WHO Global standard for safe listening venues & events

World Health Organization

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Executive summary

WHO estimates that over one billion young people globally are at risk of hearing loss due to sound exposure in recreational settings. The risk of permanent hearing injury due to unsafe listening[1] is both avoidable, and costly.

In the face of this growing threat, governments, public-health agencies, those involved in the creation, distribution and amplification of music, the private sector, civil society, and other stakeholders, all have a duty of care in understanding the sound levels to which audiences and consumers are being exposed, and creating environments that facilitate safe listening behaviours.

To address this, WHO, as part of their Make Listening Safe initiative, developed the Global standard for safe listening venues and events ("the Standard") which provides a common understanding of safe listening in entertainment venues and events. The Standard comprises six "features" which, when implemented, allow audience members around the world to enjoy amplified music with protection of their hearing, while also preserving the integrity of the artistic experience:

Feature 1: Sound level limit:[2] below 100 dB $L_{Aeq,\ 15\ min}$

An upper limit of 100 dB $L_{Aeq,\ 15\ min}$ is imposed, keeping sound safe and enjoyable for the audience.

Feature 2: Sound level monitoring

Live monitoring of sound levels is performed by a designated staff member using calibrated equipment.

1 "Unsafe listening" refers to the common practices of listening to music or other audio content at high levels or for prolonged time periods.

2 Informed by the WHO Environmental Noise Guidelines for the European Region and WHO-ITU Global standard for safe listening personal audio systems.

Feature 3: Venue acoustics and sound systems

Sound system and venue acoustics are optimized ensuring safe listening and improved sound quality.

Feature 4: Personal hearing protection

Hearing protection, such as earplugs, with appropriate instructions, are available to audience members.

Feature 5: Quiet zones

Designated quiet spaces are available, allowing audience members to rest their ears and thereby decrease the risk of hearing damage.

Feature 6: Appropriate training and information

Both audience members and staff are made aware of practical steps they can take to ensure safe listening.

The recommendations within the Global standard for safe listening venues and events can be implemented by:

- **Governments:** through development of legislation or regulation by appropriate government departments, followed by compliance monitoring and public awareness campaigns. Hearing loss is a growing public health issue and its prevention will both improve quality of life and yield productivity gains.
- **Owners/Managers of venues and events:** some or all of the features can be adopted voluntarily. Protecting the hearing of patrons and improving their listening experience makes sound business sense for an industry reliant on customers' hearing ability.
- **Acousticians/Engineers/Musicians/Event Organizers and others:** The need for this Standard, its benefits and features, can be formally taught to those involved in the creation of music and the running of entertainment venues or events. Limiting the risk of hearing damage will not only benefit audiences, but also those working in these environments.

Introduction

Listening to music using headphones or earphones, and attending venues or events that feature amplified music, are recreational activities enjoyed by millions of people every day. However, listening to music at high sound levels involves both pleasure and risks.

There is growing concern about the rising exposure to high sound levels in recreational settings, as regular participation in such activities poses the threat of irreversible hearing loss *(1–10)*.

WHO estimates that over 1 billion young people around the world are exposed to an avoidable risk of hearing injury due to sound exposure in recreational settings (see Box 1). In the face of this growing threat, governments, public-health agencies, those involved in the creation, distribution and amplification of music, manufacturers of equipment and audio devices, civil society, and other stakeholders, have a duty of care to understand the sound levels to which audiences and consumers are being exposed, and to create an environment that facilitates safe listening behaviours.

Box 1:

WHO estimates of risk due to unsafe listening practices

WHO estimates reveal that *(10)*:

- More than 430 million people (5% of the global population) live with disabling hearing loss resulting from a range of causes. This number is projected to increase substantially in the next decades unless action is taken to mitigate the risk factors for hearing loss.
- 1.1 billion young people worldwide could be at risk of hearing loss as a result of unsafe listening practices.
- Among teenagers and young adults aged 12–35 years in middle- and high-income countries:
  - nearly 40% are exposed to potentially damaging sound levels in recreational venues such as nightclubs, discotheques, and bars.
  - nearly 50% face the risk of hearing loss due to listening at high volumes or for prolonged time periods over their personal audio systems.

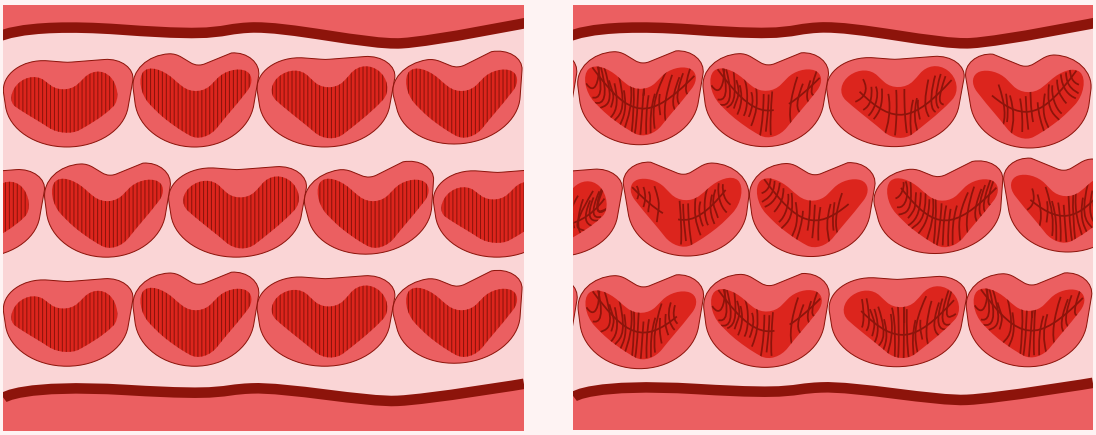
To address the threat posed by unsafe listening, WHO launched the Make Listening Safe initiative[3] in 2015. The overall vision of the initiative is a world in which people of all ages enjoy listening with protection of their hearing; the aim is to reduce the risk of hearing loss posed by unsafe exposure to high sound levels in recreational settings. As part of this initiative, in 2019, WHO and the International Telecommunication Union launched the WHO-ITU Global standard for safe listening with personal audio devices and systems. The present standard, the Global standard for safe listening venues and events, was developed by WHO to address the risk of hearing loss due to amplified music in venues and at events, such as nightclubs, discotheques, bars, concerts, and festivals.

How excessive sound exposure affects hearing

Repeated exposure to sound at high levels, for long durations, permanently injures the delicate workings of the inner ear (as illustrated in Figure 1). The most vulnerable parts of the ear include the cochlear outer hair cells, which make faint sounds audible by amplifying the ear's response to them, and the synaptic connections between inner hair cells and the auditory nerve fibers which carry sound information to the brain *(11)*.

3 WHO's Make Listening Safe Initiative. 2015. See: https://www.who.int/activities/making-listening-safe.

Figure 1:
Damage to sensory cells in the ear from repeated exposure to high sound levels.



Normal sensory cells

Damaged sensory cells

Injuries to the inner ear result in a variety of symptoms, which, if unaddressed, can significantly worsen a person's quality of life and have long-term consequences for their mental health and well-being. Over-exposure to sound may result in hearing loss, tinnitus (ringing or humming in the ears), or both. Hearing loss due to excessive sound exposure may range from mild to profound *(12)*, and lead to:

- difficulty understanding speech, especially in background noise.
- degraded hearing quality, e.g. distortion of sounds, lack of clarity.
- difficulty telling sounds apart, such as the different instruments in a mix.

Any type of sound can cause permanent hearing loss if listened to at a sufficiently high level and length of time. Although this is usually referred to as noise-induced hearing loss, it can occur from listening to deeply enjoyable music as much as it can from exposure to industrial noise (hence the commonly used alternatives, "sound-induced hearing loss" or "music-induced hearing loss"). Indeed, many musicians and other people working in the music industry have suffered career-ending hearing injury due to over-exposure to high sound levels *(13)*.

Symptoms may appear short-lived, for example, a temporary hearing loss or tinnitus that resolves in a matter of hours or days. However, even when short-term symptoms fully resolve, progressive and irreversible injury to the inner ear may continue for months afterwards *(14)*. Evidence also suggests that over-exposed ears age more quickly than non-exposed ears *(15–17)*.

Pure-tone audiometry – the current gold-standard test used to assess hearing by doctors and audiologists – is sensitive to some, but not all, forms of injury that over-exposure to high sound levels inflicts on the ear *(18, 19)*. At times, the hearing loss caused by over exposure to high sound levels may remain undetectable by routine audiometric tests, resulting in a "hidden hearing loss" *(20, 21)*. It is likely that many people struggle with hidden hearing loss; in younger age groups it may occur due to exposure to high sound levels in recreational settings *(22)*.

Hearing loss caused by exposure to high sound levels is mostly irreversible. Although people with such hearing loss may benefit from hearing aids or cochlear implants, there is currently no cure for this condition. Since lifestyle-induced hearing loss adds to the significant natural decline in hearing function due to ageing *(16)*, it is critical for individuals to preserve their hearing by caring for their ears.

Hearing loss prevention through safe listening

"Safe listening" refers to a set of practices and behaviours that promote the enjoyment of amplified music while reducing the risk of permanent hearing injury. Adopting safe listening practices at venues and events supports audience members to continue enjoying music into the future.

The risk to hearing is dictated by a combination of sound level and cumulative duration of exposure (see Box 2). In the recreational context, listening can be made safer by:

i) reducing the sound level; and/or

ii) reducing the duration of exposure; and/or

iii) reducing the frequency of exposure (i.e. being exposed less often).

Box 2:

The equal energy principle

The equal energy principle *(23, 24)* states that the total effect of sound is proportional to the total amount of sound energy received by the ear, irrespective of the distribution of that energy over time – i.e. equal amounts of sound energy are expected to cause equal amounts of hearing loss, regardless of how and when the exposure occurs. The amount of energy doubles for every 3 dB increase in sound intensity. Hence, a person may receive the same "sound dose" listening to music at 80 dB for 8 hours a day as listening to 100 dB for 5 minutes.

Simple steps that individuals can take to reduce their personal sound exposure include using hearing protection (earplugs), and periodically seeking a quieter space to allow the ears to rest. Several of the safe listening features in this Standard aim to make these options more accessible to audience members.

To achieve a more widespread reduction in risk, it is necessary to control, and in some cases reduce, sound levels at venues and events. The effective control of sound levels requires buy-in from stakeholders at all levels. This includes the development and implementation of evidence-based policies and regulations on the part of governments, the adoption of sound-control measures by venue operators and events professionals, and the cooperation and education of performers, technicians, and sound engineers.

Current status of safe listening policies and regulations for entertainment venues and events

While many countries have introduced legislation to protect the hearing of employees in the workplace, to date, relatively few have made provision to protect the hearing of audiences in entertainment venues *(25, 26)*. In 2018, 18 jurisdictions (referring to countries or specific regions within a country) around the world were found to have regulations, policies, or legislation to prevent hearing loss due to sound exposure in entertainment venues.

The most detailed and comprehensive examples of policies and regulations designed to protect the hearing of patrons and audience members are found in European nations (including Austria, Belgium, Czechia, France, Germany, Italy, Netherlands, Norway, Sweden, and Switzerland), although more limited requirements also apply in some regions of North and South America. Features commonly reflected in the available regulations include:

- an upper sound level limit
- a requirement for real-time sound level monitoring
- provision of earplugs
- provision of rest (quiet) zones
- provision of information/warnings.

The specific requirements vary between countries, with a lack of standardization across the world. To address this gap, WHO has worked with stakeholders in the field to create a global standard of uniform, evidence-based recommendations.

Purpose and scope of the Global standard for safe listening venues and events

The purpose of this Standard is to provide a common understanding of safe listening features for entertainment venues and events. These features are designed to allow audience members worldwide to enjoy amplified music with protection of their hearing, while also preserving the integrity of the artistic experience.

This Standard applies to all recreational venues and events at which enjoyment of amplified music is a central purpose of attendance, from large multiday festivals to small innercity bars and clubs (see Annex 1 for the full range of venues covered). While each venue or event poses different challenges and may demand unique solutions, the same principles, and the safe listening features of this Standard, are intended to apply to all types of venues and events.

This Standard is designed to protect the hearing of audience members attending venues and events for recreational purposes only. Staff and other people attending in a professional capacity are not covered, and should be afforded protection under occupational noise regulations. Likewise, the Standard does not address issues of noise annoyance to neighbouring properties: these issues are dealt with separately through environmental noise regulations and planning policy. Nevertheless, the effective control of sound levels within a venue or event may partially ameliorate noise complaints from neighbours.

It is important to note that the proposed safe listening features in this Standard are designed to reduce to an acceptable level the risk of sound-induced hearing injury. Eliminating all risk entirely could be achieved only through imposing a sound level limit which would be unacceptably low for both audiences and performers, and unfeasible to implement in most live-music contexts *(27)*. Individuals who frequently attend venues or events involving amplified music, or who have a pre-existing vulnerability, should take additional precautions to protect their hearing.

Development of the Global standard for safe listening venues and events

The Global standard for safe listening venues and events was developed through a collaborative process led by WHO with participation of diverse stakeholder groups, including musicians, venue operators, event organizers, professional bodies, consumer groups, international standards bodies, government agencies, and nongovernmental organizations. Inputs were received from experts in the fields of audiology, otology, public health, epidemiology, acoustics, and sound engineering.

The central feature of this Standard concerns the application of a sound level limit applied to the context of entertainment venues and events and is based on the WHO environmental noise guidelines for the European region *(23)* (see Annex 2). The remaining supportive features were informed by expert opinion and the following:

i) a review of existing evidence from the scientific literature;

ii) consultation and in-depth interviews with professionals from across the music industry;

iii) an online survey exploring the attitudes of people who attend music venues and events, delivered in English, French, Chinese, Russian, and Spanish; and

iv) open information sessions, consultations, and calls for contribution from partners including case studies and examples.

Implementation of the Global standard for safe listening venues and events

This Standard serves as a framework that can be used by governments as the basis for developing their own guidelines, regulations, and funding models for safe listening, taking into consideration local conditions, culture, and legislative approach and reflecting the viewpoints of local stakeholders. The safe listening features outlined can also be voluntarily adopted and applied by venue operators, event organizers, and music-makers wishing to follow best practice and protect the hearing of their audiences. All stakeholders including regulatory bodies, venue owners, music-makers and civil society should be partners in this effort that aims to reduce the risk of hearing loss in the population. Further insights regarding implementation are addressed in the section: “Adoption and implementation of the WHO Global standard for safe listening venues and events”.

Definitions of terms used in the safe listening features

Assumed protection value:
The attenuation in decibels (dB) expected to be achieved in a particular octave band by a particular make and model of **personal hearing protection** by at least 84% of individuals.

Audience:
One or more **audience members** collectively.

Audience area:
All locations in a **venue** or at an **event** that could reasonably be expected to be occupied by an **audience member**.

Audience member:
A person attending a **venue** or **event** for recreational purposes.

A-weighting:
Frequency weighting function used to measure **sound levels** when the purpose is to assess the risk of hearing injury; emphasizes mid frequencies and mimics the sensitivity of human hearing to sounds at low-to-moderate sound pressure levels (SPL).

Backline:
Amplifiers and loudspeaker enclosures placed behind the band on stage; typically the musicians' own equipment used to amplify electric guitars, bass guitars, or keyboards.

Bass shaker:
A tactile transducer that is typically attached to a drummer's stool to allow them to monitor their kick/bass drum through low-frequency bodily transmitted vibration, negating the need for a **subwoofer monitor loudspeaker/drum fill**.

Calibrator:
A compact device that generates a tone at a known frequency and sound pressure level (usually a 1000 Hz tone at either 94 dB SPL or 114 dB SPL) – the calibrator is placed over the microphone of the **sound level measurement system** to verify that sound levels are being measured accurately and to allow the sensitivity to be adjusted if necessary.

Core audience area:
The primary area in a **venue** or at an **event** that would ordinarily be occupied by **audience members** actively listening to the music (e.g. the area in front of the stage or the main dancefloor); the core audience area extends from the front row to the rear of the area ordinarily occupied by audience members (or, for venues with a balcony, from the front row to the front edge of the balcony).

Correction:
The value, or values (where frequency-band-specific correction is performed) to be added to the **sound level** measured at the **long-term measurement position** to estimate the corresponding **sound level** at the **reference measurement position**.

C-weighting:
Frequency weighting function that weights frequencies relatively evenly across most of the audio bandwidth (20 Hz to 20 kHz); mimics the sensitivity of human hearing to sounds at high sound pressure levels.

Decibel (dB):
A relative unit used to measure the intensity of a sound by comparing it with a reference value on a logarithmic scale; many different types of acoustical measurement are expressed in decibels.

Delay-fill:
One or more secondary **loudspeakers** used to support the delivery of sound to the rear of an **audience area** when the **main loudspeakers** are unable to adequately cover this area; the signal to the delay-fill loudspeaker(s) is electronically or digitally delayed so that sound arrives in synchrony with, or slightly later than, sound from the **main loudspeakers**.

Drum-fill:
A **side-fill monitor loudspeaker** that is used to help a drummer hear the other musicians over the (typically very intense) acoustic sound of the drum kit.

Effective sound level limit:
A corrected **sound level limit** that accounts for a difference in **sound level** between the **long-term measurement position** and the **reference measurement position**.

Equal energy principle:
The assumption that the total effect of sound on hearing is proportional to the total amount of sound energy received by the ear, irrespective of the distribution of that energy over time.

Event:
An occasion on which an **audience** attends a **venue** or other site at which enjoyment of amplified music is a central purpose of attendance.

Floor monitor:
A type of **monitor loudspeaker** with an angled back which, when positioned on the stage floor, allows sound to be projected upwards towards the performers' ears; often referred to as a "monitor wedge".

Front-fill:
One or more secondary **loudspeakers**, usually positioned on the front edge of the stage and used to support the delivery of sound to the front rows of the **audience**.

Front of house (FOH):
The location at a **venue** or **event** from which the **sound engineer** mixes a performance.

Hidden hearing loss (HHL):
Neural degeneration in the inner ear that is not revealed by standard tests of hearing threshold sensitivity and yet which may cause difficulties in areas such as speech understanding in noise, **tinnitus**, and **hyperacusis**.

Hyperacusis:
An increased sensitivity to sound that makes everyday sounds seem much louder than they should, sometimes resulting in pain or discomfort.

In-ear monitoring (IEM):
An alternative to the use of **monitor loudspeakers** in which each performer hears a personalized monitor mix through an insert earphone.

Limiter:
An electronic device that prevents the amplitude of a signal from exceeding a predetermined value by attenuating peaks above a certain threshold; used as a safety device to prevent a **sound system** from generating dangerously high **peak sound levels**.

Line array:
A **loudspeaker** system comprising several individual loudspeaker elements mounted in a (usually vertical) line; typically used as the **main loudspeakers** at mid-to-large-sized **venues** and **events** to help distribute sound uniformly across the **audience area**.

Long-term measurement position:
The position at a **venue** or **event** where the measurement microphone (a component of the **sound level measurement system**) is placed during ongoing monitoring of sound levels.

Loudspeaker:
A component of the **sound system** that is responsible for converting an electrical signal into acoustic (sound) energy.

Main loudspeakers:
The **loudspeaker(s)** responsible for delivering broadband sound to a majority of the **audience**.

Monitor engineer:
A sound engineer whose focus is on operating the monitoring system that allows performers to hear themselves and one another clearly on stage.

Monitor loudspeaker:
A **loudspeaker** positioned on stage and facing the performer(s) to allow them to hear their own performance.

Monitor wedge:
Synonymous with **floor monitor**.

Noise-induced hearing loss:
Hearing loss occurring due to exposure to high sound levels. Such exposure may take place in recreational environments or occupational settings. The term encompasses music-induced and general sound-induced hearing loss.

Out-fill:
One or more secondary **loudspeakers**, used to support the delivery of sound to the outer edges of the **audience area** when the **main loudspeakers** cannot adequately cover these areas.

Patron:
Synonymous with **audience member**.

Peak sound level
The peak instantaneous C-weighted sound level without any time weighting or averaging (L_{Cpeak}); a measure of the highest sound levels that occur during sudden transients in the music.

Personal hearing protection:
Devices such as earplugs worn by an individual to reduce their personal **sound exposure**.

Point-source loudspeaker:
A single **loudspeaker** unit (usually containing multiple drivers to handle different parts of the frequency spectrum) that radiates sound in an approximately spherical pattern; typical of the type of public-address loudspeaker commonly used at smaller **venues** and **events**.

Public address (PA) system:
Synonymous with **sound system**.

Quiet zone:
An area at a **venue** or **event** in which sound levels are purposefully kept lower—i.e. a place where **audience members** can rest their ears.

Reference measurement position:
A pre-identified position at a venue or event, at which compliance with the **sound level limit** is to be assessed.

Responsible party:
The person or organization having ultimate responsibility for ensuring that safe listening features are adequately implemented and that the **sound level limit** is not exceeded at a **venue** or **event**.

Responsible actor:
A person having the authority and means to adjust the sound level at a **venue** or **event**.

Reverberation:
The multitude of reflections that occur as sound repeatedly bounces off the surfaces of a room, causing sounds to persist for up to a few seconds after the sound has ceased at its source.

Reverberation time (RT60):
A property of a room describing the time it takes for sound energy to decay by a set amount (60 dB); sometimes RT60 is measured by timing the decay over a smaller range and multiplying that time by an appropriate factor (e.g. measuring the time taken for the energy to decay by 30 dB, and multiplying by a factor of 2, gives a measure known as T30).

