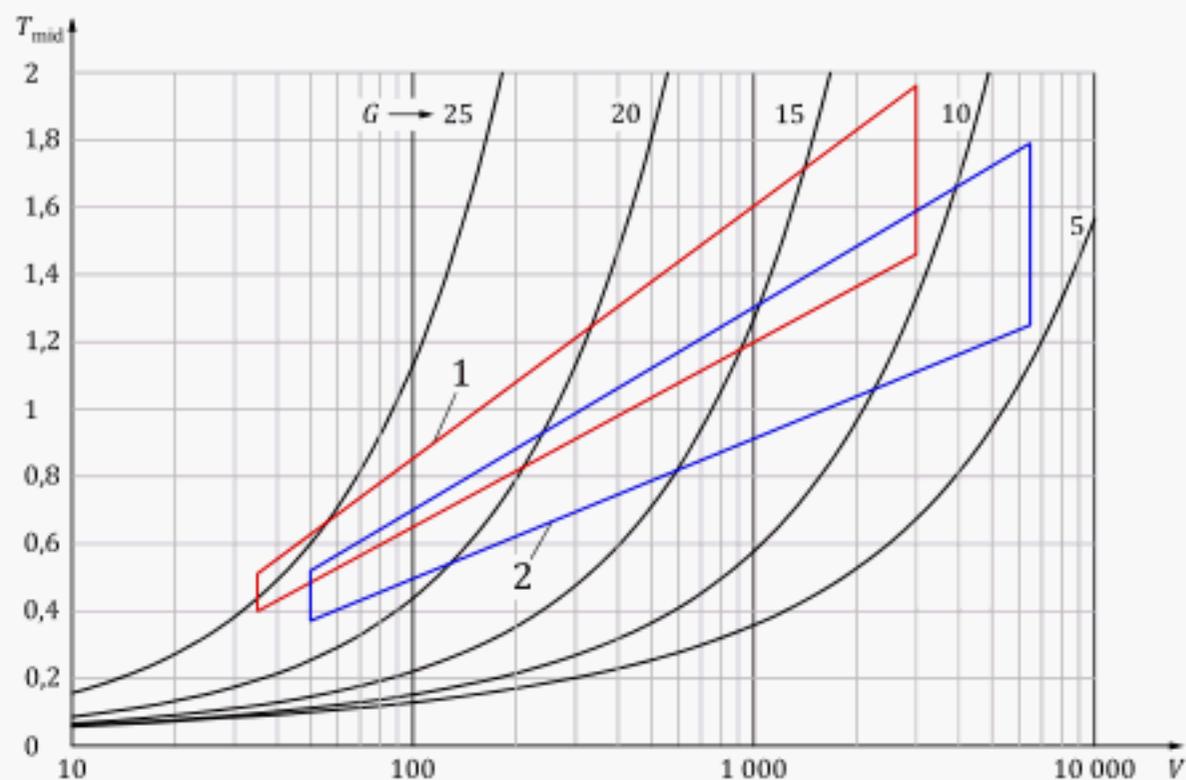
In a music room which is well suited to a given ensemble, the sound level at forte in the audience area lies within a relatively narrow range between 85 dB and 90 dB, or possibly a little higher for very loud ensembles such as concert bands and brass bands. If the sound level at forte is higher than 90 dB, this means that the sound level at fortissimo will exceed 100 dB, which may entail a risk of hearing damage. If the sound level at forte is lower than 85 dB, this means that the music loses intensity and is perceived as distant, especially in quiet passages where the details disappear. It is therefore important for the room to have sound strength that is adapted to the instrument types and ensemble size<sup>[19]</sup>.

The net volume of a large ensemble room for loud acoustic music is decisive for the sound pressure level which musicians and conductors are exposed to. For realistic room sizes, one can expect sound pressure levels at forte of up to 97 dB in rehearsal rooms for large loud acoustic ensembles.

Figure A.1 shows how the reverberation time may be adapted to the type of music and room size. If the reverberation time is too long, the sound becomes thick and unclear. However, if the reverberation time is too short, the music becomes dry, and the tones lose some of their timbre and brilliance. This is most significant for vocals, woodwind instruments and brass instruments, while it is less of a problem for piano and string instruments which have a built-in sound board.

