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Code of practice for designing, specifying, maintaining and operating emergency sound systems at sports venues

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 62, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI and came into effect on 30 September 2011. It was prepared by Technical Committee EPL/100, *Audio, video and multimedia systems and equipment*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 7827:1996, which is withdrawn.

Relationship with other publications

This British Standard has been drafted to complement and avoid conflict with other standards with similar scope, but not specifically for sports venues, notably:

- BS 5839 (part 8 in particular);
- BS EN 54 (all parts); and
- ISO 7240 (parts 16 and 19 in particular).

See the introduction for further information.

Information about this document

This is a full revision of the standard, and introduces the following principal changes.

- Cross references to other standards have been updated. These are mostly in relation to voice alarm systems used in conjunction with fire detection and alarm systems.
- References to speech intelligibility have been updated to reflect advances in technology and practical experience.
- More guidance has been given on design criteria.
- Information has been provided to help the purchaser understand the need to allow sufficient funding to enable a properly functioning system to be engineered.
- Environmental issues have been taken into account.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Section 1: General

0 Introduction

This standard specifically applies to sports venues. Sports venues include a variety of building types and typically consist of enclosed, covered and open spaces all within the same venue. Design standards apply to all sports venue buildings as they do to any other public facility. More specifically, fire standards such as BS 5839 (and Part 8 on voice alarm systems in particular) as well as BS EN 54 and ISO 7240-19 on sound systems for emergency purposes apply in the normal way

Contained within many, but not all, sports venues are buildings and spaces that warrant special attention with regard to the most effective way to inform and manage spectators and other members of the public through the safe and clear use of the emergency sound system. Important factors and characteristics include the following.

- Sports venues often contain spaces designed to hold members of the public who do not know any pre-planned evacuation procedures.
- Sports venues often contain spaces designed to hold spectators in high numbers and densities, which introduces the requirement for effective general crowd control as well as during dangerous situations, such as bomb threat, civil commotion and fire.
- Sports venues often contain large open-air areas, such as the pitch of a cricket ground or the track-side of a racetrack. The fact that these spaces do not pose a risk in terms of fire, does not preclude them from crowd-related risks such as that of people returning to a building which is in an evacuation status; a reliable and effective means to communicate with occupants is still paramount for such areas.
- Effective and intelligible emergency sound systems can be used, not only to provide clear and useful commentary to spectators, but also to provide entertainment quality music, audio for video replay, advertising, etc. It is these non-emergency enhancements which can be usefully integrated with the emergency requirements and thus give added value to the system.
- Sports venues may be put to a range of uses beyond the primary use, in some cases outnumbering the occasions of primary usage in the annual event schedule; the emergency sound system may therefore have multiple modes of operation, including that of a voice alarm.

It is therefore important that this standard not only interfaces with other standards in a non-conflicting manner, but also introduces parameters and requirements which are not usually found in built spaces for which the generic standards (e.g. BS 5839-8:2008) are intended. An example of the latter would be that in large venues, the sound pressure level needed to produce intelligible communication at the listener can probably only be achieved using products not designed for the usual voice alarm market and therefore not type approved. The risk assessment process can therefore be used to demonstrate that the proposed solution achieves the same level of integrity specifically in situ as well as achieving the required performance.

Useful guidance can also be found in *The Guide to Safety at Sports Grounds* published by The Football Licensing Authority on behalf of the Department for Culture, Media and Sport (commonly referred to as the "Green Guide" [1]), and, for pop concerts, *The Event Safety Guide* [2].

1 Scope

This British Standard gives recommendations and guidance for the design, specification, maintenance and operation of permanently installed sound systems used for emergency purposes at sports venues.

It aims to ensure that, in an emergency, voiced messages are intelligible in all parts of the sports venue to which the public have access, no matter what type of event is taking place, as well as those areas outside the sports venue that the system is intended to serve.

This standard applies irrespective of whether or not a special sound system is installed for an event.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 5839-8:2008, *Fire detection and fire alarm systems for buildings – Part 8: Code of practice for the design, installation, commissioning and maintenance of voice alarm systems*

BS 7671, *Requirements for electrical installations – IEE Wiring Regulations*

BS EN 60268-16, *Sound system equipment – Part 16: Objective rating of speech intelligibility by speech transmission index* [BS 6840-16, IEC 60268-16]

3 Terms and definitions

For the purposes of this standard the following terms and definitions apply.

3.1 area of circulation
area where the public can move freely from one compartment to another, such as concourses, stairways and pathways

3.2 area of congregation
area of a venue which causes a restriction to the natural flow of people such as a turnstile, gate or, to a lesser extent, a merchandizing or catering booth within the confines of a compartment

3.3 area of coverage
area, inside and/or outside a building, adequately covered by the voice alarm system

3.4 area of dispersal
area outside the main structure of the venue which has a minimum of restrictions to the flow of people; such as car parks, grassed areas, roadways which are not public highways, etc.

3.5 audibility
property of a sound which allows it to be heard among other sounds

3.6 automatic mode
mode of operation of a voice alarm system which does not require manual intervention

3.7 certificate holder
person or legal entity to whom a current safety certificate has been granted

3.8 clarity

property of a sound which allows its information-bearing components to be distinguished by the listener, related to the freedom of the sound from distortion of all kinds

NOTE There are three kinds of distortion involved in the reduction of clarity of a speech signal in an electro acoustic system:

a) time domain distortion, due to reflection and reverberation in the acoustic domain;

b) frequency distortion, due to non-uniform frequency response of transducers and selective absorption of high frequencies in acoustic transmission;

c) amplitude distortion, due to non-linearity in electronic equipment and transducers.

3.9 clipping

short term inability of an amplifier to provide the voltage required

3.10 compartment

part of a structure separated from all other parts of the same structure by walls, ceilings or floors

3.11 control point

area which contains an announcement microphone (with or without a zone control panel) or an area which contains a control panel for any part of a sound system

3.12 critical signal path

components and interconnections between every emergency microphone and the input terminals on, or within, each loudspeaker enclosure used for voice alarm

3.13 emergency loudspeaker zone

part of the area of coverage to which emergency information can be given separately

3.14 emergency microphone

microphone dedicated for use by the emergency services or other responsible persons as part of the sound system

3.15 emergency mode

status of a system whereby emergency messages (either live or pre-recorded) are broadcast; in manual mode, all emergency messages are preceded by a pre-announcement tone; in automatic mode, all messages have intervening tones between the messages

NOTE If the system is used for broadcasting sounds other than live messages, these sounds have to be disabled for some or all of the period of the state of emergency, in controlled zones or across the whole venue.

3.16 emergency sound system

sound system for all types of emergencies

3.17 equalization

process of adjusting the gain or attenuation of certain frequencies within a signal

3.18 equipment room

area which contains equipment associated with the fundamental processes of the sound system

3.19 headroom
ratio (usually expressed in decibels) of the maximum signal amplitude that a device can accept or produce, without unacceptable non-linearity or damage, to a specified reference amplitude

3.20 intelligibility
measure of the proportion of the content of a speech message that can be correctly understood

NOTE Satisfactory intelligibility requires adequate audibility and adequate clarity.

3.21 listener
person of normal hearing who is within the area of coverage and is able to understand the speech message broadcast

3.22 loudspeaker circuit
transmission path to an assembly of loudspeakers supplied from the same control equipment and protected against over-current by the same protective device(s) or current limitation arrangements

3.23 loudspeaker zone
part of the area of coverage to which information and/or music can be separately routed

NOTE A loudspeaker zone may be the same as an emergency loudspeaker zone, may be a sub-division of an emergency loudspeaker zones, or may be unrelated.

3.24 manual mode
mode of operation where an operator is directly in control of the broadcast of live or pre-recorded sounds

3.25 noise measurement
$\mathbf{L_{A10,t}}$
noise level exceeded for 10% of the measurement period with "A" frequency weighting calculated by statistical analysis over a representative period, t

3.26 normal mode
status of a system whereby either music or other entertainment or operational messages (either live or pre-recorded) are broadcast without intervening tones or pre-announcement tones

NOTE Typical messages are for people management, such as warnings not to leave bags unattended, or to wear personal protective equipment while on site.

3.27 PAVA system
sound system, interfaced with the fire detection & alarm system, designed to be used for both PA (non emergency) as well as VA (emergency) purposes; this includes parts of the system which are dedicated for use as either PA or VA only, as well as parts of the system which are used for both PA and VA.

3.28 pre-announcement tone
short tone or series of tones which is broadcast before each message when a state of emergency exists and the system is in manual and emergency modes

3.29 private areas with a view of the event
compartments to which the public have restricted access, such as executive suites or press viewing areas

NOTE The difference between these areas and public audience areas is that the view of the event is normally through windows.