Room mode:
One of several low-frequency resonances that exists within a room when it is excited by a sound source. This results from coherent interference between wavefronts bouncing back and forth between a room's surfaces and can give rise to an uneven bass response in smaller venues.

Safe listening event:
An event that adopts and promotes safe listening practices by implementing the features described in this Standard.

Safe listening policy:
A written policy prepared by or on behalf of the **responsible party** setting out the measures to be taken to ensure safe listening conditions at a **venue** or **event**.

Safe listening venue:
A **venue** that adopts and promotes safe listening practices by implementing the features described in this Standard.

Side-fill:
A type of **monitor loudspeaker** that sits upright on the side of the stage and is used to deliver sound to performers who are not within range of a **floor monitor**.

Sound absorber:
An object, material, or surface finish that provides **sound absorption**.

Sound absorption:
The removal of sound energy from the air as sound impinges on an object or surface and is partially dissipated through an imperceptible increase in heat.

Sound diffuser:
An object, material, or surface finish that provides **sound diffusion**.

Sound diffusion:
The spreading of sound energy in many directions as sound reflects off a convex or irregular surface.

Sound dose:
A measure of cumulative **sound exposure**, often expressed as a percentage of a reference exposure.

Sound engineer:
The person responsible for manipulating the sound delivered through the **sound system** to achieve a mix perceived as balanced and enjoyable by the **audience** – often, though not necessarily, also the **responsible actor**.

Sound exposure:
The cumulative sound energy that an **audience member** receives over the course of one or more visits to a **venue** or **event**.

Sound level:
The A-weighted equivalent continuous (time-averaged) sound level measured with an averaging time interval of 15 minutes ($L_{Aeq,\ 15\ min}$).

Sound levels:
A term used to describe sound pressure levels in general without implying any specific frequency weighting or time-integration window.

Sound level limit:
A **sound level** that is not to be exceeded at the **reference measurement position**.

Sound level measurement system:
The combination of a measurement microphone, a measuring instrument, and a visual display installed at a **venue** or **event** for the purposes of monitoring the **sound level**.

Sound quality:
The overall subjective impression of the quality (e.g. clarity, transparency, naturalness, impact, punchiness, fullness, fidelity, dynamics) of the sound heard by the **audience**.

Sound system:
The full set of electronic equipment responsible for reproducing or reinforcing amplified music at a **venue** or **event**, typically comprising microphones, a mixing desk, signal processors, amplifiers, and **loudspeakers**.

Subwoofer:
A **loudspeaker** dedicated to reproducing only low-frequency (bass) sound below around 100 Hz.

Test signal:
A reproducible digital or electronic signal played through the **sound system** to determine the required correction between the **long-term measurement position** and the **reference measurement position**.

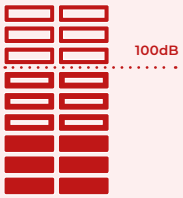
Tinnitus:
The perception of noises in the head and/or ear which have no external source – often perceived as “ringing in the ears” after exposure to high sound levels.

Venue:
An indoor or outdoor location that is regularly attended by an **audience** where enjoyment of amplified music is a central purpose of attendance.

1

Feature 1:
Sound level limit

Sound level below 100 dB $L_{Aeq,\ 15\ min}$



Feature 1: Sound level limit

Sound level below 100 dB $L_{Aeq,\ 15\ min}$

- **Feature 1 specifies an upper limit for the sound level at venues and events.**
- **Keeping the sound level below the limit makes for a safer and more enjoyable experience for the audience.**
- **The sound level limit applies at a defined reference measurement position within each venue or event.**
- **The limit is an upper limit, not a desired target; a sound level significantly below the limit would be suitable for many venues and events.**
- **A reduced limit should be implemented for events targeted at children.**
- **It is important to identify, for each venue or event, who has responsibility for ensuring that the sound level is kept below the limit.**
- **Grassroots venues may need significant support to be able to comply with the limit.**

F1.1 Key elements

F1.1.1 A key aspect of protecting the hearing of audience members at venues and events is to maintain control over the sound level. Feature 1 specifies an upper limit for the sound level that seeks to balance the need to protect hearing, on the one hand, against audience expectations and freedom of artistic expression on the other.

F1.1.2 The recommended sound level limit is 100 dB $L_{Aeq,\ 15min}$, assessed at the **reference measurement position** (see Annex 5).

F1.1.3 The sound level limit is specified as an equivalent continuous sound level (also known as a time-averaged sound level), L_{eq}, expressed in decibels.[4]

4 International Acoustics Commission, 2013. IEC 61672-1:2013. See: https://webstore.iec.ch/publication/5708.

This type of measurement is well-suited for use in recreational venues, where sound levels fluctuate over time. The equivalent continuous sound level is the constant sound level which, over a given period, would have the same total energy as the fluctuating sound level.

F1.1.4 The sound level limit is specified as an **A-weighted** equivalent continuous sound level, L_{Aeq}. A-weighting is a frequency weighting commonly used when assessing the risk of sound-induced hearing injury. It approximates the sensitivity of human hearing to sounds of different frequencies. The rationale for its use is summarized in Annex 3.

It is important to note that the 100 dB $L_{Aeq, 15min}$ sound level limit does not, and cannot, eliminate all risk of an individual audience member suffering sound-induced hearing injury, especially if he or she is a frequent attendee at music venues or events.

F1.1.5 The sound level limit is specified with an averaging time interval of 15 minutes, $L_{Aeq, 15min}$.

The sound level reported at any given moment is influenced by what has happened during the preceding 15 minutes. It is a moving-average measurement, meaning that the sound level is continuously updated, rather than being measured in discrete 15-minute periods.

The use of a 15-minute averaging time interval is consistent with the preferences of practicing live sound engineers and offers advantages over shorter (e.g. 1 minute) or longer (e.g. 60 minute) intervals *(29, 30)*. A 15-minute interval is long enough to allow the natural dynamics (the highs and lows in intensity) of a musical performance to be preserved, while being short enough to provide sound engineers with the timely information they need to control the sound level effectively (see Annex 2).

F1.1.6 The sound level limit of 100 dB $L_{Aeq, 15min}$ is intended to reduce the exposure of audiences to unnecessarily hazardous sound levels, and, with that, the global incidence of recreational sound-induced hearing loss. It is derived from the evidence-based limits recommended in WHO's Noise Guidelines for the European Region *(23)* (see Annex 2 for further information).

It is important to note that the 100 dB $L_{Aeq, 15min}$ sound level limit does not, and cannot, eliminate all risk of an individual audience member suffering sound-induced hearing injury, especially if he or she is a frequent attendee at music venues or events.

F1.2 Applicability

F1.2.1 The sound level limit applies at the **reference measurement position**, which refers to a pre-identified position specific to each venue or event (see Annex 5).

F1.2.2 The sound level limit applies whenever the audience is present at a venue or event. This means that the 15-minute time-averaged sound level, measured on a moving-average basis, should at no time exceed 100 dB $L_{Aeq, 15min}$ while the audience is present.

Depending on how the reference measurement position is determined, audience members standing or seated close to the loudspeakers or stage may experience higher sound levels. Audience members standing or seated well away from the loudspeakers/stage may experience lower sound levels.

F1.3 Peak sound levels

F1.3.1 The sound level limit of 100 dB $L_{Aeq, 15min}$ may seem low when compared to reports in the media of sound levels at rock concerts that reach 125 dB and beyond. However, it is important to recognize that acousticians use many different types of measurement to characterize sound levels, and while they are all expressed in decibels, they are not equivalent and cannot be directly compared. A concert mixed to comply with the 100 dB $L_{Aeq, 15min}$ limit may still contain momentary sound levels (quantified as L_{AFmax} or L_{Cpeak}) that routinely exceed 100 dB (see Annex 3 for further explanation).

F1.3.2 Momentary sounds that are sufficiently intense, such as can be generated by pyrotechnics, cannons, or powerful sound systems, can cause immediate and lasting mechanical damage to the ear. This is distinct from the gradually developing sound-induced hearing loss that results from sustained and repeated exposure to high average sound levels. Although it is clear that intense peaks can cause acute hearing damage, there is no agreement on a safe level *(23)*. While research is ongoing, existing evidence-based guidelines can be applied, such as a 140 dB L_{Cpeak} (peak instantaneous sound pressure level with C-weighting) limit, to protect against immediate hearing injury *(31)*.

F1.3.3 In cases where the sound system is capable, in principle, of producing peak levels above 140 dB L_{Cpeak}, the output should be controlled by a fast-acting electronic limiter to prevent such levels occurring at any location ordinarily occupied by an audience member. The purpose of the limiter is not to shut down or silence the music if the sound level becomes too high: its purpose is to protect against sudden

extreme peaks by capping the level at which the sound system will reproduce them (see Annex 3).

F1.4 Roles and responsibilities

F1.4.1 The effective control of sound levels at venues and events requires a common will and cooperation among multiple stakeholders – from musicians and sound engineers, to venue operators and event organizers.

Nevertheless, it is important that for each venue or event, a responsible party is identified that has ultimate responsibility for ensuring that **safe listening features** are adequately implemented. The responsible party would ordinarily be the person or organization that is legally responsible for the event, such as the venue owner or event organizer.

F1.4.2 The responsible party should develop a written **safe listening policy** that sets out the measures to be taken to ensure safe listening conditions, including clarification of individual roles and responsibilities and any advice or standard operating procedures that are to be followed.

F1.4.3 Where there is a requirement for third parties – for example, performers, sound engineers, or talent bookers – to play a role in achieving safe listening conditions, these requirements should be codified in a formal contractual relationship.

F1.4.4 For each venue or event, the responsible party should ensure that a **responsible actor** is appointed to periodically monitor the sound level (see Feature 2: Monitoring of the sound level) and to make any adjustments needed to keep the sound level below the sound level limit.

F1.4.5 The role of the responsible actor may be enacted by an automated system having the ability to receive and interpret sound level measurement data and make suitable adjustments to ensure that the sound level limit is not exceeded.

The operation of such a system would differ from a conventional electronic limiter in that it would generally be required to make only gradual (and, ideally, perceptually transparent) adjustments to the output level of the sound system.

F1.5 Considerations

F1.5.1 Complying with the sound level limit may pose a serious challenge in some venues, especially small live-music venues (see Box 3). Even when all reasonably practicable measures have been taken, exceedance of the sound level limit may still occur, with these occurrences being outside the control of the responsible actor. Governments and local authorities are strongly encouraged to take such limitations into consideration when developing legislation or enforcement protocols based on this Standard.

F1.5.2 It is common to see the sound level at concerts and club nights increase steadily throughout the evening, sometimes by as much as 10–15 dB L_{Aeq} *(32, 33)*.

Such increases are not always deliberate, and in some cases result from a gradual turning up of the sound system to compensate for ever-increasing ear fatigue experienced by the person responsible for setting the output level.

When a gradual increase in sound level is desired, for example as an event moves towards its climax, it is advisable that the sound level starts out sufficiently low in the early part of the event to leave room for it to rise later, while remaining below the sound level limit. In some cases it may be necessary for venue operators or event organizers to impose a contractual obligation on supporting acts (and/or their sound engineer) to keep to a lower limit, to ensure that the headline act can play "louder" while still complying with the 100 dB $L_{Aeq, 15min}$ sound level limit.

F1.5.3 A reduced sound level limit should be implemented for venues or events specifically targeted at children. The still-developing auditory system in children may be more vulnerable to sound-induced injury than the fully developed auditory system in adults, and children are less likely to be able to make free and informed decisions about their sound exposure *(34)*.

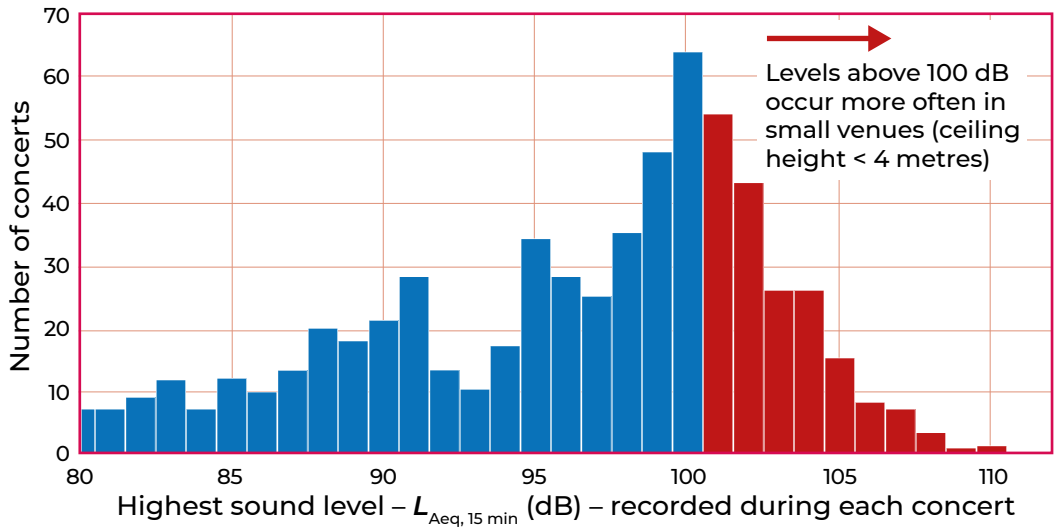
There is no clear evidence for precisely how much lower the limit should be for venues or events specifically targeted at children. However, based on international precedent *(25, 26)*, where an event is expected to attract a majority audience of children, the sound level limit should be reduced at least to 94 dB $L_{Aeq, 15min}$, with 90 dB $L_{Aeq, 15min}$ or lower recommended for events targeted at young children. Peak sound levels at venues or events targeted specifically at children should be limited to not exceed 120 dB L_{Cpeak} *(31)* (see Annex 3).

Box 3:

The challenge of controlling the sound level in small live-music venues

In bars, clubs, or other venues which only play prerecorded music, the sound level can be controlled by simply setting the sound system to an appropriate output level. The situation is more complex in live-music venues. Sound levels can change unpredictably from one moment to the next during a live performance, and, especially in small indoor venues, sound from loud on-stage sources (such as drum kits, electric guitar amplifiers, and monitor loudspeakers) can cause the sound level limit to be exceeded, independently of sound coming from the main loudspeakers. Unless adequate steps have been taken in advance, the sound engineer may be powerless to reduce the sound level while a performance is underway.

Long-term monitoring of sound levels at more than 600 concerts taking place across 50 venues in Norway revealed that sound levels at the FOH mixing desk exceeded 100 dB $L_{Aeq,\,15min}$ at around one-third of all concerts *(35)*. Levels above 100 dB $L_{Aeq,\,15min}$ occurred more often in smaller venues (ceiling height < 4 m/audience capacity < 350) than in larger venues. This is consistent with reports from other countries indicating that, while professional sound engineers often voluntarily mix shows at or below 100 dB $L_{Aeq,\,15min}$ in larger venues *(36)*, sound levels in small to medium-sized live-music venues frequently exceed 100 dB $L_{Aeq,\,15min}$ *(37)*.



Adapted image courtesy of Morten Andreas Edvardsen from his thesis: Analysis measurements from Norwegian venues for amplified music, Norwegian University of Science and Technology.

Box 3:

The challenge of controlling the sound level in small live-music venues (continued)

Research conducted for the Flemish government confirms that, in small live-music venues, the overall sound level is typically dictated by the level of the loudest on-stage source, most often an acoustic drum kit.

A case study conducted in a typical small venue found the sound level in the middle of the venue to be 99.5 dB $L_{Aeq,\ \sim 3min}$ when the drummer played the drum part to a song, solo, and without amplification. When the drums were minimally amplified to create a suitable reinforced drum sound for rock music, the sound level increased to 103.4 dB $L_{Aeq,\ \sim 3min}$. Adding in the remainder of the band (guitars, bass, and vocals) resulted in a further increase to 107.5 dB $L_{Aeq,\ \sim 3min}$.

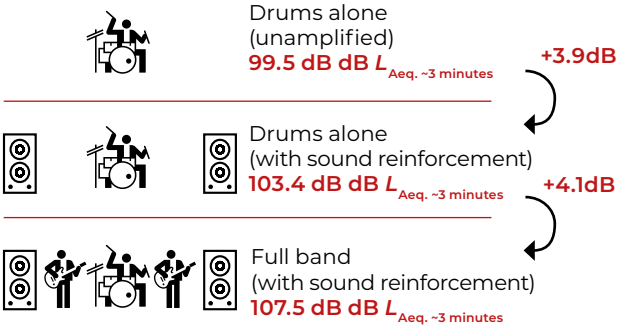


Image courtesy of Marcel Kok, dBControl.

In circumstances such as these, the sound engineer has extremely limited scope to "turn down the volume": the sound level emanating from an acoustic drum kit cannot be altered while a performance is underway, and to reduce the output from the main sound system risks rendering vocals and other instruments inaudible beneath the sound coming directly from the drums.

Insight into the scale of the measures that may be needed in a small live-music venue* comes from a case study conducted at a Swedish venue *(38)*.

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* Feature 3 provides further information about the optimization of venue acoustics and sound systems for safe listening.

Box 3:

The challenge of controlling the sound level in small live-music venues (continued)

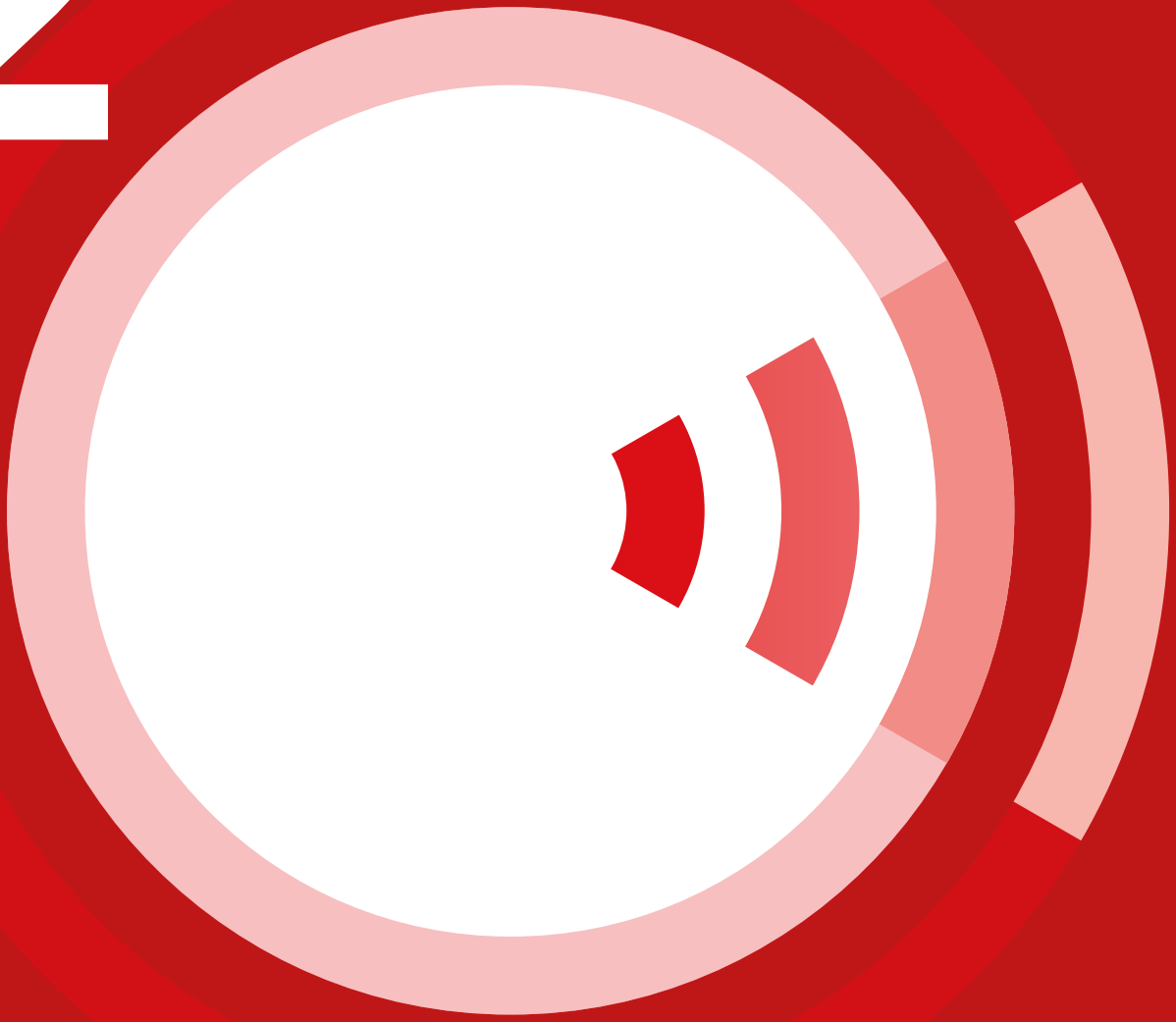
A 9 dB reduction in the average sound level during concerts (which was necessary to bring sound levels in line with a government-recommended limit of 100 dB L_{Aeq}) was achieved by:

- Installing a new suspended ceiling system
- Installing sound-absorbing wall panels
- Installing a new sound system
- Reconfiguring the stage
- Relocating the bar outside of the main performance space
- Providing the venue's in-house technician with comprehensive training about safe listening

While not all of the above measures are required in all venues, it is clear that the measures needed to keep sound levels below 100 dB $L_{Aeq, 15min}$ in small, indoor live-music venues can be costly and may require significant expertise. Despite playing a vital economic and cultural role in towns and cities, most grassroots live-music venues operate on extremely tight margins, if not at a loss, and many are unable to self-fund the necessary improvements *(39)*.