If the room is too small and has too long a reverberation time, the sound will be too powerful, and the sound can become unpleasant or damaging to the hearing. If the room is too large and has too short a reverberation time, the sound will be too quiet. In the first case, an experienced musician can compensate to a certain degree by playing quieter than normal, but this compromises the dynamic range and musical expression. In the second case, most musicians will try to compensate by playing louder than normal, but when a musical instrument is pushed into producing more sound, this compromises the timbre which becomes sharp and coarse. Novices and less practised musicians will be less able to compensate for unsuitable acoustics.

For small, individual practise rooms, it is useful to assess effective reduction of sound level more than just shortening the reverberation. For a sound source at constant power, the sound level will typically be reduced by 4 dB to 5 dB when an individual practise room is damped from "medium damped" to "strongly damped"<sup>[17]</sup>. During practical exercise, the musicians will compensate somewhat in a damped room so that in practise the reduction will be 2 dB to 3 dB even if the musicians keep to the stated sound power. In such (too) small rooms, it can be useful to focus on damping room resonances and damping trebles (2 kHz to 4 kHz) in order to reduce "shrillness" in high frequency brass instruments, instead of a pure reverberation assessment.



**Key**

$V$  volume, expressed in cubic metre

$T_{mid}$  average of mid-frequency reverberation time, expressed in seconds

$G$  sound strength in dB in 5 dB steps

1 upper and lower limit for quiet acoustic music in rehearsal rooms

2 upper and lower limit for loud acoustic music in rehearsal rooms

The lines show upper and lower limits for reverberation time in rehearsal rooms for quiet acoustic music and loud acoustic music.

**Figure A.1 — Sound strength,  $G$ , as a function of net volume and average of mid-frequency reverberation time**

**Table A.1 — Sound power level and sound power  $P$  for different musical instruments according to References [13], [14] and [15]**

Instrument	Sound power level dB re 1 pW	Reference	Sound power $P$ mW
Violin	89	[13]	0,8
Viola	87	[13]	0,5
Cello	90	[13]	1,0
Double bass, arco	92	[13]	1,6
Double bass, pizzicato	85	[15]	0,3
Recorder, soprano	92	[15]	1,6
Recorder, alto, tenor	91	[15]	1,3
Piccolo	95	[15]	3,2
Flute	91	[13]	1,3
Oboe	93	[13]	2,0
Clarinet	93	[13]	2,0
Bass clarinet	92	[15]	1,6
Saxophone	98	[14]	6,3
Bassoon	93	[13]	2,0
French horn	102	[13]	15,8
Cornet	101	—	12,6
Trumpet	101	[13]	12,6
Trombone	104	[15]	25,1
Bass trombone	105	[15]	31,6
Flugelhorn	100	—	10,0
Tenor horn (Althorn)	100	—	10,0
Euphonium	105	[15]	31,6
Tuba	104	[13]	25,1
Timpani	101	[14]	12,6
Bass drum	102	[14]	15,8
Snare drum	101	[14]	12,6
Cymbals	98	[14]	6,3
Triangle	85	[15]	0,3
Xylophone	89	[15]	0,8
Harp	92	[15]	1,6
Guitar, acoustic	86	[14]	0,4
Concert grand piano	93	[15]	2,0
Organ	102	[14]	15,8
Singer, adult	96	[13]	4,0
Singer, boy	88	[13]	0,6
Singer, soprano	97	[15]	5,0
Singer, alto	93	[15]	2,0
Singer, tenor	95	[15]	3,2
Singer, bass	96	[15]	4,0

## A.2 Calculation of sound levels in the room

When calculating sound levels from an ensemble, the number and type of instruments are first determined. Data for different instruments are given in [Table A.1](#). If more recent data are available than those in [Table A.1](#), these can be used instead.

The sound strength,  $G$ , of the space is then determined based on net volume and reverberation time by using [Figure A.1](#). The sound level of the ensemble at forte in the room is calculated from the [Formula \(A.1\)](#):

$$L_p = G + 59 + 10 \lg \frac{\sum n_i P_i}{\text{mW}} \quad (\text{dB}) \quad (\text{A.1})$$

where

$G$  is the sound strength;

$n_i$  is the number of instruments of type  $i$ ;

$P_i$  is the sound power for an instrument type  $i$ .