3.30 the public
people resorting to a place of entertainment and recreation, whether or not as members of a club and whether or not they pay a fee for attending events

3.31 public address system PA system
sound system intended to distribute signals from one or more locations to a number of other locations through a multiplicity of loudspeakers

NOTE In these systems, also known as sound distribution systems, the microphones are not normally exposed to the sound produced by the loudspeakers.

3.32 public audience areas
areas provided for the express purpose of accommodating members of the public being entertained within the venue

3.33 purchaser
person or organization responsible for the purchase of a sound system or their appointed representative

NOTE Representatives can include members of the design team or a contractor.

3.34 QoS
Quality of Service
ability to provide different priority to different applications, users, or data flows, or to guarantee a certain level of performance to a data flow

3.35 responsible person
person, identified by name or job specification, who is responsible for ensuring that a sound system is properly maintained and repaired, so as to continue to operate as specified, and for ensuring that operators are adequately trained

3.36 signal delay
electronic delay of the signal to a loudspeaker(s) placed at distant locations from a primary loudspeaker so as to be equal to the time sound takes to travel through the air from the primary loudspeaker to the distant loudspeaker

3.37 sound system
all equipment and resources necessary to reinforce original sound or to reproduce recorded sound, in appropriate parts of a place of entertainment, with adequate intelligibility

3.38 speech transmission index for public address
STIPA
measure of potential speech intelligibility over a public address system using a condensed STIU measurement format

3.39 sports ground
sports venue which is largely open space

3.40 system designer
technically competent person who takes responsibility for the technical specification and adequacy of the design for the system

3.41 transmission path
connection between sound system components (external to the cabinet of the component) used for the transmission of information, including audio, control, and/or power

3.42 user
person or organization responsible for the operation of a sound system or their appointed representative

3.43 voice alarm system
VA system
sound distribution system that provides means for broadcasting speech messages and/or warning signals in the event of any emergency and which is interfaced to the fire detection and alarm system

4 Standards and guidance with performance requirements

*COMMENTARY ON CLAUSE **4***

Many standards concerning emergency evacuation, notably fire-related standards, are, of necessity, generic. While they might allow for categorization on grounds of size or complexity of building, they are nevertheless aimed for use in standard buildings types, such as offices, shopping centres, factories, schools, and the like.

For these, the type and period of use are often common, i.e. regular days of non-use each week, and use only during the day. Other characteristics, such as a fairly consistent background noise footprint, are likely. The standards recognize these characteristics and therefore enable product standards to require minimum performance in these cases.

Where avoidable disasters have taken place and a trend is noticed, the general public demand that measures are put in place to learn from the mistakes of the past and create minimum standards of performance. This standard is one of those. It also supports the Green Guide [1], which gives wider guidance on safety at sports grounds from planning through construction to operation. Within the latter there are specific requirements in relation to crowd control, staff and management, and communications between them.

Emergency sound systems at sports venues are covered by this document as a specific case because sports venues form a class of "building" which has certain parameters which define a particular need in terms of life safety.

These include, but are not restricted to:

- *a centralized or focussed performance or activity area;*
- *peripheral audience area(s) for the public;*
- *peripheral support areas for the public;*
- *"back of house" areas for operational and administrative purposes;*
- *areas of circulation;*
- *areas of collection and dispersal (e.g. car and coach parks, railway stations).*

Due to differences in emphasis, there might be conflict between the specific guidance of national fire and emergency standards, the Green Guide [1], and European fire standards.

Where one standard or guide is in conflict with another, or the performance requirement can be considered onerous or irrelevant for a particular venue, the designers, together with the purchaser, should agree an appropriate solution subject to the following.

a) The solution and its rationale should be published and agreed with all relevant interested parties prior to commitment of a design.

b) The efficacy of the solution should be reviewed on a regular basis by the operator and/or the purchaser and adjusted accordingly if possible. Any change to any part of the building or to the planned use and procedures associated with the facility should also prompt a review.

Section 2: Planning and assessment

5 Procurement

*COMMENTARY ON CLAUSE **5***

The designer, installer or project engineer has to be a competent person. As an indication, in the UK, such a person might have corporate or full membership of one or more recognized and relevant institutions such as the Institute of Sound and Communications Engineers (ISCE), the Audio Engineering Society (AES), or the Institute of Acoustics (IOA), or be a Chartered Engineer.

Whilst the ability of a contractor to demonstrate previous successful installations conforming to the standard is desirable, this does not preclude others as long as the user or purchaser of the system is satisfied with their competence. Those responsible for design, installation, commissioning and maintenance should have been involved in at least one project where sound quality and speech intelligibility were critical requirements.

Adherence to a recognized quality standard is to be encouraged but this does not preclude installers as long as a client is satisfied with the installer's quality assurance methods.

5.1 Care should be taken in choosing a suitable supplier and installer for a compliant installation.

5.2 The person responsible for the design and its implementation should have relevant qualifications and experience.

5.3 The purchaser should ensure that the person responsible for the design is adequately appraised of the objectives of the system and any relevant requirements of enforcing authorities.

6 Need for emergency sound systems at sports venues

*COMMENTARY ON CLAUSE **6***

The need for an emergency sound system for a sports venue is determined by the local and/or sporting authorities in relation to the safety of the public at the venue and the subsequent issue of a safety certificate or licence.

Sports venues are not always large, semi-enclosed spaces like stadiums, but are often open spaces with a building for seating, refreshment and administration such as a cricket ground, racecourse or racetrack.

The recommendations for voice alarm in the context of fire detection and alarm only apply to the building and not to the open spaces. However such venues might also need to communicate with the audience in the open space in order to control the crowd, e.g. telling them not to enter the building because of an emergency, or not to go to a particular area because of a bomb threat. Equally the message might not be directed at the public, but the stewards. Where radio communication systems are not employed throughout, coded messages to the stewards are often used in order to initiate the investigation of a threat, or to position stewards prior to broadcasting an un-coded message to the public.

Even in large stadiums, the playing surface is a space which might not be at direct risk of fire, but might still need PA communications. For example, if the emergency planning strategy includes use of the pitch as a safe area to evacuate, the PA might be used to direct spectators on the pitch to a different place of safety and not into the area in an emergency condition.

Sports venues which include enclosed spaces are covered by emergency sound systems standards as well as this document, as well as open air spaces, are not be covered by emergency sound systems standards but might require clear PA coverage in response to the specific emergency planning strategy. On this basis, open-air areas (not covered by explicit emergency sound systems requirements) might not have to have system integrity to emergency sound systems requirements (e.g. monitored loudspeaker circuits, fire and mechanically protected cabling, speech intelligibility requirements). However, compliance with emergency sound systems standards in these areas may be considered appropriate within the context of the specific emergency plan, as well as providing operational benefits to the user of the system and operator of the venue. For example, there is a benefit to the user that the whole system is monitored as this eases and speeds the proving of the system prior to the turnstiles opening, as well as prompting and quickening any maintenance and fault-finding. The manpower saved by this facility translates directly into cost and can offset the initial investment in monitoring.

Therefore the system designer needs to define which areas are public address and voice alarm (PAVA) and which are only public address (PA) in order to optimize the cost to the purchaser. Furthermore, the requirements of the system in PA only areas will need to be defined in the context of the emergency planning strategy.

The emergency sound systems usually also provides a means of entertainment, for commentary and/or music, and therefore there can be an operational economic benefit derived from a system used for both life safety and entertainment purposes. The reproduction of music needs some degree of improved system performance specification, such as bass response, fine equalization, evenness of coverage and system dynamics. The implications of these improvements might have little or no effect on the system cost in some cases, and in others might have a significant but justifiable impact. However, the further augmentation to provide a primary role during music concert performances would require a considerably improved specification level (such as extended level capability, extended low frequency capability) that is unlikely to be justifiable to build into a system used mostly for commentary, DJ music and audio for video.

6.1 Where there is uncertainty regarding the need for a sound system to meet the recommendations of this standard, reference should be made by the purchaser to one or more of the following:

a) guidance documents pertaining to such venues such as the Green Guide [1];

b) any authority responsible for issuing an operating certificate or licence (without which the venue cannot admit members of the public);

c) any authority responsible for enforcing fire safety codes that apply to the premises.

6.2 The sound system designer should identify in the design scope which areas are considered appropriate for PA and which should comply with VA recommendations. Areas requiring VA messages but no PA messages or entertainment (e.g. plant rooms) should also be identified, and consideration given to whether a fire sounder/beacons in conjunction with staff training, are adequate. In general, in staff areas not requiring PA, sounders/beacons may adequately provide alert and evacuate notification, in conjunction with staff training. In many cases, the designer would indicate that the whole system is to be designed as combined PAVA in all areas covered. The details of scope decisions should be agreed with the relevant parties.