Governments and local authorities are encouraged to find ways to support venues to deliver safer listening conditions for their audiences (see section following Features: *Adoption and implementation of the WHO Global standard for safe listening venues and events* for details of a publicly funded scheme that supports Norwegian venues to make improvements to acoustics and sound systems).

2



Feature 2: Monitoring the sound level

The sound level has to be actively monitored to ensure compliance with the limit of 100 dB $L_{Aeq,\,15\ min}$

Feature 2: Monitoring of the sound level

The sound level has to be actively monitored to ensure compliance with the limit of 100 dB $L_{Aeq,\,15\,min}$

- **Feature 2 describes how sound levels should be monitored at venues and events.**
- **Requirements for accuracy and calibration of measurement equipment and record keeping are explained.**
- **Procedures are given for applying a correction where the sound level cannot be directly measured at the reference measurement position.**

F2.1 Key elements

F2.1.1 The effective control of sound levels at venues and events requires that the sound level be measured accurately and that the results be made visible to the responsible actor in real time, so that he or she can enact any changes required to keep the sound level below the sound level limit *(40)*.

F2.1.2 A **sound level measurement system** should be used to actively monitor the sound level throughout the duration of each performance or event. Where the sound level can be assumed to be reasonably static, for example, when prerecorded music is played through a sound system in a bar or club, it may be sufficient to check the sound level only when an adjustment is made to the output level of the sound system. During a live performance, where the sound level can change more quickly and unpredictably, closer monitoring of the sound level will usually be required.

F2.1.3 Where the measurement equipment allows, tamperproof, date- and time-stamped digital logs should be maintained of the sound levels measured throughout the period during which a venue or event was open to an audience.

Where possible, these logs should be augmented with information to help inform future research, including frequency spectra of the measured sound levels in octave-band or one-third-octave-band resolution, the type of event, primary musical genre, approximate audience size, and any other relevant information (for example, if a touring act used their own sound system, instead of the house system).

A sound level measurement system should be used to actively monitor the sound level throughout the duration of each performance or event.

F2.1.4 The requirement to actively monitor the sound level may be waived in cases where it can be demonstrated that the installed sound system is not capable of, or is limited by electronic means from, producing a sound pressure level ($L_{Aeq,\,15min}$) at the reference measurement position that exceeds the sound level limit.

Where the output of the sound system is limited by electronic means, users should not be able to alter or override this functionality before or during an event.

In such cases the sound system should be periodically checked by a suitably qualified person to confirm that it is operating within its design specifications and that any sound-limiting features remain effective.

Note: Optional limiting to ensure compliance with the 100 dB $L_{Aeq,\,15min}$ sound level limit at the reference measurement position is separate from and supplemental to any limiting required to control peak sound levels (see Annex 3).

F2.2 Measurement equipment and procedure

F2.2.1 The sound level measurement system should function as an integrating-averaging sound level meter, capable of measuring and displaying $L_{Aeq,\,15min}$ numerically in decibels *(41)*. The sound level should be measured on a moving-average basis, with the display updated at periodic intervals (e.g. once every second) to show the current value of $L_{Aeq,\,15min}$.

F2.2.2 The numerical display may be supplemented by other visual indicators of sound level, for example, a traffic-light style display or graphical meter designed to indicate how the current sound level compares to the sound level limit. To prevent sound levels being set higher than they need to be, careful consideration should be given to the design of such displays to ensure that they do not bias the responsible actor towards treating the sound level limit as a “preferred” sound level to be aimed for *(72)*.

F2.2.3 The measured sound level should be clearly visible to the responsible actor from the position at which he or she is able to adjust the sound level (for example, from the FOH mixing desk or place where the output level of the sound system is set).

F2.2.4 The measured sound level should not, in general, be displayed to the audience. This is to avoid a phenomenon observed, for example, at some sporting events, where the crowd engages in a competition to register as high a sound level as possible.

F2.2.5 The accuracy of a sound level meter is indicated by its "class", as defined in international standard IEC 61672-1:2013 *(41)*. A class 1 sound level meter is more accurate, although generally also more costly, than a class 2 sound level meter.

The sound level measurement system should meet, as a minimum, the main performance requirements for a class 2 device at frequencies between 63 Hz and 8 kHz inclusive, as assessed based on the periodic tests as defined in IEC 61672-3:2013 *(42)*.

By focusing on the main performance requirements for a class 2 sound level meter, as opposed to the full suite of acoustical and electrical requirements that must be met for a device to be considered fully class 2 compliant, it becomes possible to use a wider range of measurement hardware, some of which is likely to be more accessible, especially in low-income countries (see Box 4).

Box 4:

Different forms of sound level measurement system

Sound level measurement systems come in different forms. Below are some examples of common forms.

Self-contained sound level meter

This is the traditional form of most class 1 and class 2 compliant sound level meters by IEC standards *(40)*.

The device can be hand-held or mounted on a tripod.

It is usually possible to purchase a special-purpose extension cable if the measurement microphone needs to be mounted in a different location from the main body of the device.

Image courtesy of Marcel Kok, dBControl.

Box 4:

Different forms of sound level measurement system (continued)

Image courtesy of Marcel Kok, dBControl.

Computer-based system

These systems combine a software application running on a laptop or tablet with a calibrated external measurement microphone*, often connected by USB.

Some manufacturers offer plug-and-play solutions for live-sound level monitoring, in which all the required software and hardware is provided as a package.

An advantage of such integrated solutions is that the software usually includes dedicated features designed to make it easier for the sound engineer to comply with a given sound level limit, and automatic logging of measurement results to a cloud-based service is possible. Some systems may have undergone testing to verify compliance with the requirements of a class 1 or class 2 sound level meter *(41)*.

Smartphone app with external measurement microphone

Smartphones are designed to function primarily as communication devices, not as precision measuring instruments. The built-in microphones are not suitable for accurately measuring sound levels.

However, when a well-developed and validated app† is used in conjunction with a high-quality external measurement microphone, some smartphones may form the basis of a system that meets the key performance requirements for a class 2 sound level meter *(43)*.

Image courtesy of NIOSH.

Since smartphone hardware, operating systems, and apps undergo rapid development, it is strongly advised only to use a hardware and app combination that has been formally tested to verify compliance with the requirements of IEC standards.

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* Note that purchasing a "class 2 compliant" microphone does not automatically mean that the sound level measurement system will meet the class 2 performance requirements: the requirements apply to the system as a whole, including all hardware, software, and interconnecting components.

† The National Institute for Occupational Safety and Health (NIOSH) Sound Level Meter (SLM) app is validated and free-of-charge (available at https://www.cdc.gov/niosh/topics/noise/app.html).

Regular calibration is important to ensure the accuracy of sound level measurements.

F2.2.6 The measurement microphone should have an omnidirectional polar pattern (meaning that it captures sound evenly from all directions); it can be of either free-field or diffuse-field (random incidence) type.

Where a free-field microphone is used, it should be pointed towards the dominant source of sound (typically the main loudspeakers/stage).

Where a diffuse-field microphone is used, it should not be pointed directly towards any sound source, but rather upwards towards the ceiling or downwards towards the floor (if suspended from the ceiling).

F2.2.7 The use of a windscreen around the measurement microphone is advised, both to reduce the influence of wind noise when measuring outdoors and to provide added protection from dust and shocks indoors.

Note: On some sound level meters, it is necessary to change a setting in the setup menu to indicate that a windscreen is in use.

F2.2.8 Regular calibration is important to ensure the accuracy of sound level measurements (see Annex 4 for further information on the importance of calibration).

The calibration of the sound level measurement system (including any extension cables, adaptors, and display devices) should be periodically checked using a class 1 or class 2 acoustic field calibrator *(44)*, as appropriate to the class of measurement system in use.

F2.3 Measurement position and the use of a correction

F2.3.1 The measurement microphone should be positioned (as far as is practicable):

i) at or close to the reference measurement position, where the sound level limit applies (see Annex 5);

ii) at a height comparable to audience head height;

iii) out of reach of audience members;

iv) at least 1 metre from any large reflective surface (such as a wall, ceiling, or large piece of furniture or equipment); and

v) with a clear line of sight to the main loudspeakers.

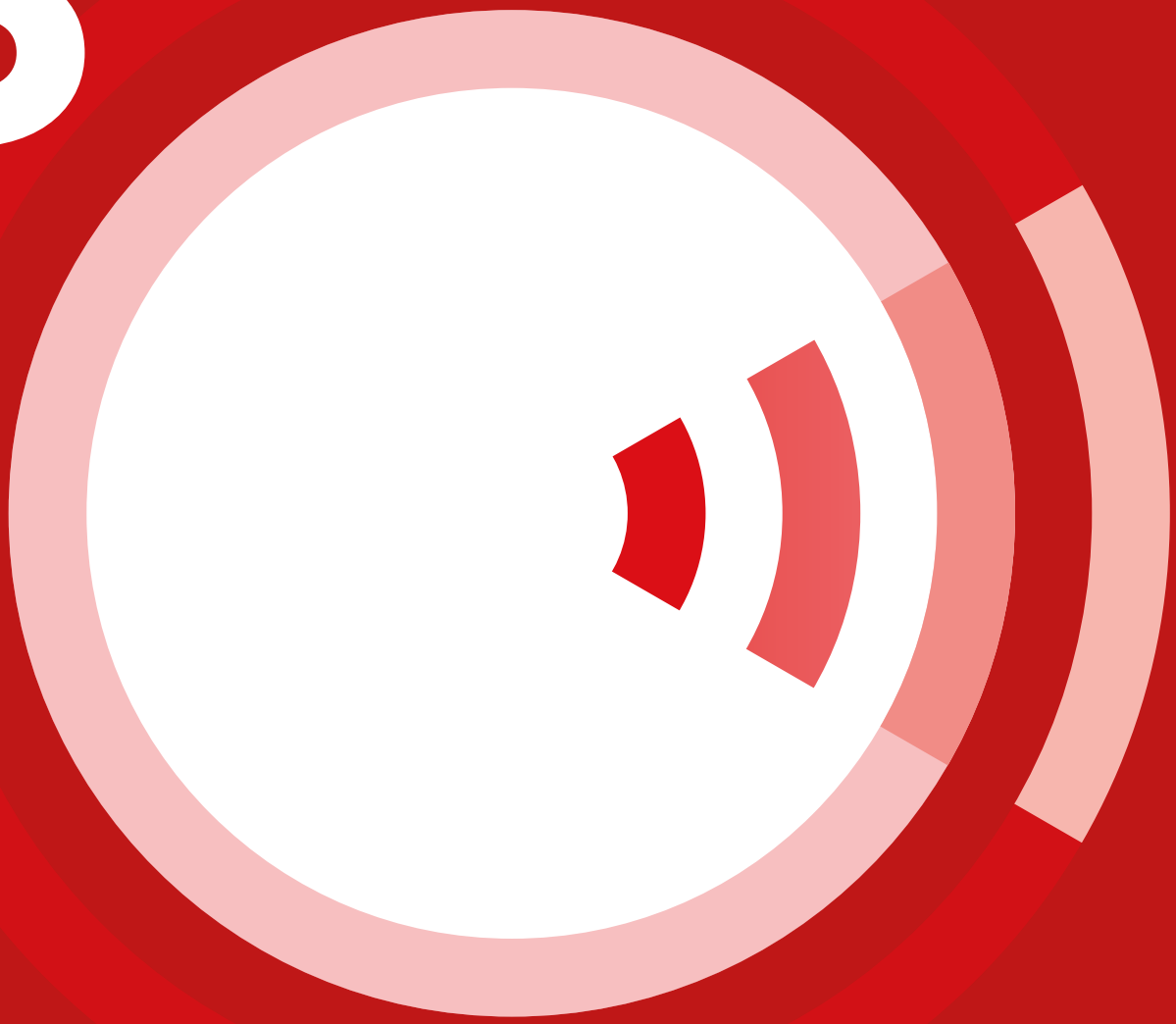
F2.3.2 Where it is not possible to position the microphone as described above, because no such location is available, or because this would not offer a safe and secure place to mount the microphone while an event is underway, the microphone should instead be positioned at a more convenient long-term measurement position. This could be, for example, directly in front of the main loudspeakers, suspended from the ceiling over the audience area, or at the FOH mixing desk.

F2.3.3 Where the long-term measurement position is different from the reference measurement position, a correction will usually be required so that the measurements reflect the sound level at the reference measurement position. Such correction may not be needed where certain conditions are met *(45)* (see Annex 5 and Annex 6).

F2.3.4 When a correction is to be applied, it should be applied automatically so that the measurements reflect the sound level at the reference measurement position. Where this is not possible, an alternative is to adjust the sound level limit by an amount equal to the correction (see Annex 5 and Annex 6).

The correction should be remeasured following any material change to the layout of the venue, upgrade or modification of the sound system, or change to the sound level measurement system (including a change of long-term measurement position).

3



Feature 3:
Venue acoustics and sound-system design

Venue acoustics and sound systems should be optimized for safe listening, so far as is reasonably practicable

Feature 3: Venue acoustics and sound-system design

Venue acoustics and sound systems should be optimized for safe listening, so far as is reasonably practicable

- **Feature 3 ensures that the acoustics of a venue and the design of the sound system support safe listening.**
- **Optimizing the acoustics and sound system for safe listening improves sound quality and enhances the listening experience for audience members and performers.**
- **High-level design goals for venue acoustics and sound systems are discussed, along with general tips and advice on how these goals can be achieved.**
- **Sound levels increase rapidly immediately in front of loudspeakers, so audience members should be prevented from approaching the loudspeakers whenever possible.**
- **Effective management of on-stage sound levels is crucial to achieving safe listening conditions in small live-music venues.**

F3.1 Key elements

F3.1.1 Suitable venue acoustics and appropriate sound-system design are critical to the delivery of a safe and high-quality listening experience for all audience members. Particularly in smaller indoor venues that host live-music performances, these elements can dictate whether it is possible to comply with the sound level limit (see Box 3 for further information).

F3.1.2 Good sound quality and safe listening go together, so optimizing the venue acoustics and sound system to support safe listening can be expected to also improve sound quality and promote greater audience satisfaction.

F3.1.3 Venue owners/operators should be supported and encouraged to take all reasonably practicable measures to optimize the acoustics and sound system for safe listening. While some measures are relatively easy and affordable to implement, many venues face significant financial barriers to making the necessary improvements, as well as possible constraints relating to architectural, structural, accessibility, safety, planning, and contractual issues.

Box 8 presents a case study from Norway, where a publicly funded scheme exists to support venues to make improvements.

F3.1.4 Safe and enjoyable listening experiences happen *(46)*:

i) when the venue acoustics are well-suited to amplified music;

ii) when the sound system is well-designed and of good quality; and

iii) in the case of live events, when the performers and sound engineer(s) cooperate to manage on-stage sound levels and deliver high-quality sound to the audience.

These three aspects are considered in the rest of this section.

F3.2 Venue acoustics

F3.2.1 Poor or unsuitable acoustics in an indoor venue can impact on sound levels in two main ways:

i) If a venue is excessively reverberant (too much sound being reflected from the floor, walls, and ceiling), sound from all sources is amplified, increasing the overall sound level. The sound engineer may need to increase the output from the sound system to hazardous levels to overcome sound coming directly from the stage and/or the audience.

ii) An overly reverberant venue, or a venue with other acoustical problems (such as prominent echoes or an unbalanced frequency response), makes it difficult for the sound engineer to achieve a clear and controlled mix. Sound levels can gradually increase as the sound engineer strives to improve the clarity of the mix *(29, 35, 47)*.

F3.2.2 Amplified music generally sounds best in venues with well-damped room reverberation, i.e. a “dry” acoustic character. Suitable reverberation times for amplified-music venues (based on Norwegian regulations) *(48)* are provided in Annex 7.

F3.2.3 In most venues, and especially those that feature predominantly hard, reflective surfaces (e.g. brick, concrete, plaster, or glass), it is necessary to introduce additional sound absorption to control room reverberation (see Annex 7 for examples of materials for acoustic treatment of a venue).

Although, in most cases, excessive reverberation is the problem, the aim should not be to absorb all reverberant sound, as an acoustically "dead" venue makes it harder for musicians to play together as an ensemble and can result in a feeling of disconnectedness from the audience.

A trained acoustician is able to evaluate the acoustics of an existing or proposed venue and advise on the nature and extent of any acoustic treatment needed.[5]

Amplified music generally sounds best in venues with well-damped room reverberation, i.e. a "dry" acoustic character.

F3.2.4 Mid- and high-frequency sound can be absorbed through the introduction of soft, porous materials. Examples include upholstered seating, carpets, curtains, and drapes. A suspended sound-absorbing ceiling can be particularly effective, in part because of the large surface area available for treatment. High-performance sound-absorbing panels are also available, typically made of open-cell foam or a fabric-wrapped fibrous material, such as mineral wool. These can be mounted to the walls or ceiling.

F3.2.5 Absorbing low-frequency sound is generally more challenging, but can significantly improve sound quality. Through better control of low-frequency reverberation, the sound engineer can more easily achieve a clear and impactful mix while also complying with the sound level limit. This commonly relies on use of resonant absorbers (examples are provided in Annex 7).

F3.2.6 To be effective, sound absorption should generally be distributed across a venue's surfaces, rather than concentrated in a single area. In some cases, however, it may be beneficial to place particular types of acoustic treatment in specific locations, in order to bring about a desired effect. Where trained acousticians are available, venue owners/managers are encouraged to seek advice on such matters.

F3.2.7 Strong reflections (e.g. from the rear wall of a venue) and sound-focusing effects (e.g. due to a domed or arched construction) can seriously affect sound quality, and consequently also the ability of a sound engineer to achieve a clear and impactful mix at a safe sound level. Acoustical problems such as these can be addressed by treating the surface(s) giving rise to the reflection or sound-focusing effect in an appropriate way. The required treatment usually takes the form of either sound absorption (to reduce the amount of sound that reflects off the surface) or **sound diffusion** (to scatter sound off the surface in all directions, rather than reflecting it back in a single direction).

5 REW (www.roomeqwizard.com/) is a popular free software package capable of performing reverberation time measurements. It may be a helpful resource for venues that do not have access to the services of a trained acoustician.

Note: Sound diffusion can be provided by a curved (convex) surface or by a surface with a varying depth profile (e.g. a series of "wells" of different depths). A surface that comprises a patchwork arrangement of absorbing and reflecting areas also provides a degree of sound diffusion (see Annex 7 for examples).

F3.3 Room modes

F3.3.1 Room modes *(46)* are low-frequency resonances that result from sound waves bouncing back and forth between a room's surfaces (see Annex 8 for further details). Room modes can be problematic in small venues, such as cafés and bars, with a volume less than around 1000 m^3. If the low-frequency (bass) response seems very uneven or "boomy" when moving around a small venue, this could indicate an issue with room modes.[6]

F3.3.2 The solution to room-mode issues is generally to introduce more low-frequency sound absorption (see Annex 7), focusing especially on treating the room corners and/or boundaries where two of the room's surfaces meet *(49)*.

F3.4 Acoustics of the stage area

F3.4.1 The acoustics of the stage area require special attention, especially in small indoor venues. There are two primary considerations:

i) The stage must provide a comfortable environment for musicians to perform, the most important factor being that they can hear themselves and one another clearly without needing to resort to excessive output level from stage monitors;

ii) Spillage of sound from the stage towards the audience should be adequately controlled. On-stage sound levels can be very high and are generally not under the control of the sound engineer.

F3.4.2 In general, the acoustics of the stage area should be similar to those of the entire venue. This means that reverberation should ideally be controlled through a balanced combination of low-frequency resonant absorbers (which may be located around the stage perimeter) and mid-to-high-frequency porous absorption (often in the form of curtains, drapes, or other "stage textiles"). Any hard surfaces should be of a sound diffusing design to help spread sound uniformly across the stage and avoid problematic reflections.

6 An uneven bass response can also indicate an issue with coherent interference between direct and/or reflected sound from one or more loudspeakers reproducing low-frequency sound (see Annex 8).

F3.4.3 In combination with other measures (see Annex 11), sound absorption on the rear wall of the stage area (behind where a drummer would ordinarily sit) can play an important role in reducing the level of stage sound that propagates towards the audience area in small indoor venues.

F3.5 Acoustics of outdoor venues

F3.5.1 The acoustics of outdoor venues are generally much simpler to manage than for indoor venues. The principal acoustical design issue is to avoid a situation where large objects such as site hoardings, buses, or the stage canopy, reflect or focus sound directly back towards the stage or audience area. In addition, care should be taken to ensure that there are no strong reflections from hard surfaces around the stage area that could interfere with the musicians' ability to hear themselves clearly.

F3.6 Sound-system design

F3.6.1 A primary goal of sound-system design should be to achieve reasonably uniform sound distribution across the audience area, both in terms of overall sound pressure level and, especially, spectral balance between low and high frequencies; all audience members can then experience high-quality sound at a safe and enjoyable level. The positioning of loudspeakers is particularly important to achieve this. Scenarios illustrating the positioning of loudspeakers and the impact on sound distribution are presented in Annex 9.

F3.6.2 While an even coverage of sound across the audience area is generally desirable, it may be appropriate to purposefully target a lower sound level in certain areas such as towards the rear of a venue, at bars, or merchandise stands, or in areas where the audience circulates. This can improve choice and comfort for audience members, some of whom may wish to enjoy an event from a slightly quieter location. This is especially relevant for areas in which audience members would not be expected to be actively listening to the performance. A lower sound level also facilitates easier verbal communication in areas where this is important.