### EXAMPLE 1

In assessing the suitability of a space for a string quartet (2 violins, 1 viola, 1 cello), the sound power is calculated from [Formula \(A.2\)](#):

$$\sum (n_i P_i) = (2 \times 0,8 + 0,5 + 1,0) \text{ mW} = 3,1 \text{ mW} \quad (\text{A.2})$$

The space has a net volume  $V = 100 \text{ m}^3$ , reverberation time  $T_{\text{mid}} = 0,8 \text{ s}$  and sound strength  $G = 23 \text{ dB}$ .

Inserting the figures into the [Formula \(A.1\)](#), the sound level is then:

$$L_p = 23 + 59 + 10 \lg 3,1 = 87 \text{ dB} \quad (\text{A.3})$$

### Assessment:

The sound level at forte is in the range 85 dB to 90 dB. The sound strength of the space can therefore be considered suitable for this ensemble.

### EXAMPLE 2

In assessing the suitability of a space for a children's choir of 24 voices, the sound power is calculated from [Formula \(A.4\)](#):

$$\sum (n_i P_i) = (24 \times 0,6) \text{ mW} = 14,6 \text{ mW} \quad (\text{A.4})$$

In order to achieve a sound level at forte of at least 85 dB, the sound strength,  $G$ , of the space should be at least:

$$G = L_p - 59 - 10 \lg \frac{\sum n_i P_i}{\text{mW}} = 85 - 59 - 10 \lg 14,6 = 14 \text{ dB} \quad (\text{A.5})$$

### Assessment:

The reverberation time should be around the upper limit for quiet acoustic music. From the upper curve in [Figure A.1](#), net volume  $V = 2\,000 \text{ m}^3$  and reverberation time  $T_{\text{mid}} = 1,8 \text{ s}$  are found.

Smaller spaces may also be suitable but not less than  $V = 400 \text{ m}^3$ , with a corresponding reverberation time  $T_{\text{mid}} = 1,3 \text{ s}$ . This space will have sound strength  $G = 19 \text{ dB}$ , and the choir will then produce a sound level at forte of 90 dB.

## EXAMPLE 3

A concert band of approximately 40 persons rehearses in a gymnasium of 1 200 m<sup>3</sup> where the reverberation time  $T_{\text{mid}} = 1,4$  s. Sound strength  $G = 15$  dB is read from the [Figure A.1](#).

The band comprises 4 flutes, 9 clarinets, 1 bass clarinet, 4 saxophones, 4 cornets/trumpets, 3 French horns, 4 trombones, 2 euphoniums, 3 tubas, 4 percussion. Calculated sound power from [Formula \(A.2\)](#):

$$\sum (n_i P_i) = (4 \times 1,3 + 9 \times 2,0 + 6,3 + 4 \times 6,3 + 4 \times 12,6 + 3 \times 15,8 + 4 \times 25,1 + 2 \times 31,6 + 3 \times 25,1 + 4 \times 12,6) \text{ mW} = 442 \text{ mW} \quad (\text{A.6})$$

Inserting the figures into [Formula \(A.1\)](#), the sound level is then:

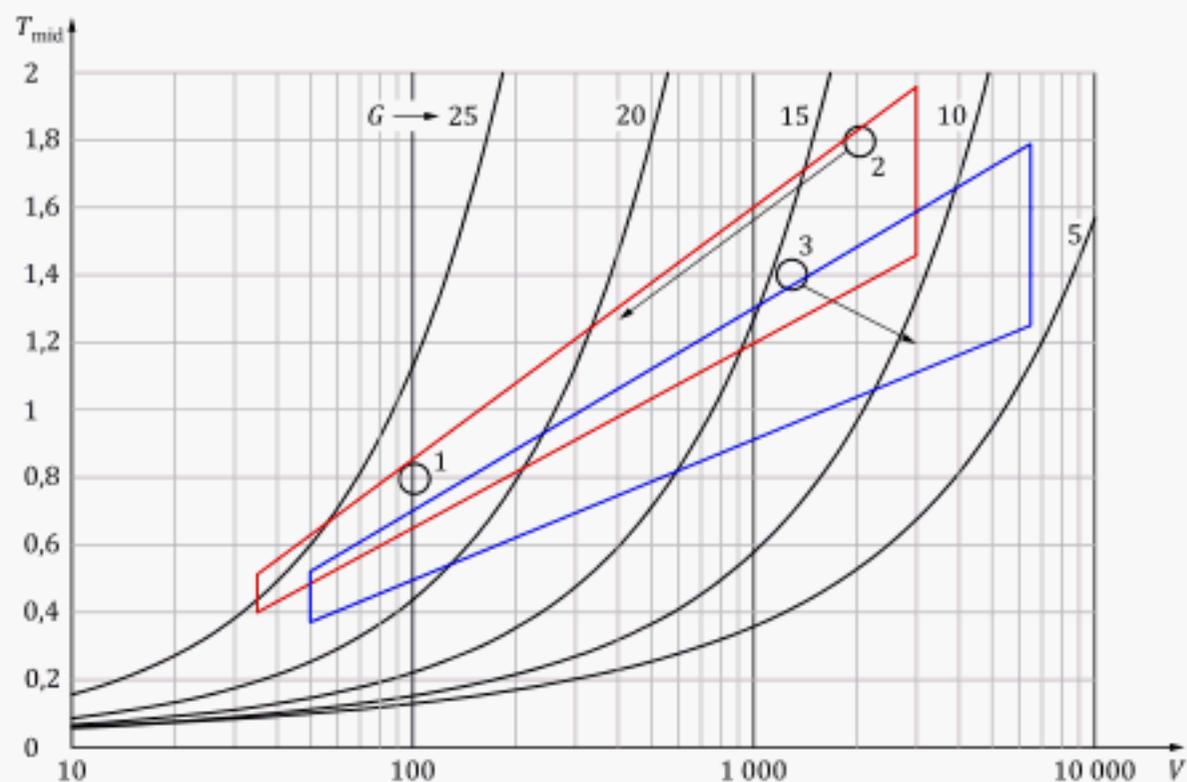
$$L_p = 15 + 59 + 10 \lg 442 = 100 \text{ dB} \quad (\text{A.7})$$

Assessment:

The sound level at forte is 100 dB, which is very high and there is a risk for hearing damage. The space is both too small and has too long a reverberation time to be suitable as a rehearsal room for this concert band.

Spaces of 3 000 m<sup>3</sup> with a reverberation time  $T_{\text{mid}} = 1,2$  s would give a sound level at forte of 95 dB and would therefore be considerably better suited as a rehearsal room for this concert band.

[Figure A.2](#) shows how the examples 1, 2 and 3 are placed in relation to the diagram in [Figure A.1](#). The result of the calculation is shown as a circle (e.g. circles 1, 2 and 3 individually represent the result for the Examples 1, 2 and 3) in the figure and the direction of the arrows indicates the desired change of range (for Example 2 and 3).



**Key**

$V$  volume, expressed in cubic metre

$T_{mid}$  average of mid-frequency reverberation time, expressed in seconds

$G$  sound strength in dB at 5 dB steps

1 example 1

2 example 2

3 example 3

The lines show upper and lower limits for mid-frequency reverberation time in rehearsal rooms for quiet acoustic music and loud acoustic music.

**Figure A.2 — Three examples plotted in the diagram from Figure A.1**

## Annex B (informative)

### Guidelines for planning rooms and spaces for music rehearsal

#### B.1 General planning

When planning spaces to be used for musical purposes (rehearsal or recital), it is important to clarify their prioritised use as a first step in the process. Clarification and prioritisation will, in the first instance, entail a selection of music types and activity, as described in [Clauses 4](#) and [5](#). It is important that this is done before the floor space plan is defined, since the same room cannot provide satisfactory conditions for all applications. Acoustic criteria for a music room will be dimensioning for e.g. storey height.

For multi-purpose rooms, it is important that prioritisation of the different applications and the different users' needs for acoustic conditions is done. This forms the basis for preparing a plan for the desired acoustic conditions in the spaces. The most important dimensions for the spaces are included in the plan and are used as the basis for the design of the room and of the acoustic requirements.