NOTE Relevant parties may include the purchaser, the user, the purchaser's professional design team, the local authority, the sport's licensing authority or any other relevant authority.

6.3 The sound system designer should use the guidance of this standard as well as BS 5839-8:2008 for areas designated to require voice alarm (VA and PAVA).

6.4 The sound system designer should identify which areas, if any, are considered appropriate for increased performance for music or speech reproduction, and agree this with the purchaser. The designer should also apprise the purchaser of the degree of the proposed increase of performance according to the application.

NOTE In general it is preferable to install one system that performs the task of both PA and VA.

6.5 The use of the emergency sound system for other purposes is not precluded but should not affect the emergency use.

NOTE Designing a system for entertainment purposes such as music can provide design and operational benefits. The zoning of loudspeakers for emergency purposes can differ from the zones used for non-emergency purposes. The system must be designed to accommodate both but without compromise to the clarity of the relevant user interfaces.

7 Exchange of information and responsibilities

In addition to following the recommendations of BS 5839-8:2008, Clause **6**, consideration should also be given to operational requirements for the full range of public events likely to be held at the venue.

NOTE Public events might include other sports and non-sporting events such as conferences, music events and religious events.

8 Planning considerations

COMMENTARY ON CLAUSE ***8***

At the planning stage of any new sports venue or refurbishment project, and especially at the planning of any refit or upgrade of public safety and information systems, due consideration needs to be given to various factors critical to the achievement of a sound system for public safety and emergency use. The emergency management plan will provide guidance to the sound designer; factors such as the size and acoustic properties/conditions of spaces, and structural support (for e.g. loudspeakers) will be critical.

It is advisable to seek professional advice at the planning stage to assist the purchaser in satisfying the following recommendations.

It is advisable that the purchaser consults with the operator of the venue before progressing to the design phase.

Where the purchaser has been noted in the following subclauses as responsible for any particular action, they may delegate the task to an appropriate member of the design team, such as the system designer, architect, structural engineer, etc.

8.1 The purchaser should ensure that the acoustic properties of the various spaces are compatible or made to be compatible with achieving the speech intelligibility and sound quality recommendations in this document.

8.2 Roof-mounted loudspeakers likely to be required for large audience areas such as the bowl of a stadium can have weight loading implications on the structure that should be taken into account by the system designer, the design team and purchaser. In this case, consideration should be given to possible failure of the primary loudspeaker fixings and to the use of secondary safety fixings to secure the most massive components of the loudspeakers to the structure.

NOTE Bass loudspeakers can be particularly heavy.

8.3 The purchaser should define all safety management plans, including evacuation methodologies, the roles of officials and marshals and the provision or proposal of complimentary emergency and essential information systems, such as fixed and variable signage, in order that the sound system can be designed in accordance with these plans.

8.4 The purchaser should arrange for the scope of the project to be evaluated by a sound system designer to ensure compatibility with the recommendations of this standard.

NOTE A sound system planning report would typically contain such an evaluation and verify that all planning considerations have been made.

9 When a system is PA but not PAVA

*COMMENTARY ON CLAUSE **9***

A sound system may contain parts which are PA only, VA only or PAVA. The classification depends upon whether that part of the system in question is to be used for life safety or not. The relationship is illustrated in Figure 1.

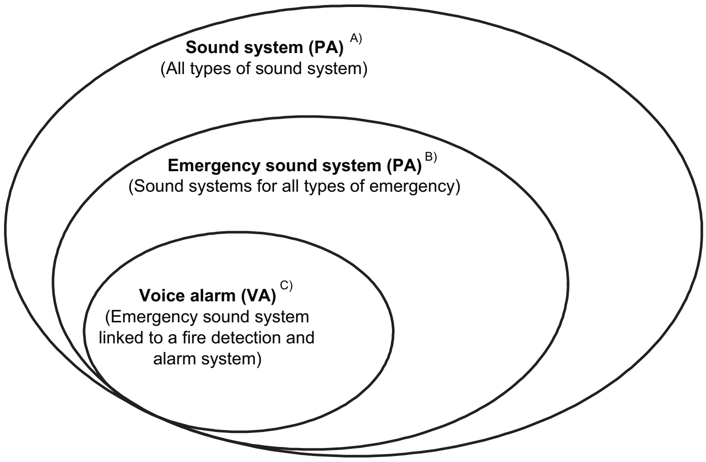
The system requirements, in particular those relating to the building evacuation procedures, have to be ascertained as accurately as possible by consultation between the user, purchaser and other interested parties, such as the enforcing authority and the emergency services (see BS 5839-8:2008).

If, after consultation, it is agreed that there is no immediate risk to life in a defined area (for example, if the area has no immediate means of catching fire, is not used for large gatherings/muster points, or is unlikely to contain a hidden bomb such as the pitch of a cricket field or the track of a racecourse) then there is no need to comply with the guidance of standards such as BS 5839-8:2008 in terms of the type of cabling used or (at the discretion of the designer) the monitoring of the loudspeaker circuits. It is possible that by introducing this relaxation to the system design, some costs can be reduced. This would be classified as an "emergency sound system only" area.

If an area is not accessible to the public but is required in the specific emergency planning strategy to be served by a voice alarm, then clearly a VA system will be required in that area. However, consideration has to be given to whether a simple fire sounder circuit would be more appropriate. In general, in staff areas not requiring PA, sounders might adequately provide alert and evacuate notification, in conjunction with staff training.

Areas that require sound for entertainment as well as an emergency sound system are classified as PAVA. Performance specifications (such as frequency response) of the system may be extended in these areas so that the reproduction of music is of appropriate quality for the entertainment purposes intended. Indeed, in some venues, the PAVA system may well be used to augment pop concert systems in an effort to reduce the environmental noise impact. Such systems would include the use of bass, or even sub-bass, speakers. If this is the case, it is wise to band limit or mute the bass parts of the system when the mains fails and the system is running on secondary power, since the cost of maintaining the extra load can be quite considerable.

Figure 1 **Hierarchy of sound systems**



A) A sound system is a system for reproducing recorded or reinforcing live sounds within one or many areas. Often called a PA system.

B) An emergency sound system is a sound system which, apart from any other uses, is able to broadcast messages to aid listeners to stay safe under emergency conditions in areas that are either inside or outside a building.

C) A voice alarm is an emergency sound system (usually restricted to the confines of a building) which is linked to, and optionally automatically triggered by, a fire detection and alarm system.

NOTE 1 All parts of an emergency sound system are governed by the recommendations of this standard relating to speech intelligibility and coverage, including the need to demonstrate that the expected performance at the design stage has been achieved at the commissioning stage.

NOTE 2 All parts of a voice alarm systems are also subject to the guidance and recommendations of other relevant standards which include the need for monitoring and maintaining system integrity.

9.1 All parts of the system should be designed in accordance with relevant standards for life safety systems (including BS 5839-8:2008) unless, following a risk assessment, there are some parts where the potential threat to life is agreed as being negligible.

9.2 All parts of the system should be designed to meet agreed speech intelligibility targets (see Annex A).

10 Variations from the recommendations of this standard

*COMMENTARY ON CLAUSE **10***

The requirements of this standard are not designed to exclude or restrict new or innovative methods of producing a suitable sound system "fit for purpose".

Where a method proposed deviates from the recommendations of this standard, any potential risks of adopting the approach should be shown to be acceptable and to achieve the intended outcomes of this standard. This should form part of the risk assessment for the project and should be agreed with the relevant parties.

11 The importance of a performance specification

*COMMENTARY ON CLAUSE **11***

The principal purpose of providing an effective emergency sound system at a modern sports venue is to allow clear speech communications to be delivered to the occupants.

The most critical application of this provision would be the delivery of instructions to evacuate the building in a timely manner, without unnecessary confusion or anxiety caused, in the event of an emergency. Such instructions would vary in complexity from an explicit evacuation to a detailed set of actions directed at the staff or specific portions of the crowd in response to an emerging situation.

The achievement of sufficient levels of speech intelligibility directly implies minimum requirements of signal levels, frequency or temporal distortion.

The system should be designed (planned and specified) and implemented (installed, commissioned, operated, demonstrated and maintained) to achieve the speech intelligibility requirements and all other performance requirements recommended in this document. Project specific requirements should be agreed by all interested parties as part of a defined and recorded emergency management plan. These may include, but not be limited to relaxation of intelligibility requirements for certain specific areas mitigated by alternative methods of achieving a safe environment.

Section 3: Engineering

12 Location and environment of emergency microphones

*COMMENTARY ON CLAUSE **12***

The environment of emergency microphones is important. It is important to ensure that messages broadcast from emergency microphones are of adequate intelligibility, and not unduly affected by interference from background noise, reverberation, feedback, etc.