F3.6.3 Every venue is different and places unique demands upon the design of the sound system. A professional sound-system designer will be able to advise on the most suitable loudspeaker configuration for a particular venue or event. Software packages are also available that allow different loudspeaker configurations to be compared by predicting the sound level that will be generated at different locations within the audience area, although most such packages currently only predict the direct sound and do not take into account the acoustics of the venue.

F3.6.4 To achieve uniform distribution of sound, and create conditions suitable for the sound engineer to produce a clear, impactful, and high-quality mix, the following general precautions can be taken *(46, 50–52)* (see also Annex 9):

i) Try to avoid a situation in which some audience members are much closer to the loudspeakers than others.

ii) Avoid a situation in which direct sound from the main loudspeakers is blocked from reaching people at the rear of the audience by other people in front.

iii) Elevate ("fly") the loudspeakers above head height whenever possible.

iv) Pay attention to the directivity pattern of the loudspeakers and try to ensure that as much of the sound as possible goes to where it is wanted (i.e. towards the audience and away from walls and ceilings).

v) Ensure that any multi-unit loudspeaker systems (e.g. line arrays), have been carefully installed and are distributing sound as intended.

vi) Use secondary loudspeakers (e.g. delay-fill, front-fill or out-fill systems) to help deliver sound to areas which the main loudspeakers cannot adequately cover (e.g. the rear of a large audience or the area beneath a balcony).

vii) Where there is no requirement for the sound to appear to originate from a specific place (e.g. in bars or clubs that play prerecorded music and do not have a stage), the use of a fully distributed (e.g. ceiling-mounted) loudspeaker system can be considered. With each loudspeaker only having to cover its own small area, sound is emitted at a lower level.

F3.6.5 Most sound systems, especially in larger venues, incorporate subwoofers (loudspeakers that are dedicated to reproducing low-frequency sound below approximately 100 Hz). It is common practice to place the subwoofers at ground level close to the stage which can result in audience members in the front rows being exposed to intense low-frequency sound *(36)*. Although, at present, it is unclear how much risk this poses to human hearing, any potential risk could be addressed by placing subwoofers above head height. Practical considerations relating to this are outlined in Annex 9.

F3.7 Exclusion zones in front of loudspeakers

F3.7.1 Sound levels increase rapidly when approaching within a few metres of a loudspeaker (see Annex 10) *(53)*, therefore the area immediately in front of the loudspeakers is an especially hazardous location. It is strongly advised that no audience member be allowed within 1 metre of any loudspeaker. Ideally, audience members should be kept at least 3 metres away from loudspeakers *(46)*.

Note: These suggested distances should be considered in light of the maximum output capability of the loudspeaker(s) in question, which can differ greatly between different makes and models. For low-powered loudspeakers, an exclusion zone may not be necessary, while for high-powered loudspeakers, an exclusion zone extending beyond 3 metres may be required.

F3.7.2 Where possible, elevating the loudspeakers above head height is an effective solution to imposing a minimum separation from audience members; this will also generally lead to improved sound distribution (see Annex 9). In settings where this is not possible, the use of a sturdy barrier can prevent audience members from getting too close to the loudspeakers *(46)*.

F3.8 Management of on-stage sound

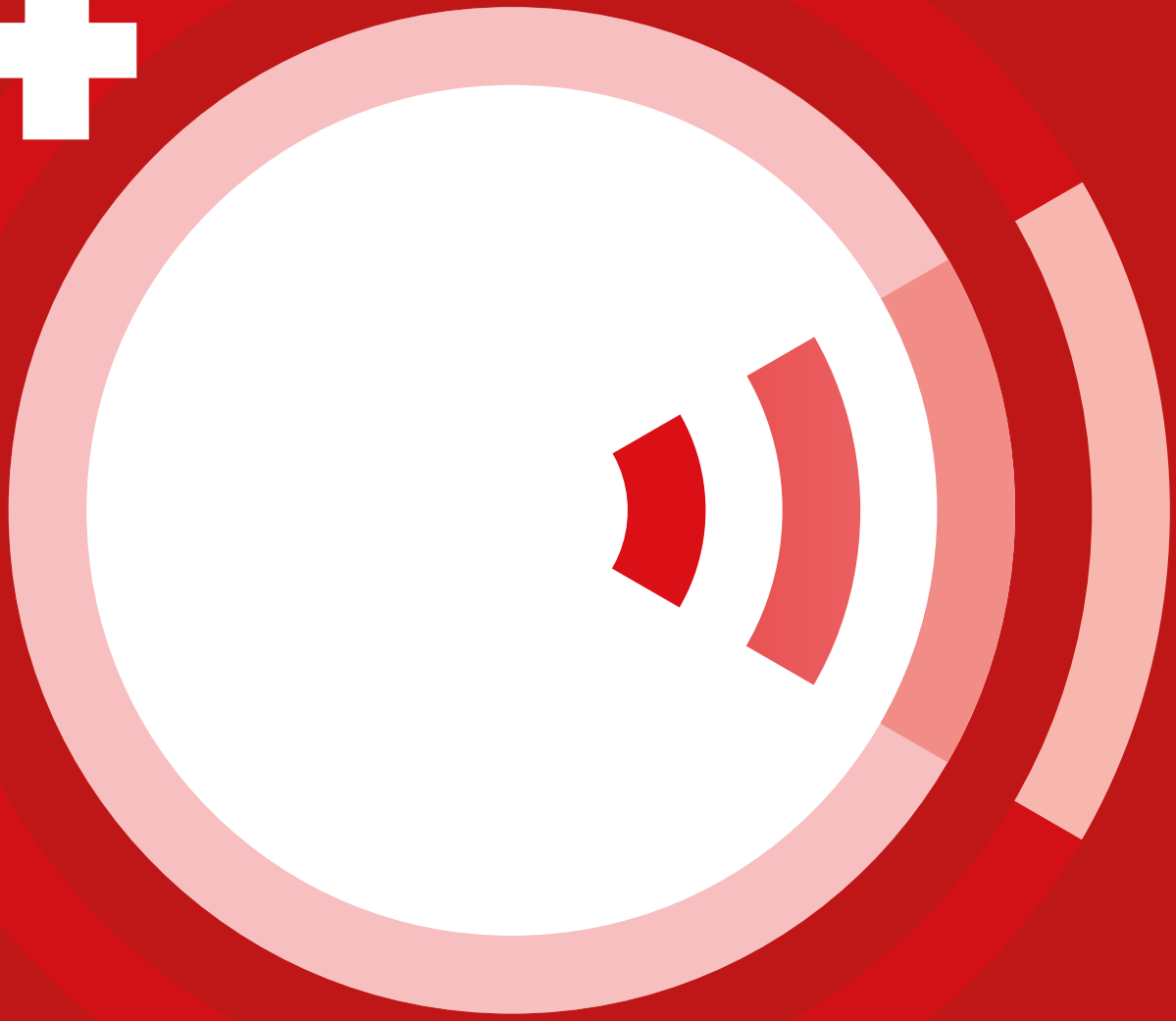
F3.8.1 In small live-music venues, high levels of on-stage sound propagating directly into the audience area poses a major challenge for compliance with the sound level limit (see Box 3). The introduction of additional sound absorption to the venue, including around the stage area, to control the build-up of reverberant sound, is often important in tackling this issue. However, in many venues, this step alone will not be sufficient. Compliance with the sound level limit will require the active lowering of on-stage sound levels.

F3.8.2 The most effective approach to the control of on-stage sound levels is to quieten (or, where possible, remove) the loudest sources *(46)* (see Annex 11 for suggestions).

F3.8.3 Once loud on-stage sources have been quietened as far as possible, the next step is to consider reducing the amount of sound that propagates from the stage to the audience area. This commonly involves projecting the sound away from the audience or using materials to block sound from reaching the audience directly *(46)* (see Annex 11 for suggestions).

These measures require the cooperation and consent of the performers, technicians and sound engineers; they are effective and need not be costly.

4



Feature 4:
Personal hearing protection

Personal hearing protection should be available to audience members at the venue/event

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Personal hearing protection should be available to audience members at the venue/event

- **Feature 4 ensures that audience members have access to personal hearing protection at venues and events.**
- **While low-cost disposable earplugs can offer effective protection, high-fidelity earplugs designed for music offer better sound quality, comfort, and useability.**
- **Adequate instructions should be provided alongside hearing protection, since earplugs are only effective when worn properly.**

F4.1 Key elements

F4.1.1 The wearing of hearing protection may be the only practicable means by which individuals can reduce their personal sound exposure while continuing to enjoy an event in an unrestricted way *(54)*.

Hearing protectors commonly include earplugs, earmuffs, and canal caps *(55)*. Earplugs are the form of personal hearing protection considered most suitable for use in entertainment venues, although other forms of hearing protection, such as earmuffs, can also be effective.

Earplug use among festival goers has been shown to significantly reduce the occurrence of temporary hearing loss and tinnitus due to exposure to music at high sound levels *(56, 57)*.

Since earplugs work by physically attenuating the intensity of the sound reaching the eardrum, it is reasonable to expect that short-term protection immediately after exposure translates to long-term protection against sound-induced hearing loss (assuming consistent use of earplugs over repeated exposures).

F4.1.2 Earplugs are made by many different manufacturers, from different types of material. They come in different forms and at various price points.

Some of the main ways in which earplugs can be categorized are as follows (in each case the least costly alternative is listed first):

i) single-use (disposable) vs. reusable

ii) ready-fit vs. custom-molded

iii) generic vs. music-specific (high-fidelity)

iv) passive vs. active (electronic).

Ready-fit earplugs can be formable (requiring a degree of manipulation prior to fitting) or preformed (requiring no manipulation prior to fitting).

Note: Active (electronic) earplugs feature an external microphone and an internal speaker and, in principle, allow for variable and selective attenuation of sounds at different frequencies. They are not currently in widespread use and are therefore not given further consideration in this version of the Standard.

F4.1.3 Earplugs designed specifically for listening to music are known as “high-fidelity” earplugs, or sometimes “uniform-attenuation earplugs”. They offer significant benefits compared to generic, single-use earplugs (see Box 5), and their use is most appropriate on useability and sustainability grounds.

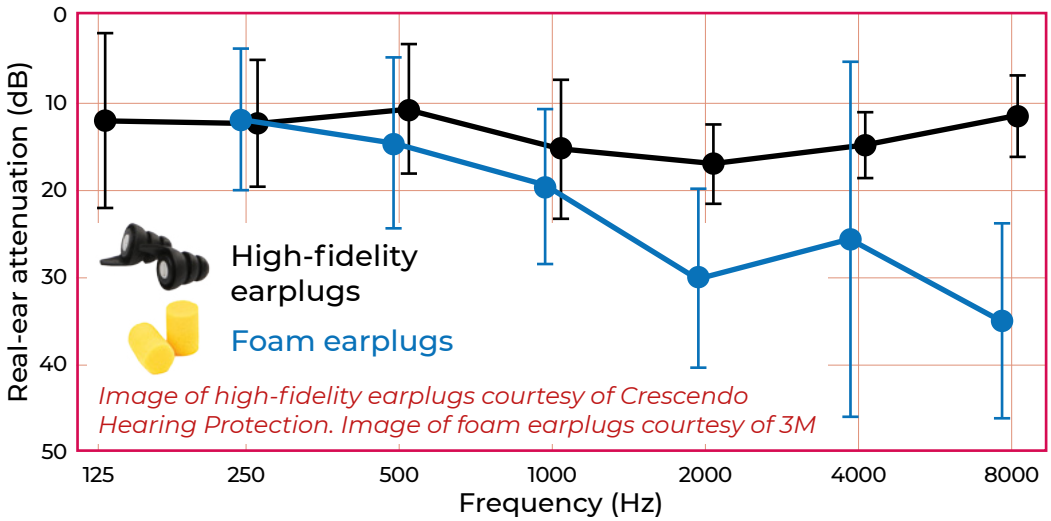
F4.1.4 Custom-molded earplugs are the preferred choice of live-sound engineers and professional musicians for comfort and sound quality. They are also potentially well-suited for use by audience members, especially those who attend venues or events regularly. However, since their manufacture requires ear impressions to be taken by a trained specialist and they are relatively costly, it is not possible to provide them on demand at venues and events *(54)*.

Governments and health-care providers are encouraged to consider whether custom-molded earplugs could be provided to individuals cost-free, or at a subsidized cost, as an important component of preventative hearing health care. To ensure best performance, the attenuation of custom-molded earplugs should be verified through a real-ear attenuation at threshold test procedure *(58)*.

Box 5:

High-fidelity versus generic earplugs for music

Unlike generic earplugs, high-fidelity earplugs are designed to attenuate sounds approximately equally at all frequencies, which leads to a more natural sound quality *(54, 59–61)*. As illustrated in the figure below, generic foam earplugs generally attenuate high frequencies far more than low frequencies, making music sound muffled and less enjoyable.



While high-fidelity earplugs cost more than generic earplugs, and typically do not provide as much attenuation overall, their sound-quality advantage makes them more compatible with the enjoyment of amplified music.

A lesser amount of overall attenuation is not necessarily a negative attribute as most users will want to hear the music clearly and with some sense of loudness preserved. In principle, even a reduction of 6 dB across all frequencies offers a 4-fold increase in the time for which exposure to a given sound level is safe. An earplug that provides a consistent, but moderate, amount of attenuation will also make it easier for users to converse without the need to temporarily remove hearing protection.

It is important to note that, in practice, not all earplugs marketed as being suitable for music and offering flat attenuation across frequencies meet that claim *(62)*. The "What Plug?" tool provided by HEARsmart* offers helpful information and reviews of high-fidelity earplugs for music listening.‡

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* What Plug? Resource. Available at: https://hearsmart.org/earplugs/what_plug/.

‡ At present availability is limited to the Australian market only.

Hearing protectors suitable for use by children should be made available at venues and events targeting children or where children are likely to be part of the audience.

F4.1.5 Earplugs are effective at attenuating sounds only if worn properly; the attenuation achieved by most untrained wearers falls below the manufacturer's stated performance *(54, 63)*. It is therefore important that clear instructions for usage are provided with earplugs of all types. Usage instructions can be provided in written or video form.

F4.1.6 While all those visiting venues or attending events where amplified music is played should consider using hearing protection, it is especially important for *(54)*:

- people who attend venues or events regularly;
- people who are employed in a noisy workplace;
- people exposed to other personal or environmental sources of high sound levels, e.g. those listening to music over personal audio devices;
- people with existing hearing problems, such as hearing loss or tinnitus, to prevent any worsening of their condition; and
- children who visit events or venues.

Note: Hearing protectors suitable for use by children should be made available at venues and events targeting children or where children are likely to be part of the audience.

F4.2 Performance requirements

F4.2.1 Earplugs for use at music venues and events must reliably provide a meaningful level of protection from hearing injury, yet at the same time they should allow audience members to continue to hear and enjoy the music and to converse comfortably. This means that the earplugs should provide enough, but not too much, sound attenuation.

F4.2.2 To ensure that earplugs provide a reasonable minimum level of protection, a laboratory-measured real-ear attenuation of 12 dB[7] or more should be achieved by at least 84% of inexperienced subjects upon self-fitting (the "assumed protection value").

Based on the average long-term spectrum of live sound (see Annex 3), an earplug meeting these requirements generally ensures that an unprotected sound level of 100 dB $L_{Aeq,\,15min}$ is reduced to

7 12 dB real-ear attenuation in each of the 250 Hz, 500 Hz, 1 kHz, 2 kHz, and 4 kHz octave bands.

88 dB $L_{Aeq,\,15min}$ or lower when worn. This, combined with the sound level limit (Feature 1), should be sufficient to protect the hearing of an audience member who attends venues or events for up to around six hours a week on average (see Annex 2). This is equivalent to the protection which is typically afforded to workers under occupational noise regulations *(27, 54)*. However, it is important to recognize that this ignores sound exposure in environments other than the one in question.

Note: The assumed protection value based on a protection performance of 84% can be estimated for each octave band as the mean attenuation across a panel of 16 or more subjects minus one standard deviation *(64)*.

F4.2.3 It is important to be aware that while earplugs are often marketed with a certain "dB rating", such claims are often based on tests conducted under favourable conditions (for example, where an experimenter fits the earplugs to each subject's ears and ensures an optimal fit). An average user is unlikely to achieve the claimed level of attenuation in real-world use. For this reason, the minimum performance criteria in this Standard are specified in terms of the assumed protection value – i.e. the attenuation expected to be achieved by at least 84% of inexperienced users upon self-fitting of the earplugs *(64)*.

Earplugs for use at music venues and events must reliably provide a meaningful level of protection from hearing injury, yet at the same time they should allow audience members to continue to hear and enjoy the music and to converse comfortably.

F4.2.4 Earplugs should also meet all other minimum requirements for construction, design, performance, marking, and user information, as specified in an applicable national or international standard (for example, standards set in Australia, Europe and the United States of America) *(65–67)*.

F4.3 Provision at venues and events

F4.3.1 Audience members should have access to suitable hearing protection at venues and events upon request, either cost-free or at an affordable cost.

F4.3.2 Without placing undue financial burden on audience members, the uptake of high-fidelity, reusable earplugs should be encouraged over basic, single-use earplugs as a more environmentally sustainable option. Such earplugs also offer a higher-quality listening experience, making it more likely that hearing protection is accepted and used consistently by audience members.

F4.3.3 The earplugs should be available to audience members at an accessible location (or locations) throughout the duration of an event. While earplugs may be offered to audience members upon entrance to the venue or event, there should also be an option for audience members wishing to acquire earplugs once an event is underway.

F4.3.4 Where possible, and to suit different ears, multiple sizes of earplugs should be made available to audience members at the venue or event. This is especially relevant for events that target children and where children are expected to attend.

F4.3.5 In addition to the printed instructions provided on the manufacturer's packaging, audience members should be directed towards a reliable source of online information where they can find video instructions on the correct use of the earplugs. This could be achieved, for example, by using a QR code on the packaging or on signage at the location where the earplugs are provided.

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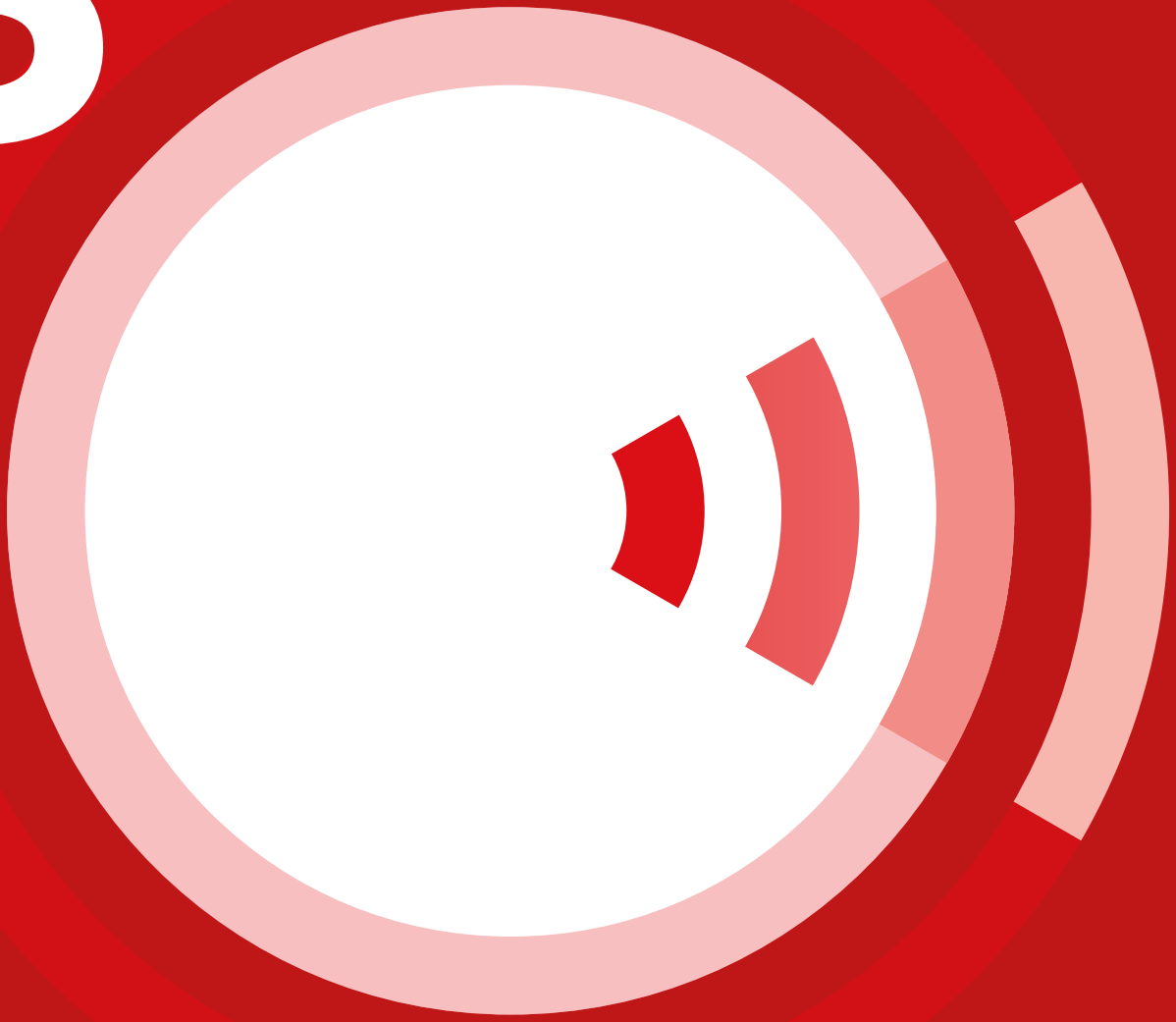


Feature 5:
Quiet zones

A designated quiet zone or zones will allow audience members to rest their ears from high sound levels

Feature 5: Quiet zones

A designated quiet zone or zones will allow audience members to rest their ears from high sound levels

- **Feature 5 provides a place for audience members to go to give their ears a rest from high levels of sound.**
- **Guidance is provided on suitable acoustic conditions and ambient sound levels in quiet zones.**
- **Alternative ways of offering periods of respite from high sound levels are suggested where venues cannot accommodate a quiet zone.**

F5.1 Key elements

F5.1.1 A quiet zone is a designated place at a venue or event that audience members can go to give their ears a rest from exposure to high levels of sound. This could help to reduce the risk of sound-induced hearing loss in multiple ways (see Box 6) *(10)*. Young people who attend events involving amplified music have indicated an interest and willingness to take advantage of quiet zones to help protect their hearing *(68)*.