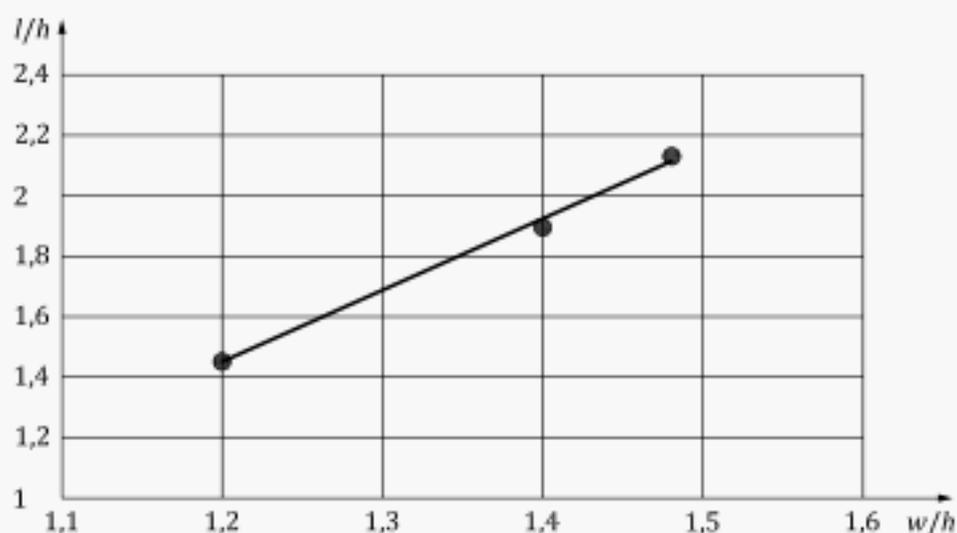
In order to achieve a good result, it is necessary that prioritisation is performed in close cooperation with relevant user groups. For all such projects, the earliest possible involvement of users in the planning is important, see for example References [\[16\]](#) and [\[17\]](#). It is necessary that personnel with experience of room acoustical design and project planning of spaces for music are connected with the project as early as possible.

#### B.2 Optimum dimension ratios in rooms

##### B.2.1 Small rehearsal rooms

In small rehearsal rooms (below 300 m<sup>3</sup>) the number of room modes is sparse at low frequencies. In order to achieve a smooth frequency response in the bass range (20 Hz to 200 Hz) it is important to have a favourable proportion between room dimensions. Dimension ratios close to 1:1:1 (a cubic room) are clearly unfavourable.

Optimum dimension ratios can be derived based on a criterion for smoothness of the transfer function in the frequency range 20 Hz to 200 Hz<sup>[20]</sup>. The optimum dimension ratios in a rectangular room depend to some extent on the volume and the absorption properties of the surfaces. For a wide range of room volumes up to 300 m<sup>3</sup> the dimension ratios 1:1,2:1,44 and 1:1,4:1,89 and 1:1,48:2,12 produce very smooth transfer functions<sup>[21]</sup>. These dimension ratios are shown in [Figure B.1](#).



**Key**

$w/h$  room width divided by room height

$l/h$  room length divided by room height

The line is the linear regression line.

**Figure B.1 — Optimum dimension ratios for net volumes up to 300 m<sup>3</sup>, data from Reference [21]**

The optima are not very sharp, and minor deviations from the optimum in actual room dimensions are normally acceptable. Thus, other dimension ratios close to the regression line in Figure B.1 can be considered as nearly optimum. This means that a range of nearly optimum dimension ratios can be applied instead of a few fixed dimension ratios. This is convenient for practical use when there are constraints on room height and volume. For example, the often-recommended dimension ratio 1:1,25:1,60 is close to this line and may be considered as nearly optimum. The formula for the regression line in Figure B.1 is:

$$l/h = 2,36 \times \frac{w}{h} - 1,38 \quad (\text{B.1})$$

where

$l$  is the room length;

$w$  is the room width;

$h$  is the room height.

The ratio  $w/h$  in Formula (B.1) is restricted to the range 1,2 to 1,6.

In rooms with slightly angled, non-parallel surfaces, the average room dimensions are applied.

In general, the height should be the smallest of the room dimensions, and the length-to-width ratio should preferably be in the interval  $1,15 < l/w < 1,45$ . The  $l/w$  ratio should not exceed 1,6<sup>[21]</sup>.

### B.2.2 Medium and large rehearsal rooms

In medium size and large rehearsal rooms (above 300 m<sup>3</sup>) the number of room modes is much higher than in smaller rooms, and the ratio of room dimensions is not so important. However, very oblong rooms are avoided, i.e. the maximum  $l/w$  ratio of 1,6 is relevant also for large rooms.

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