The prime location for initiating emergency messages during an event would be the event control room. However when there is no event taking place and the event control room is unmanned, the next logical place would be at the site "security" post which is where the fire and rescue service would expect to find the fire detection and fire alarm system control panel intended for their use.

12.1 The proposed location of emergency microphones should be assessed in order to optimize the intelligibility of the broadcast. This assessment should include:

a) typical ambient noise (e.g. avoid a security hut near a busy road or an area close to noisy machinery);

b) atypical ambient noise (e.g. a control room where during an emergency there is an increase in the ambient noise due to direct communication between other people or indirect communication such as the base station of a radio system);

c) reverberance of the space.

NOTE The adverse effects of ambient noise and reverberation may be minimized by introducing acoustic absorption in the immediate environment of an emergency microphone by means of an acoustic hood, booth or similar device.

12.2 The acoustic conditions of the emergency microphone position should have, where practicable:

a) reverberation time (average of 500 Hz, 1 kHz, 2 kHz octave bands) no greater than 0.7 s; and

b) background noise conditions due to noise ingress, building services or equipment within the room no greater than NR35 for 30 s or more, and not greater than NR55 at any time from equipment likely to operate during an emergency microphone announcement (e.g. telephones, fire panel warnings).

12.3 There should always be more than one emergency microphone. They should always be in different parts of the building so that the secondary location can be used even if the primary location is compromised.

13 Electro-acoustic modelling

*COMMENTARY ON CLAUSE **13***

*The ability to demonstrate that the proposed electro-acoustic system is likely to meet the performance requirements, not only for life safety applications but also entertainment, is desirable. The electro-acoustic design, preferably modelled in a proprietary computer software programme, is also a useful benchmark for any future verification process (See Clause **11**).*

There are computer programmes which allow the surfaces of a defined space to be modelled, attributed with absorption coefficients, and loudspeaker performance characteristics to be inserted such that the SPL and potential speech intelligibility can be predicted.

Such computer programmes generally employ a simplified geometry to represent the space. The result is that they are a fair approximation of the likely result which will be achieved if a particular electro-acoustic design were implemented. They provide the following benefits as part of the design process.

- *Different loudspeaker types, quantities, and locations can be tried.*
- *Different amounts and locations of acoustic absorption can be tried.*
- *Results can take the form of graphical representations which are easier to understand for a lay person.*

*However, in order to obtain results which are anywhere near being a fair approximation of the likely outcome, the user needs to understand sound and system design. If a verification process is to be carried out (see Clause **34**) caution is advisable in respect of the difference in data available at the time of the modelling and design versus the built environment.*

13.1 The electro-acoustic design for major areas within a sports venue should be modelled, preferably with the aid of a proprietary computer software programme.

13.2 Care should be taken in the interpretation of predictions and the overall electro-acoustic design process should only be entrusted to a competent person.

14 Audio source priorities

*COMMENTARY ON CLAUSE **14***

Most sports venues have more than one use, resulting in different operational requirements on event and non-event days. Accordingly, routing and priority levels might need to be changed to accommodate different uses.

It is likely that on a non-event day a voice evacuation system in accordance with BS 5839-8:2008 would be suitable. During event days, when the event control room is manned, the level of priorities may be changed, and it is expected that any automatic evacuation broadcast will be disabled.

The evacuation plan may include a statement that during an alert message, commentary or background music is maintained in those areas which are not being addressed by the emergency announcement in order to obviate any confusion. It might be necessary to reduce the level of these signals in adjacent zones in order to preserve the intelligibility of the emergency announcement.

14.1 For venues with an enclosed capacity of less than 500, automatic evacuation broadcast capability may be appropriate. All other venues should have the automatic broadcast disabled while the event control room is manned for an event.

14.2 A clear schedule of priorities should be created for both event days and non-event days.

14.3 For event days the priority level in descending order should be:

a) the emergency broadcast microphone(s);

NOTE It is likely that emergency broadcast microphones will have equal priority on a first-come-first-served basis.

b) emergency evacuation messages;

c) emergency alert messages, including coded staff messages;

d) public order messages; and

e) any other inputs.

14.4 On event days, particular consideration should be given to the periods before and after the event when significant numbers of untrained people (e.g. catering staff, event crew) are present while the Control Room is not operational (this is effectively a condition as per **14.5**).

14.5 On non-event days priorities should be as recommended in BS 5839-8:2008, Clause **23**.

14.6 The evacuation policy may require that after a defined period of inactivity, while an emergency status exists, the automatic evacuation broadcast is re-enabled.

15 Loudspeaker zones

*COMMENTARY ON CLAUSE **15***

*All sound systems for sports venues need zoning for one reason or another. The most common reason is given in Clause **9** and from this further sub-zones are usually required. For example, where areas are acoustically linked (intrinsically or at the periphery) it might be necessary to delay one area with respect to a primary area in order to maintain intelligibility.*

Other zoning is usually needed for areas where the public is allowed versus "back of house" areas. Under each of these categories there is likely to be sub-zones which allow just the areas with a view of the event to be addressed versus those other areas such as enclosed or semi-enclosed concourses.

As described elsewhere, the zoning can lead to an increased diversity of circuits which is beneficial in reducing the overall effect of component failure, i.e. the failure of one amplifier channel in a system with 50 zones represents 2% of the system whereas in a system of 10 zones it represents 10% of the system. Whilst there might not be a great impact on costs if a multi-channel amplifier replaces a single-channel amplifier, the desire to individually address more, smaller zones can start to increase the financial overhead. It is usual that the operational and engineering requirements determine the zones and the resultant diversity are achieved without false intervention.

Operational zoning is often dictated by the agreed evacuation strategy where one area receives an alert whilst another area receives an evacuate message according to a "cause and effect" matrix for example. This in turn may lead to sub-zoning due to the need to delay one circuit with respect to another for intelligibility reasons. The normal use of commentary on the other hand, might require a different set of delay parameters and thus those evacuation sub-zones might need to be sub-divided yet again. An example of this would be an exhibition centre which also hosts sports matches in the round.

Loudspeaker circuits should be used to form zones as required for:

- minimization of the potential differences in the times of the arrivals of sounds at a listener received from different loudspeakers (in order to achieve good speech intelligibility);
- simultaneous broadcast of alert and evacuation messages in separate zones;
- separate broadcast for mobilization of staff versus direct instruction to the public;
- the agreed "cause and effect" policy in the event of automatic evacuation after a fire has been detected;
- operational requirements of entertainment voice and/or music broadcast;

- other purposes which the client might deem desirable.

*NOTE Further useful information on zoning can be found in BS 5839-8:2008, Clause **13**.*

16 Loudspeakers

*COMMENTARY ON CLAUSE **16***

The choice of loudspeakers is part of the overall process of electro-acoustic design, critical to the achievement of speech intelligibility and sound pressure level requirements. BS 5839-8:2008 gives guidance on this subject, pointing out the parameters which need to be taken into account, and indicating the skills necessary to achieve acceptable results.

Whilst there might be a variety of sound system design solutions, the variants should be chosen by a competent electro-acoustic designer. The guidance of BS 5839-8:2008, Clause **14** should be followed, in particular that loudspeakers should be chosen primarily for their ability to produce an intelligible result rather than for aesthetic considerations such as size or appearance.

17 Power amplifiers

*COMMENTARY ON CLAUSE **17***

*BS 5839-8:2008, Clause **16** gives guidance on the choice and configuration of amplifiers for use in sound systems used for emergency purposes. In the case of sports venues, the guidance of **16.3** is of particular relevance, i.e. for large premises, the ability to configure systems to have automatic amplifier changeover with sufficient reliability is more fraught than configuring the system with diversity.*

*Amplifiers need to have sufficient power response over the required bandwidth to be able to reproduce messages with the required speech intelligibility. That power is not normally a constant delivery demand, but a dynamic demand with peaks associated with the plosives and sibilance of human speech as well as music as required (see also Clause **19**).*

17.1 Amplifiers should be chosen for their ability to deliver the required amount of power to achieve the level and speech intelligibility requirements.

17.2 Amplifiers should be configured so as to minimize the effect of a single unit failure to a degree which poses an acceptable risk in terms of evacuation communication.

18 Headroom

*COMMENTARY ON CLAUSE **18***

Headroom is needed to avoid the effects of clipping and the premature failure of loudspeaker drive coils. Headroom is needed at every part of the signal chain.

Some types of circuit topology have a much better response to transient peaks than others, so a blanket approach to headroom is not appropriate in every case. For example, loudspeakers have a varying amount of resilience to transients.

It is the ability of the overall electro-acoustic system to faithfully reproduce a message with the necessary amount of power which is the fundamental parameter that has to be considered when choosing equipment for a sound system.