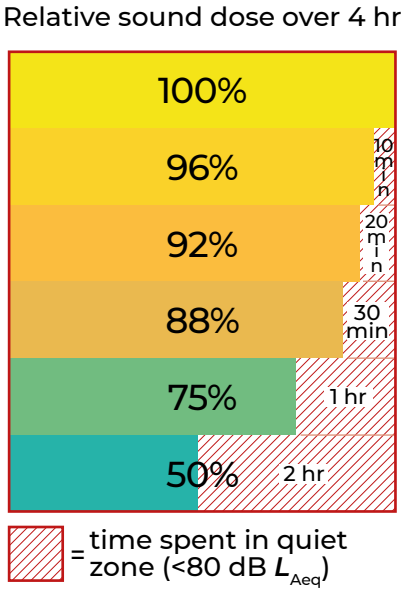
F5.1.2 The provision of one or more quiet zones at a venue or event should collectively, and safely, accommodate a reasonable proportion of the audience *(71)*. A target of at least 10 per cent of total audience capacity is suggested, although it is recognized that the practicality of achieving this is dependent on venue size, structure, and layout.

F5.1.3 Quiet zones should be clearly signed and accessible to audience members throughout the duration of the event. At permanent venues, outside areas should only be designated as a quiet zone if they are suitable for occupation in inclement weather and can be used throughout the duration of the event without contravening any local planning restrictions or environmental noise regulations *(46, 71)*.

F5.1.4 Audience members should not become more exposed to other health hazards (for example, cigarette smoke) while making use of a quiet zone.

Box 6:

Benefits of giving the ears a rest from high sound levels



There is a scarcity of studies and evidence that indicate the effectiveness of quiet zones in reducing the risk of hearing loss. However, there is clear evidence to show that the less time a person spends exposed to high sound levels, the lower their risk of hearing injury *(10, 23)*.

The figure to the left shows that, when a person spends a greater proportion of their time in a quiet zone, the relative sound dose (a measure of cumulative sound exposure) received reduces accordingly over the course of the event. This in turn can result in a reduced risk of hearing injury *(10, 23, 27)*.

While it is necessary for a person to spend considerable time (e.g. 30–60 minutes during the course of a 4-hour event), in a quiet zone to substantially reduce their overall exposure, there are other reasons why it may be beneficial to regularly give the ears a rest:

- There is some evidence that, by allowing partial recovery of the ear's delicate structures, regular periods of rest during otherwise continuous sound exposure have a protective effect exceeding that expected based on the modest reduction in cumulative sound dose alone *(69, 70)*.
- It is often only after entering a quiet environment that the perceptual effects of over-exposure to high sound levels (e.g. ringing in the ears, sounds seeming muffled, difficulty conversing) become clear. At this point individuals may be more likely to adopt self-protective behaviours, such as making use of personal hearing protection.

F5.2 Acoustic conditions within quiet zones

F5.2.1 For a quiet zone to be effective, sound levels must be purposefully kept to a level that poses minimal risk of causing or exacerbating any sound-induced hearing loss and that allows a degree of recovery of the delicate physiological structures within the inner ear following exposure to high sound levels. Audience members should also be able to converse without needing to raise their voices.

F5.2.2 To achieve this, the ambient sound level within a quiet zone should be kept as far below 70 dB $L_{Aeq,\,15min}$ *(23)* as is reasonably practicable.

The ambient sound level may be determined by sources such as mechanical ventilation noise, ingress of transportation noise from outside the building, low-level ambient music, or leakage of sound into the quiet zone from adjoining spaces in which music is played or performed at high levels *(46)*.

Sounds generated by the occupants of the quiet zone are excluded since, in practice, the level of these sounds would be extremely difficult to control. Ensuring that the ambient sound level in the quiet zone is, at most, moderate, creates conditions in which the overall sound levels naturally remain below 70 dB $L_{Aeq,\,15min}$ much of the time, even when factoring in the activity of the occupants.

F5.2.3 Indoor quiet zones should feature a reasonable amount of sound absorption (e.g. carpet, drapes, curtains, soft furnishings, or dedicated sound-absorbing panels) to control the build-up of reverberant sound. A suggested minimum is 20% of the total surface area of the walls and ceiling of the quiet zone. Absorption should be distributed around the room. This helps to prevent sound levels spiralling upwards when the room is occupied.

F5.2.4 Internal partitions separating a quiet zone from an adjacent space in which music is played or performed at high levels should be of a suitable construction to stop excessive sound leakage into the quiet zone. In general, either a solid masonry wall or a double-skinned partition of sufficient mass is likely to be required.

F5.2.5 Where a quiet zone directly adjoins a space in which music is played or performed at high levels, the spaces should be separated by two well-sealed door sets at either end of a lobby lined with sound-absorbing material. This helps to reduce airborne sound transmission into the quiet zone as people enter and leave through the doors.

F5.3 Alternative ways of offering respite from high sound levels

F5.3.1 In some venues, it may be impossible to provide a quiet zone of appropriate size because of space, architectural, fire safety, or access constraints *(46)*.

In such cases, it is still beneficial to offer audience members periods of respite from high sound levels. Such measures might include, but are not limited to:

i) temporarily dropping the level of any prerecorded music that is being played through the sound system to below 70 dB $L_{Aeq,\,15min}$ at periodic intervals (e.g. during the changeover between acts); and

ii) ensuring that sound levels are kept to a low-to-moderate level in auxiliary areas, such as bar areas, corridors, lobbies, and toilets.

F5.3.2 These alternative measures do little to reduce the cumulative sound exposure for audience members while at the venue or event. Nonetheless, importantly, they allow audience members an opportunity to recognize in themselves the signs of ear fatigue and consider adopting self-protective behaviours such as the use of personal hearing protection.

Box 7.
Case study: Quiet zones in Swiss music venues

According to the Swiss Ordinance to the Federal Act on Protection against the Risks associated with Non-Ionising Radiation and with Sound (O-NIRSA) *(71, 72)*, quiet areas (respite areas) must be provided when an event has an hourly sound level of up to 100 dB(A) and a duration longer than 3 hours. The quiet area must comply with the following requirements:

- the average sound level must not exceed 85 dB $L_{Aeq,\,1hr}$;
- the area must make up at least 10 per cent of the total area provided for the audience at the event;
- the area must be clearly marked and readily accessible to audience members throughout the event;
- more than 50% of the quiet area must be a smoke-free zone.

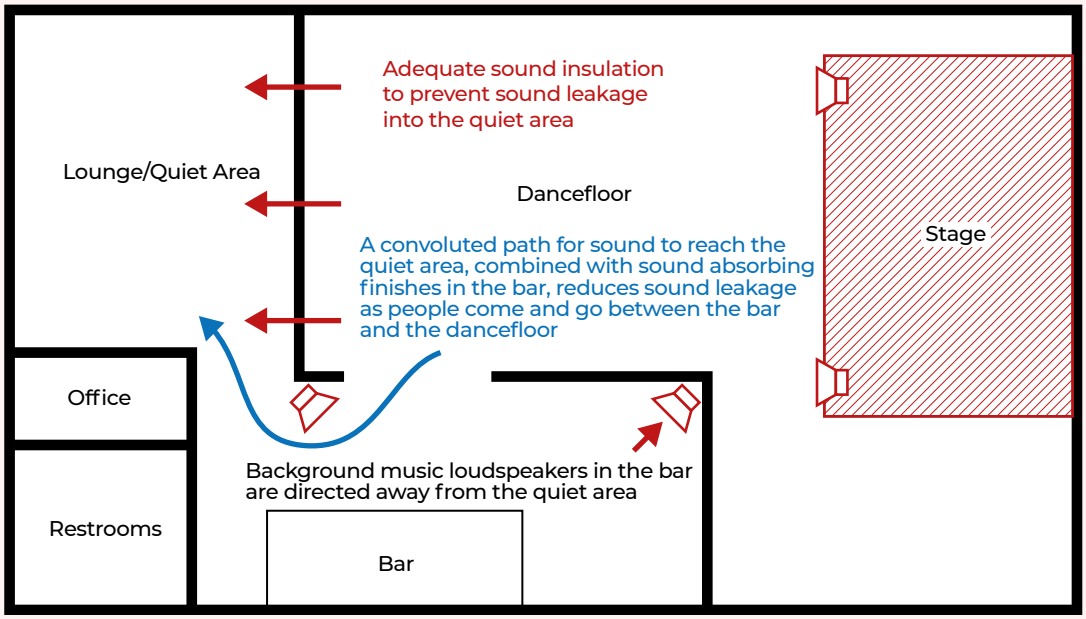


Image courtesy of Raphael Elmiger, Federal Office of Public Health Switzerland.

Box 7.

Case study: Quiet zones in Swiss music venues (continued)

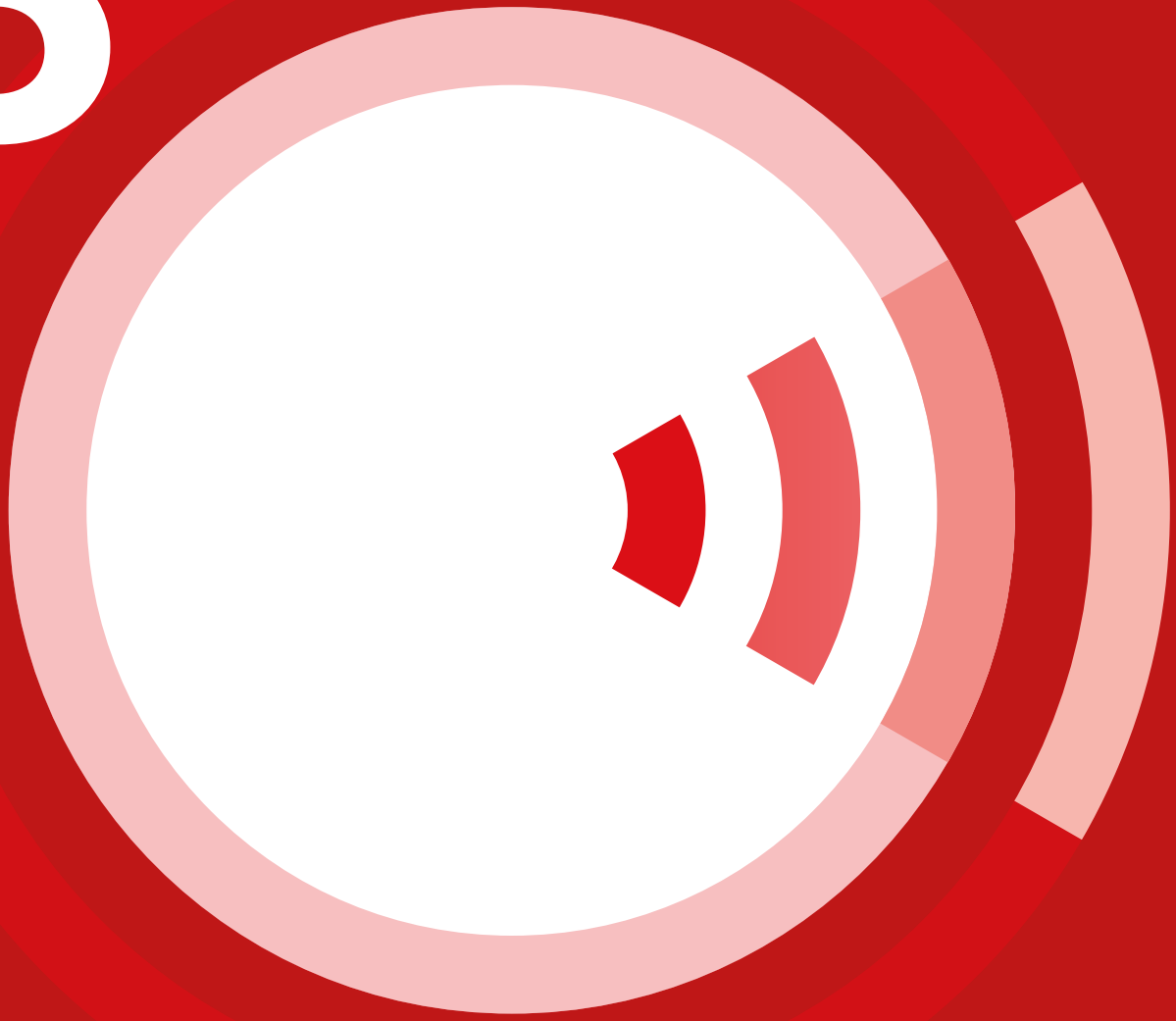
Experience in Switzerland shows that patrons typically make use of quiet zones for multiple purposes, beyond resting their ears. These include:

- to chat with friends if sound levels are too high to do so comfortably in the main venue room;
- to eat or drink;
- to rest during long parties; and
- to smoke (where permitted).

Interviews with venue owners and industry representatives in Switzerland have identified important considerations when planning a quiet zone:

- A suitably low ambient sound level in the quiet zone can be difficult to achieve if too much sound is leaking from the main room:
  - Ensure adequate sound insulation between the main room and the quiet zone.
  - Ensure that loudspeakers (especially high-frequency drivers) are not directed towards the quiet zone.
- Patrons may not want to make use of an unsuitable quiet zone:
  - Design the quiet zone to be a comfortable and attractive space.
  - Try to avoid the use of smokers' lounges, hallways, or other rooms without infrastructure as quiet zones.
- Finding suitable space for a quiet zone is challenging for smaller venues with limited space.
- Some patrons prefer to take a break outdoors, so try to facilitate this where possible:
  - Avoid one-way entry policies that prevent guests from re-entering after stepping outdoors.
  - Outdoor breaks must be balanced against the risk of noise disturbance to neighbouring properties.

6



Feature 6:
Provision of training and information

Appropriate training and information about safe listening is needed and must be provided

Feature 6: Provision of training and information

Appropriate training and information about safe listening is needed and must be provided

- **Feature 6 aims to make staff and audience members aware of the practical steps that can be taken to make listening safer and the importance of doing so.**
- **All staff in managerial, technical, and patron-facing roles should have a basic awareness of the safe listening measures in operation at the venue or event.**
- **More in-depth training is required for individuals who have responsibility for monitoring and controlling the sound level.**
- **Audience members should be provided with information about safe listening on tickets and on notices at the venue or event.**
- **A venue or event that has been certified by a competent authority as adequately implementing the features of this Standard may identify as a "safe listening venue" or "safe listening event".**

F6.1 Key elements

F6.1.1 Raising awareness among audiences and people working in the music and entertainment industries about the risk of permanent hearing injury following exposure to high sound levels, and the safe listening practices that can help to reduce that risk, is critical to achieving the overarching goal of this Standard: to create an environment in which people are empowered to enjoy amplified music while protecting their ears *(73–76)*.

F6.1.2 It must be acknowledged that many people who attend or work at venues and events do so because they enjoy the feelings and sensations associated with listening to music at high levels. Effective health communication messaging around safe listening must reflect this reality *(76–78)*.

F6.2 Training

F6.2.1 All venue or event staff employed in managerial, technical, and patron-facing roles should receive basic training that covers *(79)*:

i) the risk of suffering permanent hearing injury due to exposure to high sound levels; and

ii) the safe listening measures that are in operation at the venue or event.

F6.2.2 Individuals who are responsible for monitoring and controlling the sound level (the "responsible actor" under F1.4) should receive more in-depth training that, in addition to the above, covers:

i) the operation of the sound level measurement system (including, where relevant, procedures for maintenance and calibration);

ii) how to interpret the measured $L_{Aeq,\,15min}$ sound level;

iii) the sound level limit (or effective sound level limit – see Annex 5) that must be adhered to; and

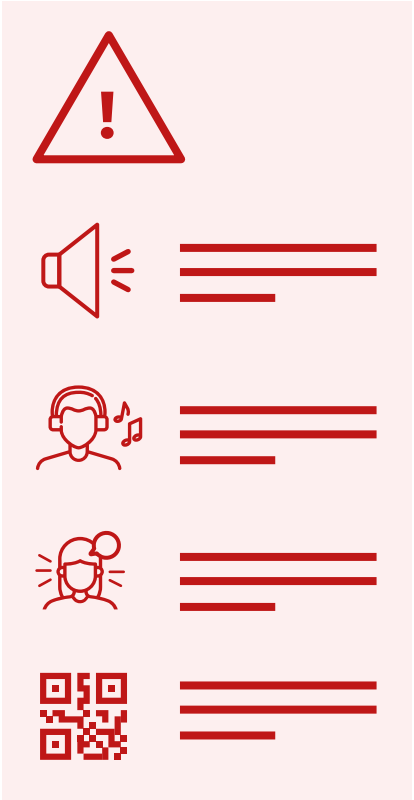
iv) how to control the output level (volume) of the sound system.

F6.2.3 Training should be refreshed at regular intervals, and when new staff members join, to ensure that skills and knowledge are kept up to date.

F6.2.4 Preliminary proposals have been put forward for a global training and certification scheme for live sound engineers *(79)*. Such a scheme could play a valuable role in developing the knowledge and skillset of live sound engineers, and in particular help equip them to tackle some of the unique challenges of controlling audience sound exposure in live-music settings. This could include negotiating with performers to reduce on-stage sound levels, and achieving a high-quality mix while complying with a sound level limit *(80)*.

F6.3 Information for audiences

F6.3.1 Where high sound levels are anticipated at a venue or event, electronic and printed tickets could include a warning about the risk of permanent hearing injury, alongside a link or QR code directing audience members towards a reliable source of information about safe listening (for example, the WHO Make Listening Safe FAQs).



F6.3.2 Notices should be prominently displayed at the entrance to venues and events and in visible locations inside venues (e.g. at bars or on internal doors) informing the audience about the safe listening measures that are in operation. These notices should as a minimum:

i) state that the sound level is being monitored;

ii) state where audience members can obtain hearing protection;

iii) state the location of any quiet zone(s); and

iv) include a link or QR code directing audience members towards a reliable source of information about safe listening (for example, the WHO Make Listening Safe webpage).

F6.4 Identification as a "safe listening venue" or "safe listening event"

F6.4.1 Where a venue or event has been certified by a competent authority as adequately implementing the features of this Standard, it may identify as a "safe listening venue" or "safe listening event". This could include the use of these (or similar) phrases on notices, on tickets, and in event listings and other marketing materials, online and in print.

F6.4.2 If a venue or event fails to meet the ongoing requirements of this Standard, as regards monitoring of sound levels, for example, then it ceases to be a "safe listening venue" or "safe listening event" and should immediately stop using either of those phrases in its online and printed materials.

F6.4.3 Governments may consider putting in place a mechanism to certify the status of venues and events to prevent unauthorized use of the "safe listening venue" or "safe listening event" labels and to allow audience members to look up the certification status of a venue or event.

Adoption and implementation of the WHO Standard for Safe Listening Venues and Events

Adoption and implementation of the WHO Standard for Safe Listening Venues and Events

This Standard is designed to support countries, owners and managers of entertainment venues and events, and civil society, in approaching hearing loss prevention in a way that is strategic, evidence-based, and user-friendly.

Adoption and implementation by governments

Implementation of this Standard can be promoted in the following ways:

Legislation or regulation: relevant departments in the government should develop appropriate laws/regulations/policies that address the issue of sound exposure mitigation in venues or events where amplified music is played. Such regulations should be based on the WHO global standard and developed through collaborative engagement with stakeholders including:

- different government departments such as health, education, environment, youth and culture;
- experts in acoustics and sound-system design;
- civil society groups, including associations of hard-of-hearing; NGOs, professional societies;
- youth organizations;
- associations of venue owners;
- major event organizers;
- consumer protection organizations; and
- others relevant to the context of the country.

It is anticipated that the diverse stakeholders will have varied and, at times, contradicting interests and opinions. A skilled chairperson must be appointed to coordinate the discussions. The aim would be to bring all groups to the common understanding of reducing exposure to amplified music at excessively high sound pressure levels. This could greatly facilitate the uptake of, compliance with, and acceptance of, the measures proposed in this Standard.

Support to venue owners and event organizers: the role of government or regulatory bodies should extend beyond development and implementation of regulations. They should partner with venue owners to ensure safe listening for the public, supporting them in this effort. Special attention should be given to:

- smaller inner-city venues that may have limitations of space and resources and hence may find it difficult to implement all features outlined in this Standard. Reasonable accommodations should be made in the policies for such venues while maintaining the required sound level limits. Specific implementation strategies for such venues have been discussed throughout this document.
- ensuring that venue owners do not face undue financial hardships or threats to their business model in implementing the Standard. Wherever possible, financial support should be considered for these businesses. An example of this is in Norway where the government has implemented a not-for-profit programme to help improve acoustics and sound systems in new and existing venues (see case study in Box 8).