The system should be designed in such a fashion to avoid any artefacts due to limited headroom, specifically those which reduce the quality, intelligibility or longevity of the resultant installation.

19 Sound pressure levels, frequency response and intelligibility

*COMMENTARY ON CLAUSE **19***

Frequency response (together with temporal accuracy) is the basic requirement for clarity, and the sound pressure level (SPL) is the basic requirement for audibility. Clarity and audibility are the essence of speech intelligibility, so the frequency response, temporal accuracy and SPL together form an intelligibility requirement.

A tolerance has to be applied to each requirement, including speech intelligibility. At the design stage, the acoustic characteristics can be estimated and included in the calculations. The prediction might indicate that the ideal intelligibility target cannot be met comprehensively throughout the venue, in which case a pragmatic approach to setting tolerances is sometimes necessary. Any resultant risk has to be mitigated and reduced to an acceptable level, and the system still has to provide an effective means of communication (and, where appropriate, entertainment). The details of areas of reduced intelligibility have to be kept on record throughout the lifetime of the system.

The primary parameters can all be measured without an audience, but intelligibility is affected critically by the acoustic characteristics of the space. Essentially, these characteristics are the reverberation time of the space and the ambient noise (mainly generated by the audience).

19.1 Each space or zone within the venue should be identified and allocated design target parameters relating to clarity and audibility. These areas should also be allocated an intelligibility requirement which should be measurable.

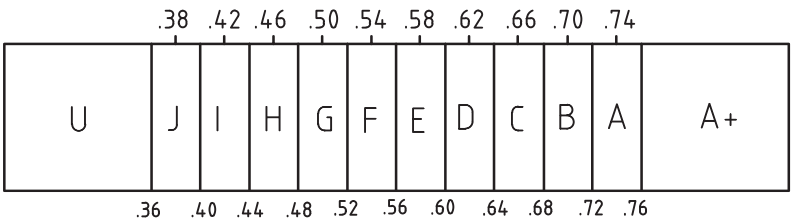
19.2 Intelligibility, as defined and measured in accordance with BS EN 60268-16 should meet the values given in Table 1 (extracted from BS EN 60268-16) according to the spaces under consideration.

Table 1 **Intelligibility categories**

Category	**Nominal STI value**	**Type of message information**	**Examples of typical uses** (for natural or reproduced voice)	**Comment**
F	0.54	Complex messages, familiar context	PA systems in shopping malls, public buildings offices, VA systems, cathedrals	Good quality PA systems
G	0.5	Complex messages, familiar context	Shopping malls, public buildings offices, VA systems	Target value for VA systems
H	0.46	Simple messages, familiar words	VA and PA systems in difficult acoustic environments	Normal lower limit for VA systems

The categories represent the qualification bands given in Figure 2 for STI.

Figure 2 **Intelligibility categories by STI**



NOTE For more detail see BS EN 60268-16.

19.3 Where intelligibility is likely to be compromised, the reason for this, together with description of all mitigating factors should be given at the design stage and agreed by all interested parties. These details should be included in all documentation from design, through specification, contract, and commissioning to the operations and maintenance (O&M) manuals.

19.4 A summary and overview of such deviations should be included in the agreed safety policy and evacuation plan documentation.

19.5 Designs based on steady state test signals should be reduced by 3 dB for real world signals. See BS EN 60268-16, Annex J.

NOTE Also see BS EN 60268-16, Annex A regarding the limitations of high sound pressure levels due to the absolute reception threshold.

20 Networked systems

*COMMENTARY ON CLAUSE **20***

A networked system usually transports audio signals control data and monitoring data over a digital (or hybrid digital/analogue) backbone (see Figure 3). Whereas analogue signals may be used as a primary or secondary means of communications, for the purposes of this standard, a networked system is one in which the inputs and outputs are transmitted throughout the venue in the digital domain. The network transmission method can take the form of either a manufacturer's custom audio/data network or use a suitably designed computer data network.

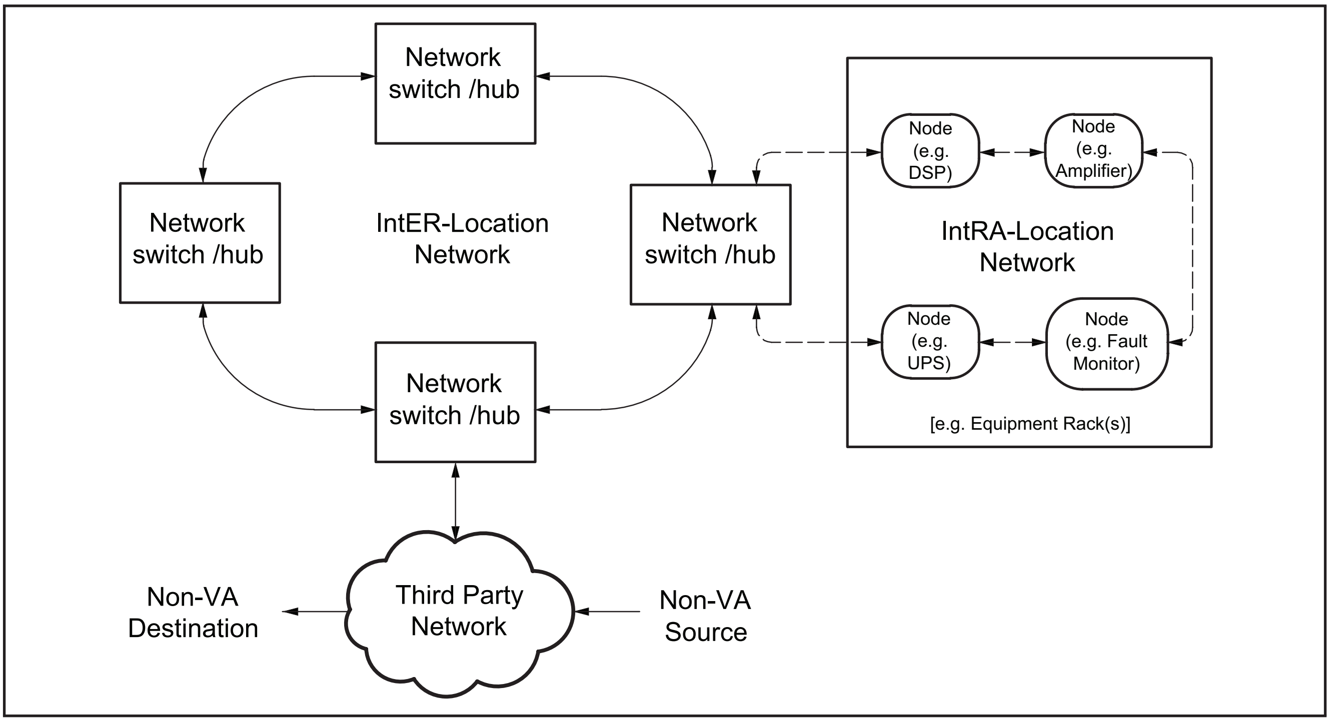
Such a system can also integrate the audio processing within networked devices in the digital domain. For example the network might include not only inter-location connectivity but also intra-location connectivity such as processing and amplifiers.

For the avoidance of doubt in this standard any network which is used as part of a voice alarm system has to be designed to minimum requirements of:

- *diversity;*
- *monitoring;*
- *power supplies; and*
- *quality of service (QoS).*

Where, in this context, diversity is taken to mean a method for improving the reliability of a message signal by using multiple communication channels, and monitoring to mean the surveillance of the signal path to ensure integrity of communication.

Figure 3 **An example of a networked system**



20.1 Where networked systems are to be utilized, a dedicated network for exclusive use by the PA/VA should be employed, thereby ensuring that suitable bandwidth and thus QoS is available at all times.

NOTE Separation of the differing types of data might be accomplished using a virtual local area network (VLAN) or similar mechanism.

20.2 The responsibility for network design and performance should remain vested in the voice alarm system providers, whatever design approach is adopted.

20.3 There should be no conflict between audio and control data on the same network.

20.4 The network should recover from any transmission media or network hardware failure within 30 s. Any latent faults remaining in the network should be reported on the fault monitoring system. The recovery event should also be logged and reported.

20.5 Simulation of all permutations of network failure should be undertaken during the commissioning process.

20.6 Transmission media should be standardized through a network system to maintain data integrity. Any change of transmission media should be accomplished within dedicated equipment cabinets.

20.7 It is important that the audio signals within the same acoustic space should have sufficient temporal accuracy to maintain intelligibility, including those derived from different networked sub-systems, as described in BS 5839-8, Clause **25**.

NOTE This includes the replay of messages broadcast from different networked sub-systems when independently triggered.

20.8 Acoustic alignment between loudspeaker circuits in the same acoustic space should not be subject to deviation due to transmission network latency changes.

20.9 Systems where the audio processing is distributed across the network should maintain commissioned parameters in the event of any failure and subsequent switch to a back-up unit.

20.10 In any critical path network, transmission hardware should be duplicated. Alternatively the network paths should be interleaved, i.e. circuits should be derived from more than one source of network hardware.

20.11 The network bandwidth required by the voice alarm application should be established during the design process. This requirement should be tested during the commissioning process to ensure compliance with the design.

20.12 Monitoring of network bandwidth capacity and utilization should be implemented and deviation from tested values reported as a fault.

20.13 Data transmission failure resulting in reduced bandwidth may be mitigated by the use of dynamic compression algorithms on the audio data. Such processes should maintain the performance criteria specified.

21 Electricity supplies

*COMMENTARY ON CLAUSE **21***

A complete PAVA system is legally required to comply with the EMC Directive [3], which places an onus on designers to ensure that systems do not produce, or are affected by undesirable mains borne or radiated artefacts such as high harmonic content, switching pulses or radio-frequency interference. Guidance on achieving this is given in BS 7671.

Power supplies to equipment and systems required during an emergency are commonly a source of failure. Recent government guidance extends the principle of a system being able to operate after a period of primary supply failure, to that of being able to actually continue with the whole event after the onset of a primary supply failure. The rationale behind this is that sports venues typically attract thousands of people who present a crowd control issue in their own right. To have an event potentially cancelled at the last minute is likely to heighten any feelings within the crowd and thus give rise to civil commotion. The ability for the venue to continue with the event running on secondary supplies is therefore part of the Green Guide [1].

However, guidance from the various standards available conflicts on the length of time which the alternative power source is needed to maintain the system in both quiescent and emergency states. The Green Guide [1] requires 3 hours, BS 5839-8:2008 recommends 24 hours quiescent plus 30 min emergency, whilst DD CEN/TS 54-14 requires 72 hours quiescent plus 30 minutes. Each authoring body is drawing upon different examples for their norm: the Green Guide calculation is predicated upon a football match where the time from the gates opening to the crowd having dispersed is easily contained within 3 hours, in other words, from the onset of the power problem, the whole event can take place and thus avoid any public disorder problem. The BS 5839-8:2008 calculation is predicated upon an office or factory where no-one is likely to be on site on a Sunday, and hence 24 hours is fine. The DD CEN/TS 54-14 calculation is predicated upon a building unoccupied over a national holiday. In each case, a fair and reasonable predication.

21.1 Electricity supply specification

The designer should assess the impact of power factor correction needed by the system as a whole, to meet the requirements of the district network operator, or private supplier/provider.

21.2 Alternative power

21.2.1 All parts of the sound system associated with emergency use should be powered such that they remain in reliable continuous service whether the power is primarily derived from public service mains, standby generator mains, standby batteries, or a combination of these.

21.2.2 The length of time which the alternative power source should be capable of maintaining the system should based upon the likely usage of the venue in question. Consideration should include the primary use of the venue as well as any longer lasting but less frequent uses of the venue, and how different requirements might be effectively accommodated. Alternative power supply systems, especially UPS, should be selected and installed following the recommendations of BS 5839-8:2008 and avoid single points of failure.

21.2.3 Factors which should be included in the calculation of battery-based secondary/tertiary power should include:

a) whether there is a standing standby generator which will automatically run up and take over in the event of a primary power failure;

b) whether the primary power failure status is only available at specific locations on site, or tallied via communications systems to key personnel who can take action;

c) the likely time required for the primary power to be restored;

d) any provisions which can be brought into play to act as a substitute for the primary power, e.g. plug-in points for rented mobile generators;

e) the likely time it would take, during an event, for the public to evacuate the building to:

   1) a place of safety on site, but where communication with them is necessary for crowd control purposes, e.g. the playing surface;

   2) a place of safety where no communication with them is likely to be needed in future, e.g. a car park;

   3) the likely time it would take, when no major event was taking place (e.g., use of conference facilities only), for the public to evacuate the building to:

      i) a place of safety on site, but where communication with them is necessary for crowd control purposes;

      ii) a place of safety where no communication with them is likely to be needed in future;

f) the likely time to evacuate the building in question when there is no member of the public on site.

21.2.4 The calculation and its rationale should be published and agreed with all relevant interested parties prior to commitment of a design and should form part of the evacuation plan for the venue.

21.2.5 Due regard should be given to the effect of excessive battery requirements on global resources both initially and in the future such that a proper balance is struck regarding the types of alternative power deployed.

21.3 Tertiary supplies for sensitive equipment

As a minimum, the control system should be locally supported by an online UPS as a tertiary alternative power source, especially to cover for any temporary power loss during changeover between power supplies.

NOTE This applies especially to computer or micro-processor based control systems, and can provide mains conditioning.

21.4 Integrity monitoring of supplies

All electrical supplies should be continually monitored and their status indicated by the fault monitoring system.

22 Cabling – Integrity of circuits

*COMMENTARY ON CLAUSE **22***

Cabling is needed such that it carries the necessary signals from source to destination in accordance with the sound system specification.

In order to continue carrying out its function, it is important that the correct cable construction and installation method is used dependant upon the risks associated with the cable route taken. That is, to survive incidents such as the outbreak of fire, attack by rodents, or vandalism by event attendees.

Fibre optic cables are preferred where issues of galvanic isolation, signal integrity and electromagnetic interference might be of concern, especially over long cable runs.

When assessing the suitability of cables, constructions such as mineral insulated copper cables (MICC) might not be appropriate for low level signals such as microphone connections, or might introduce excessive capacitance in some loudspeaker runs, however they can be perfectly suitable for other applications. Equally, a screened twisted pair with a PVC sheath for the microphone connection is not appropriate if the cable run includes a high fire risk area.

22.1 Cables should be selected and installed in accordance with BS 5839-8:2008 and BS 7671.

22.2 The integrity of the cabling should be maintained, both mechanically and electrically, under normal operation as well as when the sound system is being used as a voice alarm system.

23 Structural integrity of mounting hardware

Notwithstanding the mounting recommendations in BS 5839-8:2008, **14.5** the design of any custom mounting hardware should be verified by a suitably qualified engineer.

24 Integrity and fault monitoring

*COMMENTARY ON CLAUSE **24***

The importance of monitoring the integrity of a sound system in a sports venue cannot be understated because crowd control within, or the evacuation of, such places is complex. Manual evacuation is usually controlled by stewards, due to the large number of people involved.

The sound system is usually a voice alarm system connected to the fire detection and alarm system. For this reason it needs to have a fault monitoring system which acts independently of, but reports a common fault status to, the fire detection and alarm system.

An announcer needs to have a display of information of any actual or latent problems in the sound system so that, in the event of an emergency, the effect(s) can be mitigated. The contingency plan required by the Green Guide [1] might include such measures as deploying more stewards to an area of the building which is exhibiting a VA fault so that, with radio communications and loud hailers, the area could still be evacuated in the event of an emergency.

*The subject of whether fault monitoring is required for those areas covered by PA only is one for discussion between the designer and the purchaser of the system (see Clause **8**). A fault monitoring system might become less costly since there is no need to manually check its correct operation 24 hours prior to each event (see Clause **35**). It might not save anything to leave small areas of PA only un-monitored.*

*Systems which use a number of distributed racks of equipment require a networked monitoring system. Clause **20** gives guidance regarding network topology and the advantages or disadvantages of separate networks for audio, control and other data.*

The designer is advised to consider the use of real-time off-site storage of logged data to enable such examination in the event of total destruction or failure of the system.

24.1 The integrity of the critical path for audio and control should be monitored and indicated at all times, where the critical path consists of the routes from all emergency sources to all loudspeaker circuits used for emergency broadcasts.

24.2 Any fault reporting should be simultaneously available in all control locations.

NOTE Collection of fault data may be in one location with the results displayed at multiple remote locations over monitored links.

24.3 Attention should be drawn to a fault condition by three methods of indication:

- *generic*: a common fault status should be indicated at each emergency microphone, equipment room and control location; this common fault status should also be sent to the fire alarm system;
- *user*: for example any individual message zone, any emergency source, plus an indication of any other faults leading to loss of functionality;
- *engineering*: indication at equipment and interconnection level which with suitable description could assist in diagnosis and rectification of faults; this information should not normally be available to the user.

24.4 Description of faults should be clear and unambiguous for each method of indication. This description should not require manual interpretation of external data other than to obtain additional information on the fault.

24.5 All faults should be logged, indicating when they occur and when they have been cleared, complete with the accurate dates and times. The storage of any log should be robust and its content should be available for offsite examination and storage.