Certification of safe listening venues: as mentioned in F6.4, governments should consider establishing a mechanism to certify venues or events as "safe listening". Due process for certification and regular monitoring is essential to ensure that the label is not misused.

Public awareness campaigns: along with legislation and other policies to implement the Standard, governments should launch a public awareness campaign within their country to raise awareness about:

- the risks posed by high sound levels, especially those experienced in recreational settings; and
- safe listening practices that can reduce the risk of hearing loss among listeners

Voluntary adoption by owners and managers of entertainment venues and events

Owners and managers of entertainment venues, concert halls, clubs, bars, gyms, or other venues where amplified music is played, as well as organizers of music festivals or other relevant events, can voluntarily implement all or some of the features outlined in this Standard, depending on what may be feasible. Sound engineers, technicians, and others involved with sound management at venues and events should also familiarize themselves with the features outlined here and implement them as part of good practice.

Investing in the hearing health of audiences and customers makes good business sense for an industry that relies on the hearing ability of its clients. Moreover, research shows that many people leave venues or events dissatisfied with having experienced sound levels that they consider to have been too high *(68, 74)*. Reduction in sound levels, along with improved venue acoustics and sound-system design, may well encourage people to spend more time at these venues and events, knowing that they will be able to enjoy high-quality sound without discomfort or risk to their hearing.

Schools of music and other institutions with education or training programmes on acoustics, sound engineering, and sound level management; as well as industry associations

Content on safe listening rationale and the features of this Standard should be included in the curriculum of all relevant courses that educate or train people involved in the creation, production, or performance of amplified music. Deans and professors of such institutions should ensure that a module on safe listening is included within the course curriculum. The module should focus on:

- the importance of hearing health;
- the effect of sound on the auditory system and human body;
- the prevention of sound-induced hearing loss;
- the principles of safe listening; and
- the features of the WHO Global standard for safe listening venues and events.

Furthermore, relevant industry associations representing musicians, audio engineers and others, should advocate on behalf of their cohort for the implementation of the features of this Standard: minimizing hearing risks is in the interest of the groups they represent.

Box 8.

Supporting venues to make improvements: a case study from Norway

Kulturrom is a not-for-profit organization that supports privately owned venues and rehearsal spaces in Norway, including for the purpose of improving facilities and equipment in order to achieve safer listening conditions. The organization receives funding each year from the Norwegian Department of Culture and Equality, via the Norwegian national lottery.

New venues, and those undergoing renovation, can apply for financial support for the following issues:

- Acoustic assessment
  - This includes assessment of the venue by a professional acoustician. Having a report of assessment is a pre-requisite for eligibility to apply for further funding.
- Acoustic treatment
  - This includes improvements in venue acoustics, based on the recommendations of the independent acoustic report.
- Equipment purchase
  - This includes the purchase or upgrade of equipment such as sound systems, mixing desks, lighting rigs, shared-use backline equipment (drum kits, amplifiers).
- Maintenance
  - This includes the assessment of existing equipment by a professional, repairs, and upgrades to ensure proper functioning.

Financial support is usually granted based on 75% funding of the total cost, with the venue contributing the remaining 25%. Each year, Kulturrom awards around 4 million Euros, and since starting in 2009, has invested close to 35 million Euros to improve concert venues, theatres, multipurpose houses, and rehearsal spaces. Each year around 200 initiatives receive funding – from small choirs to large concert venues.

For some years, Kulturrom has funded many venues to make improvements that have helped to achieve safer listening conditions for audience members by improving the venue acoustics and/or upgrading the sound system.

Kulturrom has also provided funding to install sound level measurement systems in more than 100 venues in Norway. These systems not only support individual venues in monitoring sound levels, they have also provided invaluable research data to inform safe-listening guidelines and regulations *(35)*.‡

‡ Støfringsdal B. Expected sound levels at concert venues for amplified music. Auditorium Acoustics. Hamburg, Germany; 2018.

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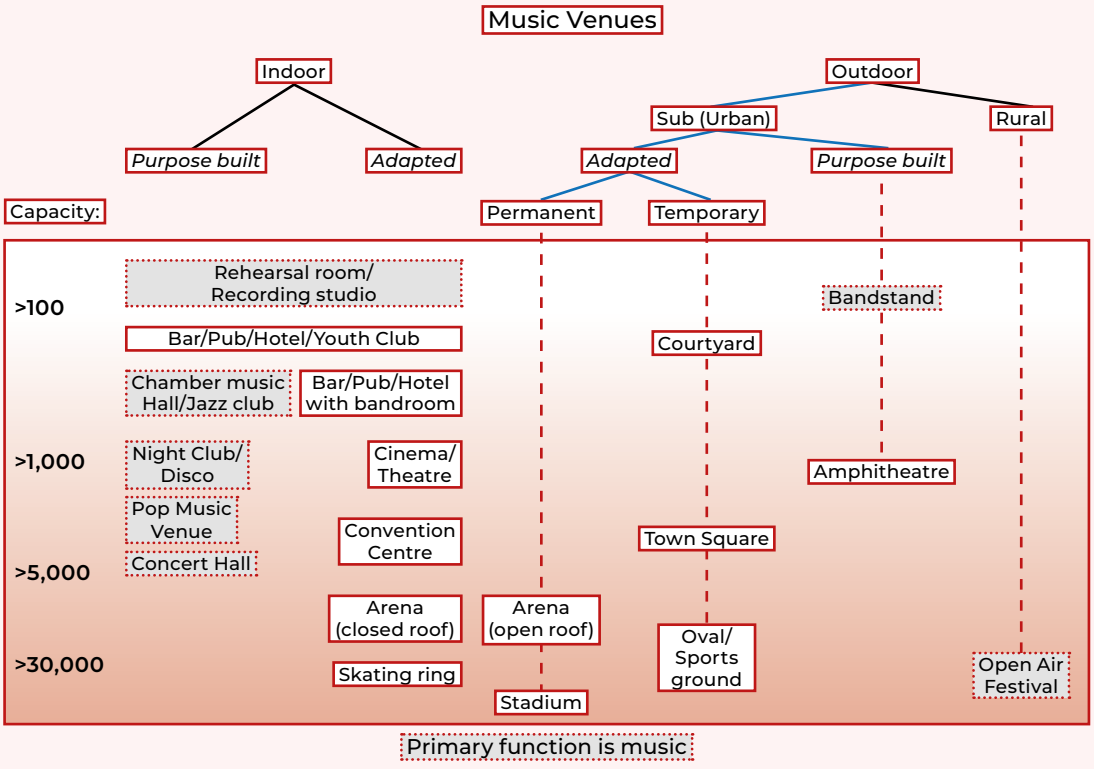
Annex 1.
A taxonomy of music venues

A diverse range of venues host events that feature amplified music as a central element. Some of the main dimensions on which venues vary are *(1)*:

- indoor vs. outdoor (with consequent differences in acoustics);
- whether the venue was purpose-built for music or adapted from another purpose;
- whether the venue's primary function is music or another purpose (e.g. sports); and
- size and audience capacity (from tens to hundreds-of-thousands of people).

The taxonomy in Figure A1.1 below describes the main variable dimensions for venues with amplified music.

Figure A1.1:
A taxonomy of music venues



Reference

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Annex 2.
Application of the WHO Noise Guidelines for the European Region to the sound level limit

The 100 dB $L_{Aeq, 15min}$ sound level limit set out in Feature 1 of the Standard is informed by the WHO Environmental Noise Guidelines for the European Region *(1)*, which recommends:

- Reducing the yearly average from all leisure noise sources combined to 70 dB $L_{Aeq, 24h}$, as leisure noise above this level is associated with adverse health effects.
- The equal energy principle can be used to derive exposure limits for other time averages, which might be more practical in regulatory processes.
- For single-event and impulse noise exposures, existing guidelines and legal regulations to limit the risk of increases in hearing impairment from leisure noise, in both children and adults, should be followed.
- Following a precautionary approach, to reduce possible health effects, policy-makers should take action to prevent exposure above the guideline values for average noise and single-event and impulse noise exposures.

Derived from these guidelines, and informed by a review of all available evidence *(2)*, the WHO-ITU global standard for safe-listening personal audio devices and systems *(3)* recommends a weekly limit of 1.6 Pa^2 h (Pascal squared hours) per 7 days as the reference exposure, which is equivalent to 80 dB(A) for 40 hours a week.

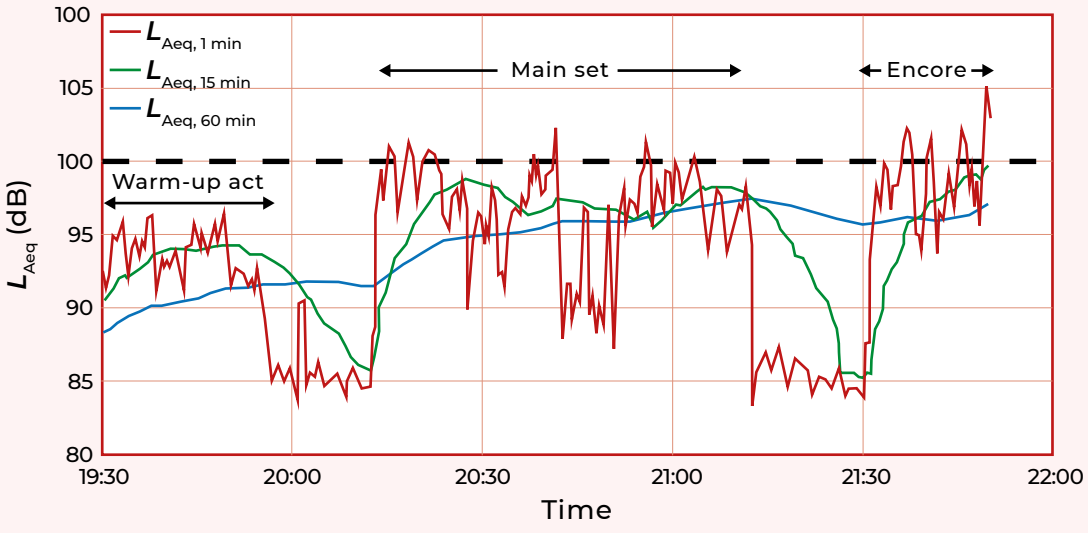
For parity across standards, the sound level limit for entertainment venues and events further applies the equal energy principle to the 80 dB(A) for 40 hours a week recommendation. This translates into a sound level limit of 100 dB(A) for approximately one hour 45 minutes per month. A survey undertaken by WHO and its collaborating centre to study behaviours of the target group regarding visiting venues shows that the majority (65%) of respondents visit entertainment venues once or fewer times a month on average *(4)*. Most people spend 1–3 hours at these venues *(4)*.

Based on these observations, a 100 dB(A) level is likely to cause no harm to the hearing of most audience members who visit entertainment venues or events on average no more than once a month and for around 2 hours (or less) per visit. Use of personal hearing protection such as earplugs should provide a minimum attenuation of 12 dB(A) (see Feature 4). This can increase the safe-listening period for its users by 16-fold. Hence, a 100 dB(A) sound level limit combined with the use of hearing protection such as earplugs can further offer protection to those visiting venues at greater frequency or staying longer, totalling up to around 6 hours a week on average.

Choice of averaging time interval

Figure A2.1 below shows how the time-averaged, A-weighted sound level, L_{Aeq} evolves over the course of a typical live-music event when different averaging time intervals are used (1 minute, 5 minutes, or 60 minutes).

Figure A2.1:
Evolution of time-averaged, A-weighted sound level: example for a live-music event



As a basis for monitoring and controlling the sound level during a live performance of a music band, the use of a 1-minute averaging time interval ($L_{Aeq,\,1\,min}$), would be problematic. The value of $L_{Aeq,\,1\,min}$ fluctuates by 10 dB+ within a band's set, and there are regular spikes in sound level as the crowd applauds between songs. It would not be practicable or appropriate for the sound engineer to be continually adjusting the output of the sound system in response to these fleeting changes in sound level.

The use of a 60-minute averaging time interval ($L_{Aeq,\,60\,min}$), which forms the basis of sound level regulations in some countries *(5, 6)*, can also be problematic in practice. Due to the long averaging time, $L_{Aeq,\,60\,min}$ tends to rise only gradually during a band's set, never reaching a stable value. Similarly, $L_{Aeq,\,60\,min}$ is slow to fall after a band has finished their set, meaning that when the next act comes on stage (typically after a break of around 20–30 minutes), the value of $L_{Aeq,\,60\,min}$ remains influenced by the performance of the previous act. If each band uses their own sound engineer, this could cause friction, with sound engineers finding that their freedom is constrained by the decisions and actions of their predecessor (unless the measurement system is reset before the start of each set, leading to discontinuities in the sound level measurements).

The use of a 15-minute averaging time interval ($L_{Aeq,\,15\,min}$), as recommended in this WHO Global standard for safe listening venues and events, represents a pragmatic choice. It is sufficiently long to allow the natural dynamics (the highs and lows in intensity) of a musical performance to be preserved within a band's set, while being short enough to provide sound engineers with the timely information they need to control the sound level effectively and independently between acts.

References

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Annex 3.
Spectrum of live sound and types of sound level measurements

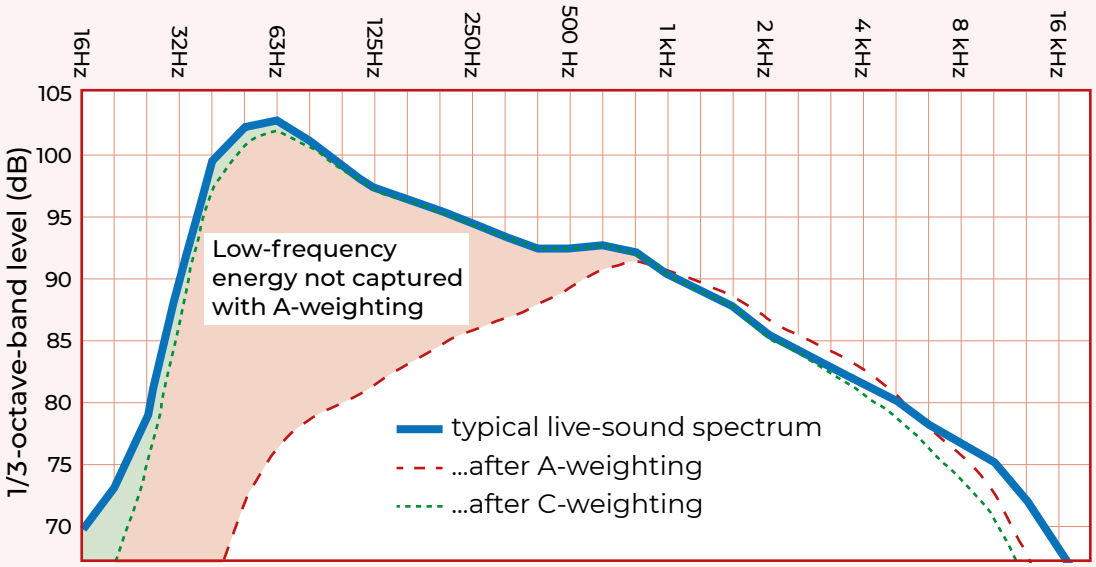
A-weighting and the spectrum of live sound

A-weighting is the most widely used frequency weighting for sound level measurements. Established risk criteria for noise-induced hearing loss are based on A-weighted exposure limits. For this reason, the sound level limit is specified as an A-weighted level.

A limitation of A-weighting is that it does not capture the entirety of the sound energy present in amplified music, nor does it reflect the way the human hearing system responds to intense sounds. Long-term sound level logging in music venues hosting pop, rock, and jazz concerts reveals the presence of prominent low-frequency ("bass") energy in amplified live sound.

As can be seen in Figure A3.1, after the application of A-weighting, this low-frequency region is significantly down-weighted and so contributes little towards the overall sound level. A-weighted measurements thus do not inform much about the level of low-frequency sound energy to which an audience is exposed.

Figure A3.1:
Discrepancy in low-frequency contribution with A-weighted sound-level measurements



An alternative frequency weighting, C-weighting, gives more weight to the low frequencies and is closer to the way that humans perceive sounds at high sound pressure levels. As can be seen in Figure A3.1, unlike A-weighting, C-weighting is able to capture the energy of live sound over the full audio bandwidth (20–20000 Hz).

Fortunately, transmission of low frequency sound through the outer and middle ear is far less efficient than for sound in the mid-frequency range (250–4000 Hz) *(2)*, hence low-frequency exposure is widely assumed to be less harmful to hearing. Nevertheless, it is yet to be proved that exposure to intense low-frequency sound does not cause hearing injury *(3)*.

Recognizing the potential risk posed by intense low-frequency exposure, the safe-listening regulations developed in some European countries, most notably France *(4)*, include an additional time-averaged, sound level limit based on C-weighting, expressed as L_{Ceq}.

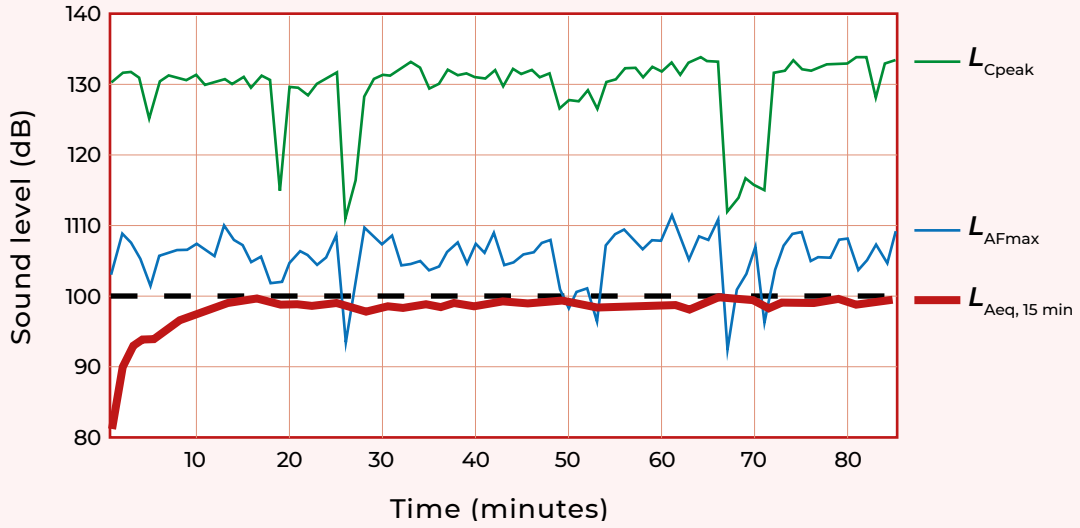
The WHO Global standard for safe-listening venues and events does not include a C-weighted sound level limit for the following reasons:

- further research is needed to clarify the risk of intense low-frequency sound exposure to human hearing;
- there is currently a lack of clear evidence on which to base a specific C-weighted sound level limit; and
- obtaining reliable measurements of low-frequency sound levels can be challenging, particularly in small indoor venues.

Different types of sound level measurements

Figure A3.2 shows sound level data collected over the course of a professional performance at an outdoor festival in Germany .

Figure A3.2:
Different types of sound level measurements throughout a performance



Three separate traces are plotted in the figure, corresponding to different types of acoustic measurement:

1) $L_{Aeq, 15min}$ — this is the A-weighted equivalent continuous sound level with a 15 minute averaging time interval, the same type of measurement used to define the sound level limit in this Standard. The sound level remains below 100 dB $L_{Aeq, 15min}$ at all times (the limit that was in place for this particular event).[1]

2) L_{AFmax} – this is the maximum time-weighted sound level using A-weighting and "fast" time weighting (exponential time constant of 125 milliseconds). The L_{AFmax} level fluctuates far more than the L_{Aeq}, and regularly approaches 110 dB L_{AFmax}.

3) L_{Cpeak} – this is the peak instantaneous sound level without any time weighting or averaging. The peak sound level is normally measured using the C- frequency weighting. Apart from during gaps between songs, the peak sound level routinely exceeds 130 dB L_{Cpeak}.[2]

This example demonstrates that different types of sound level, while all measured in decibels, cannot be directly compared. When measuring, reporting, or interpreting sound levels, it is crucial to specify precisely the type of measurement under consideration, including any frequency or time weightings applied.

Setting up the sound limiter

Where the sound system is capable, in principle, of producing peak levels above 140 dB L_{Cpeak}, the output from the system should be controlled by a fast-acting electronic limiter to prevent peak levels above 140 dB L_{Cpeak}. Ordinarily the operation of the sound limiter is set up in advance (e.g. during commissioning of the sound system or at sound check) to ensure that peak levels do not exceed 140 dB L_{Cpeak} at the most-exposed location in the audience area. Once appropriately set, the limiter is a reliable fail-safe last resort. Real-time monitoring of peak sound levels need not be undertaken: control of peak sound levels is considered a system-design feature, separate from the need for ongoing monitoring of the A-weighted sound level.

1 Note that even though the limit of 100 dB $L_{Aeq, 15 min}$ was adhered to throughout, the sound dose received over the duration of this ~90 minute performance would have been equivalent to around 600% of the allowable daily noise dose under occupational noise regulations

2 Note that the measurement microphone was positioned at the FOH mixing desk for all of these measurements; audience members in the front rows would have been exposed to considerably higher peak sound levels than shown.

The purpose of the limiter is not to shut down or silence the music if the sound level becomes too high: its purpose is to protect against sudden extreme peaks by capping the the level at which these will be reproduced through the sound system.