24.6 Fault information should be readily distinguishable from log entries for other purposes.

NOTE Preventative maintenance may include examination of the log to identify intermittent problems. The log may also be used for forensic examination.

24.7 A display of any actual or latent problems in the sound system should be available to the announcer at the emergency microphone in order for that user to be able to deploy an alternative strategy to mitigate the effect of the failure.

24.8 Fault condition displays in the control room, and preferably also at the secondary control location, should be laid out in a topographical format in order to be as intuitive as possible.

24.9 Fault condition displays should show individual emergency (VA) loudspeaker zones. Faults in individual emergency sources, and transmission or power supply faults may be shown in a generic location on the display, especially if they are not necessarily location specific.

25 Maintainability

*COMMENTARY ON CLAUSE **25***

In accordance with CDM regulations, there are legal obligations to identify risks associated with all aspects of the project during design, pre-installation, installation, operation, use and maintenance. Any risks are to be identified, registered, categorized and mitigated against by a change to the design and/or installation method, where practicable, or a prescribed safe working method where not.

An example of such a risk to consider might be the mounting of loudspeakers high in the building structure to achieve desired performance but which renders them inherently difficult to access, potentially creating an avoidable risk for maintenance. In this case, mitigating considerations may include wiring each location individually such that the loudspeakers circuits can be isolated and tested at a more convenient location, such as the equipment room or an accessible marshalling box. This may similarly apply to ambient noise sensing microphones.

In addition, it is advisable that practicality and usability in critical situations forms part of the maintenance planning. An example of such a consideration could be the location of a critical piece of equipment which due to space limitations has been installed in an area with highly restricted access during an event, e.g. a cupboard in the police control room. Such situations might preclude maintenance or urgent access to the equipment during an event.

The design of the installation should take into account maintainability in terms of physically accessing the equipment in a location which is readily available at all times.

26 Engineering for a sustainable environment

*COMMENTARY ON CLAUSE **26***

Current British Standards for voice alarm are focused on evacuating the public from a building. The imperative is to keep the system working and to ensure that it is working at all times.

It is important to consider that in most sports grounds the system is not in active use for most of the time. This is when the system is in automatic or non-match day mode.

However even in their quiescent state the systems need to remain powered and monitored which can result in large amounts of energy being used, not just to power the systems but also for the air-conditioning to cool the equipment rooms. By reducing the heat generated in the first place, this requirement can be reduced too. Disposal requirements are also a particular environmental concern when considering battery back-up systems.

*An important issue is the measurement of the real acoustic output of the system, not the theoretical one. Currently, pink noise is used for this test, but real world signals such as music and speech at the same level require significantly less power (perhaps even 1/10th). This is due to the fact that amplifiers can deliver much higher peak loads for short periods, as required by speech and music, than they can for a continuous load required by pink noise. Such a reduction in amplifier power would also mean a reduction in batteries. The subject of headroom is discussed in Clause **18** and the subject of acceptability (intelligibility) is discussed in Annex G and Annex H.*

Some loudspeaker monitoring systems use continuous sub-audible tones to measure the status of the system. This requires driving the amplifier at levels higher than quiescent even though no audible signal is being reproduced. Alternative methods of monitoring could include:

- *periodic sending of tones, in a manner that allows recording of faults within the time recommended, for example, in BS 5839-8;*
- *sending data along the loudspeaker lines and having loudspeakers or an end of line circuit report their status;*
- *using a d.c. voltage and an end-of-line monitor.*

Many items of equipment have the ability to adjust their current draw depending on their use at any particular time. This could take the form of a sleep mode, having its processor speed reduced or reducing its power supply output voltage.

In general, the main power users in sound systems are the amplifiers and loudspeakers, so it is likely that changes to this element will have the greatest benefit, but other parts of the system ought to be considered too.

26.1 General

Designers should look at whether they can design their systems using fewer physical components, especially loudspeakers, provided that this is not at the expense of redundancy because the system forms a VA system or sound system used for emergency purposes.

NOTE In some cases this might simply result in fewer materials being required for the loudspeakers themselves but such a system will need lower powered amplifiers, smaller batteries, less containment and less cabling.

Modern technology and better design techniques mean it is possible move on from just having systems that work; consideration should be given to systems that include any of the following energy saving measures:

a) exploitation of the differences between match days and non-match days and the use of the equipment for both modes;

b) use of amplifiers that are not overpowered for the acoustic output that needs to be delivered;

c) use of techniques that eliminate or reduce the power running through an amplifier simply to monitor the loudspeaker circuit;

d) use of more efficient amplifiers;

e) use of more efficient loudspeakers;

f) use of system components that can go into a low power mode, except when in use or when/if monitoring is required;

g) design of systems that, whilst maintaining diversity and correct zoning, use fewer separate components or output channels, providing that results in a system with less environmental impact; this also includes consideration for dual-use systems; and

h) use of correctly sized cables to reduce power losses.

26.2 Specific resource and energy savings

NOTE These recommendations concern themselves with the use of electrical power, generation of heat and the associated effect this has on battery size. They also consider quantities of equipment and materials required. Guidance on the use of more sustainable product design may be found in BS 8887-1.

26.2.1 Automatic and manual mode

The following restrictions should be observed for match days and non-match days respectively when using the system.

a) On match days:

   1) it is recommended that no power saving methods are used that could reduce or restrict the speed of response and use of the system; and

   2) if any equipment goes into a low power mode, it should be capable of restoring to normal use and being operated within three seconds.

b) On non-match days:

   1) some equipment may be powered off but should still be capable of restoring to normal use and being operated within the time frame recommended in BS 5839-8:2008;

   2) in the event of any equipment going into low power mode it should be capable of restoring to normal use and being operated within the time frame recommended in BS 5839-8:2008.

26.2.2 Loudspeaker circuit monitoring

It is recommended that methods are used that do not require continuous high power inaudible tones running to the amplifiers.

26.2.3 Use of more efficient amplifiers

Given that the sound system will be running quiescently for most of its life, it is recommended that amplifiers are used that are more energy efficient in quiescent mode.

Consideration should be given to the thermal output of the amplifier and how that affects rack room cooling requirements.

26.2.4 Use of more efficient loudspeakers

Given that reproduction of an acoustic output is the principal requirement for any sound system, it is recommended that, when other considerations have been taken into account, that loudspeakers are used that can output a higher acoustic output for the energy put into them. This may allow the system to use fewer loudspeakers and/or lower powered amplifiers, provided that this is not at the expense of redundancy because the system forms a VA system or sound system used for emergency purposes.

26.2.5 Sleep or processor slow down modes

It is recommended that equipment be able to reduce its current draw when not in use.

26.2.6 Dual use systems

It is recommended that the system designer considers whether it is possible to use fewer components in the sound system, in particular whether the quantity, specification and location of loudspeakers can be refined to use fewer materials.

It is recommended that in systems where a sound system is required for other purposes such as for music or for conferences, that this system is designed to be the voice alarm system too; this avoids two sound systems being energized to cover the same physical space.

26.2.7 Use of correctly sized cables

It is recommended that system designers strive to achieve a balance between the resources saved by using smaller cross-sectional area loudspeaker cables and the additional power required in the amplifiers to compensate for those reductions.

Section 4: Commissioning and handover

27 Noise impact during alignment and testing

*COMMENTARY ON CLAUSE **27***

Sound systems used for emergency purposes not only have to be tested and aligned at the installation stage, but also may be measured during a verification process. These processes inherently mean that the system is operated at a sound level which is higher than the ambient noise of an event, let alone of a non-event period. The residents in the locality might well find this to be a form of nuisance, and it is advisable to consult the Local Authority on this, prior to any such testing, in respect of mitigating the impact of noise disturbance.

It is advisable for the venue operator to write to local residents explaining these contradictory requirements, and assuring them that the process of alignment and measurement will be temporary, kept to a minimum, kept within certain stated timescales, and that every effort will be made to reduce the impact upon them.

27.1 It is recommended that when a new system is being installed at a venue, early consultation should take place with the Local Authority both in terms of proving that the system does indeed meet the requirements of BS 5839-8:2008 and hence satisfies Building Control, as well as that the systems might have to be tested at sound levels which could be considered as Environmental Noise.

27.2 Whilst the Local Authority might have stipulated noise level limits for the construction process, it is recommended that these should not be considered as being the same limits for the alignment and testing process for a sound system for emergency purposes/voice alarm.

27.3 In general, it should be ensured that sound is only sent to the area under inspection and not to all or large parts of the venue, except where the evacuation strategy requires multiple zones and where it is important to check for cross-talk or signal delays. Test signals should be used in preference to music in order to establish signal routing, level, relative levels, evenness of coverage, delay times, equalization, intelligibility, etc. Only when the system has been proved to be in an almost finished state should the subjective quality be assessed using music. Finally, the subjective quality should also be tested using both live and pre-recorded messages.