References

1. Støfringsdal B. Expected sound levels at concert venues for amplified music. Auditorium Acoustics. Hamburg, Germany; 2018.
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Annex 4.
The importance of calibration

Sound level meters, and especially measurement microphones, are delicate pieces of equipment that are easily damaged if mishandled. Furthermore, even fully functioning devices are sensitive to changes in environmental conditions including temperature and humidity. Many venues present a hostile environment for precision measurement equipment, in which devices may be subject to physical knocks and changes in temperature or humidity over the course of an event.

Regardless of the quality or expense of a sound level meter, the only way to know that it is giving accurate readings is to subject it to a known sound pressure level and verify that it reports the correct level *(1)*. If necessary, small adjustments may be made to the sensitivity of the meter so that it reports the correct value. This process is known as calibration. International standards for the measurement of sound levels ordinarily require that the calibration of the sound level meter is verified immediately before and after every set of measurements *(2)*.

Image courtesy of Marcel Kok, dBControl.

Calibration can be verified using an acoustic field calibrator – a small, battery-powered device that generates a tone at a known frequency and sound pressure level (SPL) (usually a 1 kHz tone at 94 dB SPL or 114 dB SPL).

Image courtesy of Marcel Kok, dBControl.

The measurement microphone is inserted into the calibrator, and the reading displayed on the sound level meter is then checked to verify that it matches the expected sound level within an acceptable tolerance (e.g. ≤+/-0.2 dB). Regular calibration before and after each event is the best way to monitor for any signs of damage to the measurement equipment and/or unexplained drift in the measurements over time. Any such issues should be investigated promptly to determine their cause.

The highest level of accuracy can be ensured by checking the calibration immediately before and after every event, maintaining records of the calibration results, and investigating the cause of any drift of more than ±0.2 dB between consecutive calibration events. However, a more relaxed calibration schedule (for example, weekly or monthly calibration checks with a tolerance of ±1 dB) might be considered adequate for long-term sound level monitoring in venues.

The calibrator must itself be checked from time to time to ensure that it is generating the correct sound pressure level. This is usually achieved by sending the calibrator to an approved laboratory for calibration using specialist equipment.

References

1. Mulder J, McGinnity S. Sound level measurement, monitoring, management, and documentation in music venues. Make Listening Safe. World Health Organization; May 2020 (https://cdn.who.int/media/docs/default-source/documents/health-topics/deafness-and-hearing-loss/monograph-on-sound-level-measurement-management-and-documentation-in-music-venues.pdf?sfvrsn=69990849_5, accessed 29 November 2021).

2. ISO 1996-2:2017. Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of sound pressure levels. International Standardization Organization; 2017.

Annex 5. Location of sound level measurement

Determination of the reference measurement position

The sound level limit applies at the reference measurement position, which must be determined in advance for each venue or event. Different approaches to determining the reference measurement position are possible. The greatest protection of audience hearing is achieved by identifying as the reference measurement position the location within the audience area at which the sound level is at its highest (typically directly in front of the main loudspeakers). This ensures that all audience members experience a sound level no higher than the sound level limit, regardless of where they are seated or standing. However, this approach may be infeasible in smaller venues and/or those that cannot afford to invest in a high-end sound system.

An alternative, and broadly applicable approach, is to identify as the reference measurement position a location at which the sound level is representative of that to which a majority of the audience is exposed (accepting that individuals choosing to stand close to the stage or loudspeakers may experience a higher sound level). For this purpose, it is appropriate to identify the reference measurement position as being at the centre of the "core audience area." The core audience area is the primary area that would ordinarily be occupied by audience members actively attending to the music (e.g. the area in front of the stage, or the main dancefloor). It extends from the front row to the rear of the area ordinarily occupied by audience members (or, for venues with a balcony, from the front row to the front edge of the balcony). Example scenarios for measurement locations included in the following section assume application of this approach.

Use of an alternative long-term measurement position

It is often not practicable to measure the sound level directly at the reference measurement position. In such cases, it is necessary to measure the sound level elsewhere (at a "long-term measurement position"), and, where necessary, apply a correction to

the measured values. No correction is needed if the long-term measurement position is:

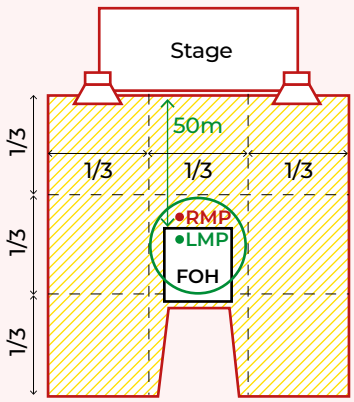
i) within the central 1/3rd of the core audience area across its width and depth;

and

ii) no more than 70 metres from the front row of the audience.

This is due to evidence generated through research conducted for the Government of the Netherlands *(1)*. The evidence indicates that, across a variety of venues of different types and sizes, the sound level within this central region will typically deviate from that at the reference measurement position by no more than ±1.5 dB(A). If the long-term measurement position falls outside of the prescribed area around the centre of the core audience area, a correction must be determined following the procedure described in Annex 6. Figures A5.1, A5.2, and A5.3 describe possible scenarios with appropriate measurement positions.

Figure A5.1:
Scenario A

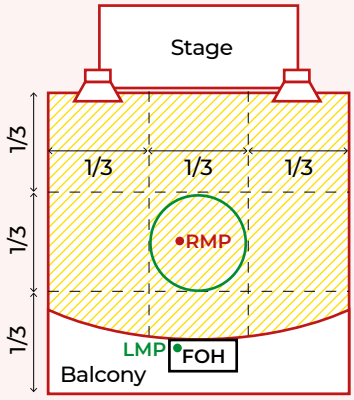


- **RMP =** Reference Measurement Position
- **LMP =** Long-term Measurement Position
- **=** Core audience area

Scenario A depicts an outdoor festival stage. The reference measurement position, at the centre of the core audience area, lies within the crowd. It is not practicable to place a measurement microphone here, and so the sound level is instead measured at the FOH mixing desk (the long-term measurement position).

The long-term measurement position at FOH lies within the central third of the core audience area (in both width and depth) and is less than 70 metres from the front row of the audience. The sound level measured at the long-term measurement position is therefore considered representative of that occurring at the reference measurement position, and no correction is needed.

Figure A5.2:
Scenario B



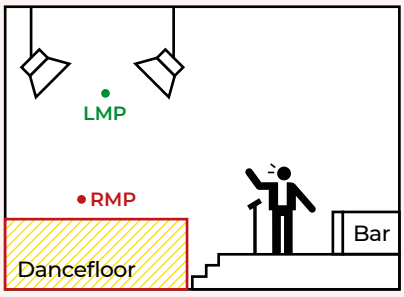
- **RMP =** Reference Measurement Position
- **LMP =** Long-term Measurement Position
- = Core audience area

Scenario B depicts an indoor concert venue. There is a balcony at the rear of the venue, and the FOH mixing desk is located at the front of the balcony, overlooking the stage.

The core audience area covers the area at main floor level between the front row of the audience and the front edge of the balcony. The reference measurement position is in the centre of the core audience area.

For reasons of practicality, FOH is again used as the long-term measurement position. In this venue, the long-term measurement position does not lie within the prescribed area around the reference measurement position. A correction must therefore be applied to the sound level measured at FOH to estimate the sound level occurring at the reference measurement position (see Annex 6).

Figure A5.3:
Scenario C



- **RMP =** Reference Measurement Position
- **LMP =** Long-term Measurement Position
- = Core audience area

Scenario C depicts a nightclub with a sunken dancefloor. The sound system comprises ceiling-hung loudspeakers to achieve an even distribution of sound and to prevent anyone getting too close to a loudspeaker.

With this scenario, there is no stage in the venue: the core audience area corresponds to the main dancefloor. The reference measurement position is at audience head height in the centre of the dancefloor.

To keep the measurement microphone safe from damage, it is suspended from the ceiling, above the dance floor. Because the long-term measurement position is at an elevated height, with the loudspeakers directed downwards towards the dancefloor, the sound level may be different at the long-term measurement position compared with the reference measurement position. A correction is therefore required (see Annex 6).

Display of sound level measurement with correction

Where a correction is required, it should be applied automatically so that the sound level displayed to the responsible actor directly corresponds to that at the reference measurement position.

Where this is not possible, an alternative is to adjust the sound level limit by an amount equal to the correction. For example, if the required correction is +5 dB(A), and the uncorrected sound level is displayed, the responsible actor will then need to work to an effective sound level limit of 95 dB $L_{Aeq,\,15min}$. In such cases, the effective sound level limit should be prominently displayed next to the sound level display.

References

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Annex 6. Procedure for determining the required correction for sound measurement

Where the long-term measurement position is different from the reference measurement position (see Annex 5), the required correction can be determined as follows.

The process should be undertaken when the venue is unoccupied and at a time when ambient noise levels are low enough to not interfere with the measurements.

All measurements should be made with a duration of at least 30 seconds.

i) Set up the measurement microphone or a self-contained sound level meter at the reference measurement position.

ii) Play a suitable test signal through the sound system at a moderately high sound level (according to whether following Variation A or Variation B – see below).

iii) Take a measurement of the time-averaged sound level at the reference measurement position ($L_{eq,\ ref}$).

iv) Move the measurement microphone or self-contained sound level meter to the long-term measurement position.

v) Restart or continue to play the test signal through the sound system, taking care to ensure that its level at source has not been changed in any way.

vi) Take a measurement of the sound level at the long-term measurement position ($L_{eq,\ long\text{-}term}$).

vii) Calculate the required correction as the difference in sound level between the reference measurement position and the long-term measurement position ($L_{eq,\ ref} - L_{eq,\ long\text{-}term}$).

There are two variations of the method:

1. Variation A – frequency-specific method (preferred)

- Using this method, the required correction ($L_{eq,\ ref} - L_{eq,\ long\text{-}term}$) is calculated separately for each frequency band.
- The calculation may be performed in either octave bands or 1/3-octave bands with centre frequencies spanning, as a minimum, the range from 63 Hz to 16 kHz.
- Frequency-band-specific levels should be measured with linear frequency weighting.
- The recommended test signal when using Variation A is broadband pink noise.
- This method is suitable only when the sound level measurement system includes a feature to automatically apply the correction on a frequency-band-specific basis.
- The advantage of this method is that it continually accounts for variation in the frequency spectrum of the sound being reproduced through the sound system.

2. Variation B – broadband method

- Using this method, the required correction ($L_{eq,\ ref} - L_{eq,\ long\text{-}term}$) is calculated as a single, broadband value.
- The sound levels at the reference measurement position and the long-term measurement position should be measured as broadband, A-weighted levels.
- The recommended test signal when using Variation B is broadband brown noise, as this type of signal has a frequency spectrum that approximates real musical material.

A limitation of this approach (common to Variations A and B) is that it does not account for the spillage of sound from the stage into the audience area that may occur during a live performance; only the sound level produced by the sound system is corrected.

Annex 7.
Suitable reverberation times for amplified music and acoustic treatment

Suitable reverberation times for amplified music *(1)*

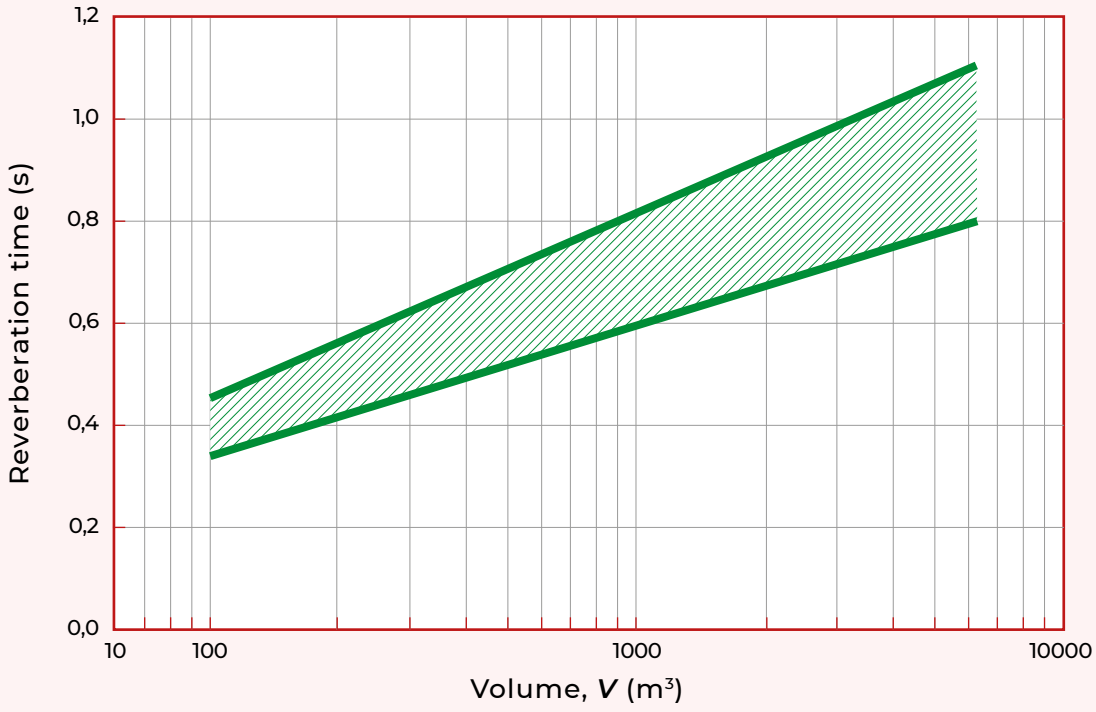
Amplified music generally sounds best in venues with well-damped room reverberation, i.e. a “dry” acoustic character. At the same time, venues should not aim for an excessively short reverberation time, as an acoustically “dead” venue tends to result in unsatisfactory conditions for the musicians. A balance is therefore needed.

Building on extensive research conducted by Niels Werner Adelman-Larsen, summarized in his book, *Rock and pop venues: acoustic and architectural design (2)*, Norwegian standard NS 8178:2014 recommends reverberation time (RT60) design targets for performance halls for amplified music *(3)*.

Recommended mid-frequency reverberation times are given as a function of room volume. These relate to the reverberation time measured in a furnished, but unoccupied, venue. Upper and lower limits for the acceptable reverberation time are provided, indicated by the shaded region in Figure A7.1 below.

Figure A7.1:

Recommended mid-frequency reverberation times* for venues for amplified music, as a function of room volume

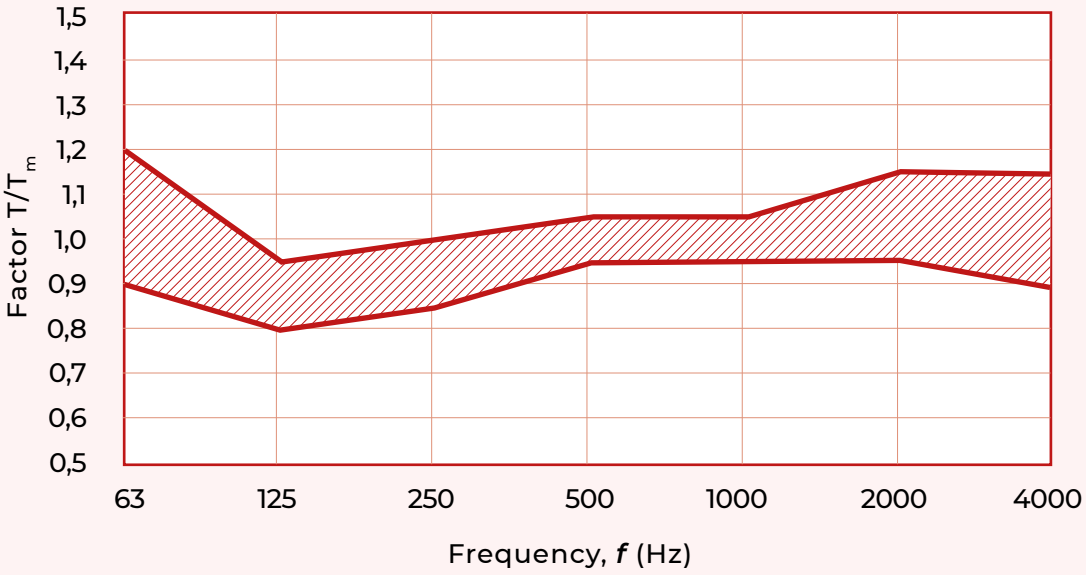


* mean RT60 across the 500 Hz and 1 kHz octave bands.

Good sound quality in a venue for amplified music depends not only on the overall level of reverberation being adequately controlled, but also on the reverberation time being reasonably equal in all frequency bands. Control of reverberation in the 125 Hz octave band is especially important to allow sound engineers to achieve a clear and controlled mix *(4)*. Norwegian standard NS 8178:2014 therefore also gives recommended tolerances for RT60 in octave bands from 63 Hz to 4 kHz, expressed as a ratio of RT60 in each octave band to the mid-frequency RT60 (average RT60 across the 500 Hz and 1 kHz octave bands – see Figure A7.2) *(3)*.

Figure A7.2:

Recommended tolerances for reverberation time* at different octave bands for venues for amplified music



* T expressed as a ratio to the mid-frequency reverberation time T_m (mean RT60 across the 500 Hz and 1 kHz octave bands).

These recommendations apply to venues that are dedicated to hosting amplified-music events, such as rock/pop concerts or club nights. Since longer reverberation times are generally required for acoustic music (such as orchestral or choral performances), multipurpose venues that host both amplified and unamplified events are advised to explore options for variable acoustics. This could involve, for example, retractable curtains, or rotatable panels that can present either a sound absorbing or sound reflecting surface, allowing the acoustics to be tailored to the needs of a specific event.

Acoustic treatment of a venue

The acoustics of a venue can be modified by introducing new materials or surface finishes. There are different types of acoustic treatment, designed to achieve different goals.

Sound absorption

Sound absorbers remove sound energy from the air when a sound wave impinges on them. Sound absorption is mainly used to control room reverberation or to reduce the strength of sound reflecting off a surface.

Different approaches are needed to absorb sound in different frequency ranges. Most soft materials, for example, soft furnishings, curtains and drapes, and dedicated acoustic panels made of material such as mineral wool, naturally absorb sound at mid-to-high frequencies. Absorbing sound at low frequencies is more challenging and relies on the use of thicker absorbers and/or damped resonant systems. Examples of these include Helmholtz and membrane resonant absorbers, and inflatable absorbers. Figure A7.3 provides a visual representation of the absorption properties of different objects as described above.

In some cases, it may be possible to incorporate low-frequency absorption without reducing available space in the venue. For example:

- In a venue with perimeter seating, the volume under the benches could be converted to act as a resonant absorber.
- A suspended ceiling can also provide effective low-frequency absorption, if it is mounted at least 30 cm below the structural ceiling and has a layer of sound-absorbing material (e.g. mineral wool) overlaid atop the tiles within the ceiling void.

Figure A7.3:
Absorption properties of different objects

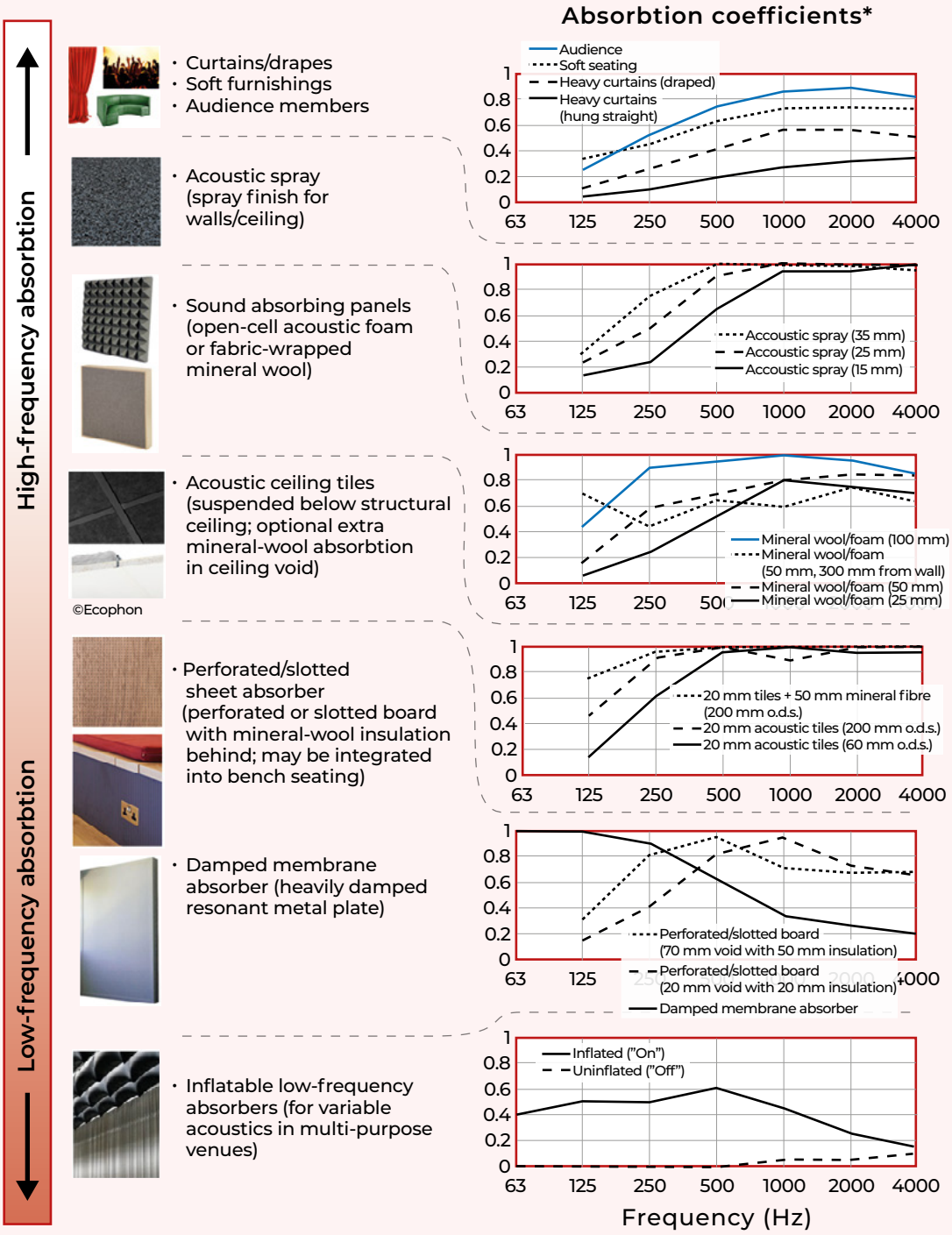


Image examples above courtesy of: Stil Acoustics, t.akustic, Ecophon, RPG Acoustical Systems, and Flex Acoustics. Inflatable absorbers from Flex Acoustics created and patented by Niels W Alderman-Larsen.

Sound diffusion

Sound diffusers are surfaces or objects designed to reflect sound in many different directions. Sound diffusion is used to spread sound energy as evenly as possible or to deal with problematic reflections. This can be through use of:

- Convex reflecting surfaces

Images courtesy of RPG Acoustical Systems.

- Surfaces with varying depth profile

- A patchwork arrangement of absorbing/reflecting surfaces.

Safety

When introducing any form of acoustic treatment into a venue, it is crucial to ensure that all materials meet appropriate standards for fire resistance/retardancy and will not release carcinogenic or otherwise toxic fibrous particles into the air.

References

1. Wiggins IM, Liston K. Sound distribution for safe listening in entertainment venues: a review. Make Listening Safe. World Health Organization; September 2020 (https://cdn.who.int/media/docs/default-source/documents/health-topics/deafness-and-hearing-loss/monograph-on-sound-distribution-for-safe-listening-in-music-venues.pdf?sfvrsn=c16f7a38_5, accessed 29 November 2021).
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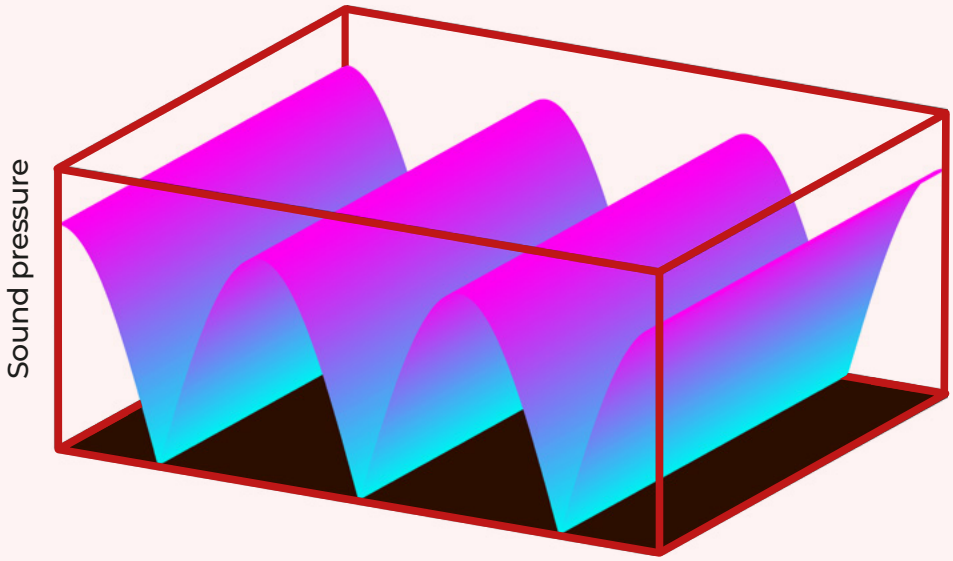
Annex 8. Low-frequency acoustic issues

Low-frequency acoustic issues have limited direct influence on the A-weighted sound level because of the relative insensitivity of the A-weighting curve to low frequencies (see Annex 3). However, good acoustic control of the low-frequency range, especially in the 125 Hz octave band, is critical to the sound quality of amplified music *(1)*. In part, this is due to a phenomenon called the upward spread of masking *(2)*, in which lower frequency sounds have a more pronounced effect on the ability to hear higher frequency sounds than vice versa. It is important to deal with any low-frequency acoustic issues in a venue so that sound engineers can achieve a clear and impactful mix at a controllable sound level.

Room modes can be a cause of low-frequency problems in small indoor venues with a volume less than around 1000 m^3 *(3–6)*.

Room modes *(7)* occur at frequencies where the distance sound travels between opposing surfaces of the room is an exact multiple of half a wavelength. At these frequencies, sound bouncing back and forth between the surfaces undergoes systematic constructive and destructive interference, setting up a “standing wave” pattern. The result is alternating regions of high and low sound pressure throughout the room, as depicted in Figure A8.1.

Figure A8.1:
Example illustration of a room mode



If the low-frequency (bass) response seems very uneven or "boomy" when moving around a small venue, this may indicate an issue with room modes. The introduction of more low-frequency sound absorption is generally required (see Annex 7).

Room modes are generally not a problem in mid- and large-sized venues; in these settings many room modes overlap at a given frequency, causing an averaging of the fluctuations and resulting in a more spatially uniform sound field.

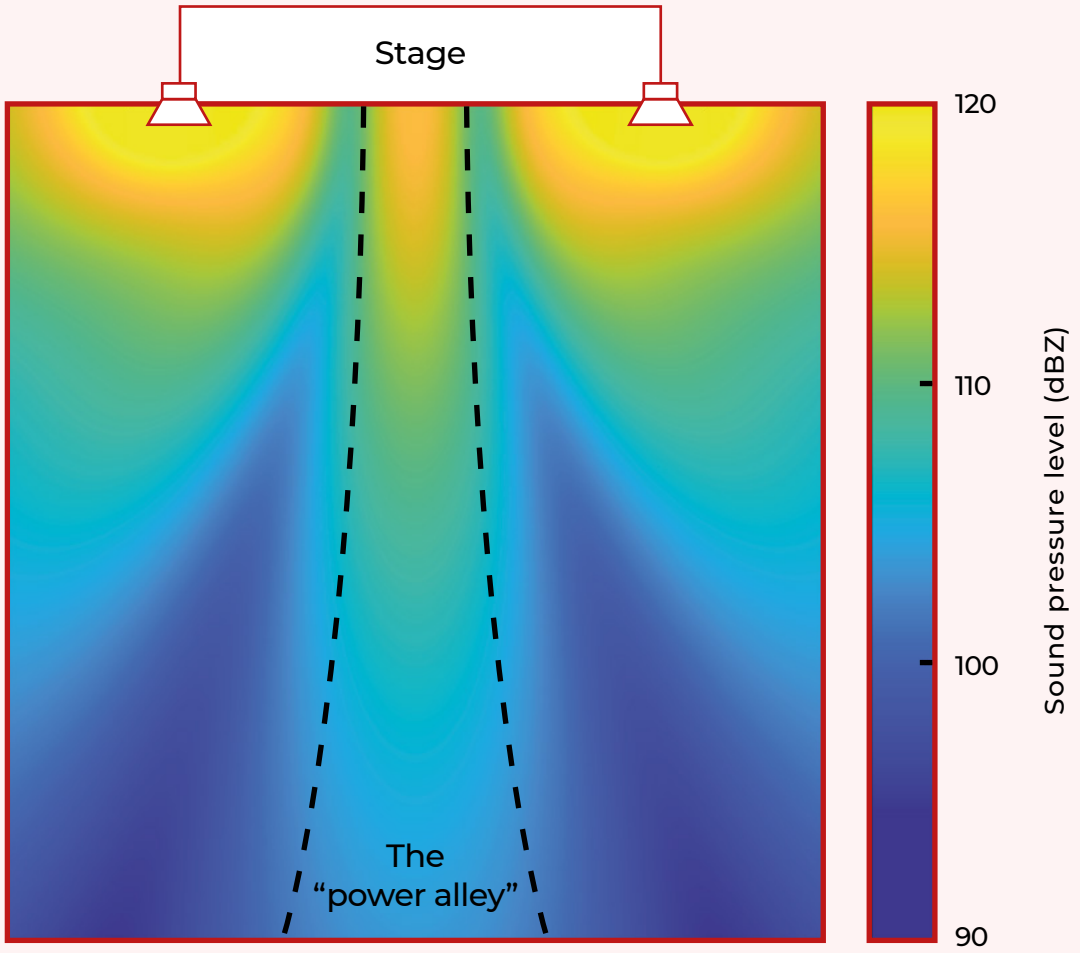
Coherent interference and the "power alley" effect *(7)*

A different type of low-frequency issue, which can arise in indoor or outdoor venues of any size, results from coherent interference between direct and/or reflected sound from one or more loudspeakers.

For example, in the common case of a spaced left–right pair of subwoofers placed on either side of the stage, coherent interference between the loudspeakers can result in a channel of increased low-frequency sound energy running down the centre of the audience area (known colloquially as the "power alley"). Members of the audience may experience a very different balance between low and high frequencies, depending on whether they are standing inside or outside of the power alley (see Figure A8.2).

Physical and electronic approaches can be taken to reduce coherent interference between loudspeakers *(8)*.

Figure A8.2:
Example illustration of the low-frequency "power alley" effect



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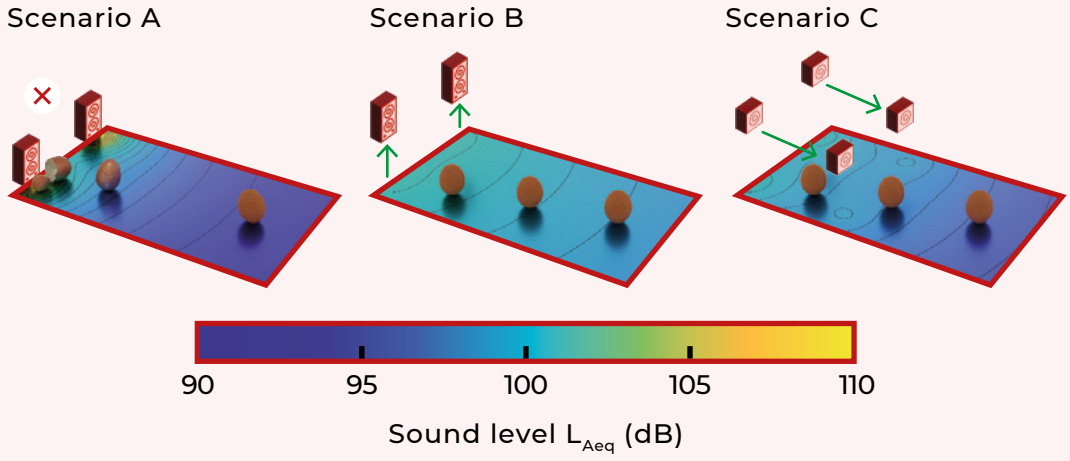
Annex 9.
Sound distribution for safe listening

Loudspeaker positioning

In order to achieve a reasonably uniform distribution of sound across the audience area, it is fundamental to avoid a situation where some audience members are much closer to the loudspeakers than others *(1)*. This is because the level of the direct sound decreases with distance from the loudspeakers, falling off at a rate of up to 6 dB for every doubling of distance.

Figure A9.1 illustrates three scenarios. Scenario A depicts a worst-case, yet commonly seen, arrangement, in which the loudspeakers are stacked on the floor (or on the front of the stage) with nothing to stop audience members from approaching them. Listeners at the front of the audience are many times closer to the loudspeakers than those at the rear. Sound from the loudspeakers will also be partially blocked from reaching the rear of the audience by the people standing in front. The result is that audience members at the front are dangerously over-exposed, while those at the rear may struggle to hear the music clearly.

Figure A9.1:
Positioning of loudspeakers and the effect on sound distribution



Scenarios B and C show two ways in which the situation can be improved. If the venue has sufficient ceiling height, the loudspeakers can be elevated ("flown") by hanging them from the ceiling (Scenario B). The listener-to-loudspeaker distance is thus more equal across the audience area, and everyone has a clear line of sight to the loudspeakers. The result is a safe and satisfactory sound level for all audience members, regardless of location.

Scenario C shows an arrangement that can be used to good effect in venues with a more limited ceiling height *(2)*. The main loudspeakers are again suspended from the ceiling, but at a lower height than in Scenario B. The delivery of sound to the rear half of the audience area is supported by a set of (smaller and less powerful) delay-fill loudspeakers. The signal sent to these loudspeakers is electronically or digitally delayed so that the sound from them arrives in synchrony with, or very slightly later than, the sound from the main loudspeakers at the front. This creates the perceptual impression that the sound originated from the band on stage, and not from a set of loudspeakers mounted midway over the audience area.

Placement of subwoofers

Subwoofers are loudspeakers that are dedicated to reproducing low-frequency sound below approximately 100 Hz. There is currently no clear evidence to suggest that such low-frequency sound is harmful to human hearing. However, flying the subwoofers above head height can lead to a more uniform distribution of low-frequency sound from front to back of an audience *(3)*. This may not always be possible due to limitations of a venue's ceiling height and/or load-bearing capacity. However, it is preferable to fly the subwoofers where possible, pending a better understanding of the risk that low-frequency sound exposure poses to hearing.

The positioning of the subwoofers will generally have only a limited direct effect on A-weighted sound levels at the reference measurement position, and therefore on the ability to comply with the 100 dB $L_{Aeq,\,15min}$ sound level limit. It may, however, dictate the overall level of low-frequency sound that can be produced by the sound system without causing audience members in the front rows to be exposed to peak levels above 140 dB L_{Cpeak} (see F1.3.3).

Loudspeaker directivity

Loudspeakers do not emit sound equally in all directions, particularly at mid and high frequencies, where most sound-reinforcement loudspeakers are designed to project sound over a defined coverage angle (e.g. 90 ° horizontal x 60 ° vertical).

The benefits of directing loudspeakers are to:

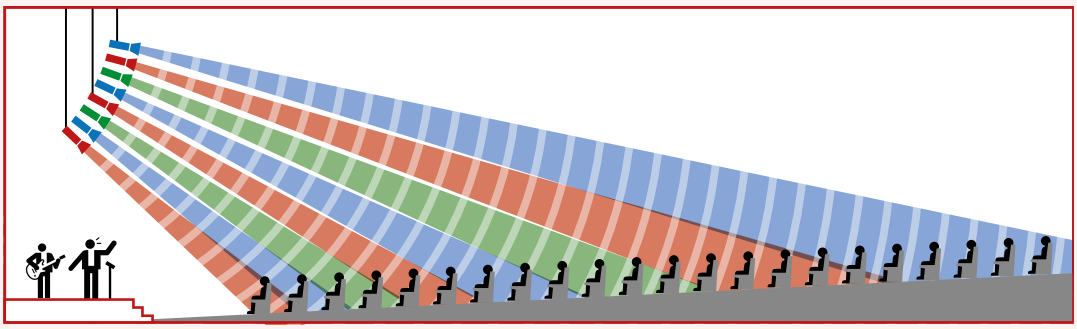
i) focus sound where it is wanted (e.g. on the audience, not on the walls and ceiling);

ii) minimize sound interference between loudspeakers (e.g. when multiple loudspeakers are used, each providing coverage to a specific part of the audience area);

iii) help to compensate for the natural attenuation of sound level with distance (e.g. by pointing an elevated loudspeaker towards the rear of the audience area, the fact that audience members at the front are closer to the loudspeaker is offset by the fact that it is not pointing directly at them, resulting in a more even sound level at front and back of the audience).

In professional sound-reinforcement applications, the use of a loudspeaker configuration known as a “line array” is now widespread at larger venues and events (Figure A9.2). A line array comprises multiple individual loudspeaker units hung adjacent to one another in a vertical (sometimes curved) line. With careful design and setup, a line array can achieve a wide coverage in the horizontal plane along with a narrow and well-directed coverage in the vertical plane; this makes it effective for uniform delivery of sound from front to back of a large audience area.

Figure A9.2:
Visual representation of sound distribution with a line array loudspeaker configuration



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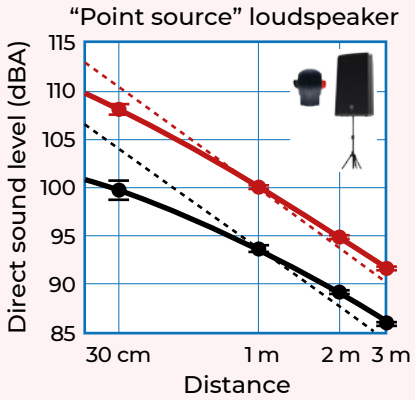
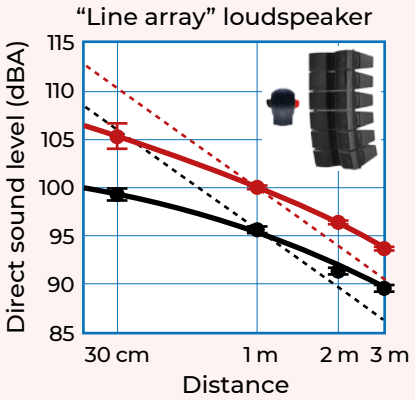
Annex 10.
Sound levels close to loudspeakers

Sound levels increase rapidly when approaching a loudspeaker, making the location immediately in front of the loudspeakers especially hazardous *(1)*.

Figure A10.1 below shows the results of a series of measurements undertaken in Metronome, a purpose-built live music venue in Nottingham, England, to understand how A-weighted sound levels vary close to loudspeakers *(2)*.

Figure A10.1:
Direct sound levels close to point source and line array loudspeakers





In each plot, the red lines correspond to sound levels received at the right ear (when faced towards the loudspeaker) of an acoustic mannequin, while black lines correspond to sound levels at the (less-exposed) left ear. The dashed lines show predictions from a simple hypothetical model based on a 6 dB increase in level for each halving of the distance between listener and loudspeaker.

The rate at which sound levels increase differs depending on the type of loudspeaker; nonetheless, regardless of these differences, the sound level always rises significantly when approaching close to the loudspeaker, especially at distances less than 1 metre.

Sound levels at 30 centimetres distance from a loudspeaker were found to be as much as 17 dB(A) higher than at 3 metres. This corresponds to a 46-fold reduction in the effective "safe listening" time between these locations (e.g. spending 4 hours at 3 metres distance from a loudspeaker is equivalent to spending only 5 minutes at 30 centimetres). This highlights the importance of keeping audience members at a distance from loudspeakers wherever practicable.

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Annex 11.
Reducing on-stage sound levels

Suggestions to control on-stage sound levels are presented below *(1)*. This is not an exhaustive list. Some are low-cost solutions accessible to venues and events of all types (e.g. dampening of acoustic drums, elevation of floor monitors). Others, however, may involve significant costs, impinge on artistic integrity, and/or require training and acclimatization for musicians to accept them (for example, in the case of in-ear monitoring). Not all measures will be suitable for use in all types of venue or event.

i) Acoustic drum kits

Sound levels from an acoustic drum kit (typically the loudest instrument on stage) can be reduced by dampening drums and cymbals using tape, towels, or a variety of proprietary drum-dampening products. The bass(/kick) drum can be dampened by stuffing the cavity with cushions, pillows, sheets, blankets, or other soft material, as if often required to achieve a robust reinforced kick-drum sound *(2)*. In limited cases, it may be possible to replace an acoustic drum kit with an electronic one, the sound level from which is more easily managed.

ii) Backline amplifiers

A power attenuator can be used in line between a guitar amplifier and its loudspeaker cabinet to get the “high-volume sound” at a lower sound pressure level. Speaker cabinets can sometimes be “mic’d up” in an off-stage location (e.g. under a raised stage). In limited cases, it may be possible to remove amplifiers altogether and replace them with a direct-injection box or amplifier simulator.

iii) Stage monitors

The use of a high-quality and well-maintained stage monitoring system can help musicians hear themselves clearly without needing to resort to excessive levels.

Elevating floor monitors (e.g. by placing them on drinks crates), or moving them closer to the performers, allows the same sound level to be achieved at the performers' ears with a lower output level from the loudspeaker. The use of a bass shaker (a device that allows a drummer to monitor his or her own performance via vibration) can reduce the need for high-intensity acoustic monitoring via a drum-fill. In limited cases, it may be possible to replace stage monitors with in-ear monitoring for the performers.

Once loud on-stage sources have been quietened as much as possible, the next step is to reduce the amount of sound that propagates from the stage to the audience area. The following steps may be considered:

i) Angle backline amplifiers so that they project sound away from the audience.

ii) Block direct sound from backline amplifiers from reaching the audience by placing a sturdy, upright wooden board lined with sound-absorbing material (e.g. open-cell foam or a mineral-wool slab) in front of the amplifier.

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iii) Block direct sound from a drum kit, or other loud acoustic instrument, using a clear screen made of acrylic or polycarbonate (the screen should ideally extend around the sides of the instrument, and the rear wall behind should be treated with sound-absorbing material to reduce reflected sound).

Image courtesy of www.gear4music.com/ (WHD Drum Shield).

All of the above-mentioned measures require the cooperation and consent of the performers, technicians and sound engineers.

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