NOTE Sounds broadcast at any level above ambient will impede verbal communication, including face to face and telecoms and that this could be a safety issue for all trades working on site since they might not be able to hear a warning sound.

27.4 The construction team should agree adequate time slots towards the end of construction when the sound system can be aligned and tested. This should also take into account the need for abiding by any voluntary timescales in the notice to residents, and any other limitations set out by the Local Authority.

27.5 It is important to ensure that the system continues to meet the intelligibility requirements during its lifetime and this too will require that the system is re-tested regularly, in accordance with the maintenance schedule. Again, the contractor carrying out the work should be sensitive to the general concerns regarding environmental noise, and if the re-testing is likely to take a long time to do, it might be necessary to repeat the procedures of consulting with the Local Authority and/or advising the residents accordingly.

28 Test and alignment signals

*COMMENTARY ON CLAUSE **28***

*The precise process of commissioning varies according to the specific venue as well as the inevitable operational restraints imposed by other trades or activities. Guidance on the overall commissioning process is given in Clause **30**. The signals used to make tests may vary from those used to take measurements for verification of compliance (see Clause **32**).*

A variety of test signals may be used to align, test and evaluate a sound system. The most frequently used are often based upon "pink noise". Pink noise is a sound that contains every frequency within the range of human hearing that has been filtered to have equal energy in every octave. While this might be very useful for testing equipment performance in the electrical state, it is not representative of the acoustic content of real world sounds.

It is preferable to filter the test noise so as to represent the spectrum of the speech, otherwise the system might be unfairly judged in terms of its ability to reproduce out-of-band energy (see Annex J).

The initial purpose of the test signal is to prove that the signal passes from the correct source to the selected and desired destination. Where a base SPL is required to be achieved, a steady state source is easier to measure than a dynamic source.

The next purpose of the test signal is to balance the SPL of one zone with its neighbour in order to achieve an evenness of coverage. This requires a steady state broadband source, i.e. pink noise. A sine wave signal is unsuitable as wave interference effects are likely to have serious effects on the perceived uniformity.

Following on from this, the frequency response of the system in the space might need correcting by means of equalization.

Finally, any areas which need the audio signal to be delayed with respect to the primary sound or primary loudspeakers need to be assessed. This can be carried out in a number of ways. Subjective tests using programme material can be used but clicks or bursts of noise often give a clearer indication of misalignment. The alignment can also be tested objectively. A variety of test signals are available dependent upon the instrumentation employed. It is critical that no subjective or objective verification measurements are attempted until the system has been aligned since the system cannot achieve its potential until it is aligned.

28.1 The various tests and alignment which should be carried out are:

- signal routing;
- sound pressure level;
- relative sound pressure levels;
- evenness of coverage;
- equalization; and

- signal arrival, "time" alignment.

28.2 No measurements for the verification of compliance with any specified parameter should be considered valid until the alignment process is complete.

29 Commissioning

COMMENTARY ON CLAUSE ***29***

Sound systems installed in sports venues are rarely small systems, and rarely simple systems. It is therefore important that the person or persons commissioning them has been involved in at least one project of a similar type, though not necessarily a sports venue. Further guidance is given in Annex B and Annex C.

The sound system has to be tested independent of the testing of associated systems, such as the fire detection and alarm system, and properly aligned so that it is capable of intelligible sound reproduction.

In order to produce intelligible sound, the relative sound pressure levels, equalization and signal delays have to be separately aligned for each space (zone). These parameters do not have to be adjusted at full power, and for the sake of those working nearby, it is preferable to test at moderate volume, with a low disturbance source signal.

The final part of the testing and commissioning needs to be made using pre-recorded messages, music (where applicable) and finally live announcements. It is these subjective tests which are critical to the handover process.

29.1 The system should be commissioned by a person or persons who are experienced and qualified in sound systems of the type and size which has been installed. It should be commissioned for its ability to produce intelligible sound before being connected to any other system such as a fire detection and alarm system.

29.2 The following steps should be followed.

a) The system should have any protective circuits such as limiters and/or compressors set prior to the first electro-acoustic operation.

b) The system should initially be set such that the relative sound pressure levels between zones are correct.

c) Any equalization should be introduced on a zone-by-zone basis to render the frequency response of the whole system even.

d) Any relative delay times between zones should be set as necessary.

e) Only when these parameters have been set should the system be tested for maximum sound pressure level and intelligibility (see Clause **27**).

29.3 The commissioning process should also follow the recommendations of BS 5839-8:2008.

30 Acceptance

COMMENTARY ON CLAUSE ***30***

The acceptance process is not as comprehensive as the commissioning process, nor is it as technical. It is an opportunity to demonstrate to a lay audience that the system works as per the agreed design.

That audience is likely to consist of the client, any responsible authorities, the design and construction team (where appropriate), and potentially the operational ***users*** *of the system.*

Before accepting the handover of the system, the purchaser (or his appointed representative) needs to ensure that they are satisfied with the installed system, that the user has an adequate understanding of the operation of the system and the emergency messages that could be broadcast, and that relevant documentation has been provided.

30.1 Acceptance procedures should be carried out in accordance with the agreed purchase specification, including any tests that are to be witnessed and details of the witnessing procedure.

30.2 The client (or representative of the client) should conduct an inspection of the system, witness a demonstration of its operation by the commissioning engineer, handover of the relevant documents to the user, and witness relevant tests, as part of a formal and structured acceptance procedure, in compliance with BS 5839-8:2008.

NOTE The demonstration may also be made to any responsible authorities, the design and construction team (where appropriate) and potentially the actual users of the system.

30.3 The parameters of the system which are going to be demonstrated should be set out in a method statement (or equivalent) and circulated and agreed in advance, together with the date and time of the acceptance demonstration.

30.4 The demonstration should check that:

a) all installation work appears to be satisfactory;

b) the system is capable of giving an emergency message broadcast, from the emergency broadcast microphone(s) as well as from the voice alarm control and indicating equipment (VACIE);

c) all emergency broadcasts are at the correct priority (see Clause **14**);

d) the system is capable of providing intelligible emergency broadcasts in accordance with Clause **20**;

e) the system operates as intended when the primary power supply is removed;

f) where applicable, the system can carry out an evacuation, with appropriate messages, in accordance with the emergency evacuation plan; and

g) the system will remain operational in the event of network failure.

30.5 The acceptability of a sound system should always remain the subjective quality perceived by human experience en masse, supported by objective measurements.

31 Measurements for verification of compliance

*COMMENTARY ON CLAUSE **31***

The design process may use computer modelling of one or more of the spaces to provide predictions of the performance likely to be achieved by the electro-acoustic design in the resultant system. These predictions are a valuable starting point for determining the scope of the performance requirements in the specification, and thus the measurements used to determine compliance.

Many of the measurements may be carried out using shaped pink noise (i.e. to match the frequency response of typical speech) for level and frequency response purposes. The intelligibility measurements use either the STIPA signal or swept sine wave. These are all steady state (in terms of energy) and none of these represent real world signals.

However, production of the maximum sound pressure level using pink noise or the STIPA signal is far more onerous on the amplifiers and power supplies than its production by real world sound signals. This is due to the fact that pink noise contains all the frequencies at once (constant) whereas real world sound only contains some of the frequencies for some of the time (dynamic). As a result, achieving a particular target maximum sound pressure level with pink noise needs more energy (and electrical power) than real world sound signals of the same loudness. See also BS EN 60268-16, Annex J as noted in Clause ***19****.*

It might be possible to take into account short-term characteristics of amplifiers (see BS EN 60268-3) and loudspeakers (see BS EN 60268-5) in order to avoid specifying components and power supplies that are unnecessarily highly rated for the application. However, this requires considerable skill from the designer.

The designer of any system designed upon such principles is therefore advised to stipulate what characteristics and values are specified for verification measurements using steady state sources and then what principles are to be used for the verification of performance using real world signals. The latter may include listening tests (see Annex H) and the former may include intelligibility measurements (see Annex G).

Typically in a stadium bowl it is likely that between 50 and 100 measurements would be taken, but 200 is not unusual for more complicated architectural configurations.

31.1 The type of verification of compliance measurements and the methods to be employed should be determined at an early stage in the design process and agreed with all interested parties.

31.2 The number and location of measurements for verification of compliance should be determined at the time of the systems design and agreed with all interested parties.

31.3 Any deviation from the agreed types, methods, and quantity of measurements at the time of executing said measurements should be justified, agreed by all interested parties and recorded as an addendum to the specification which forms part of the O&M manuals (see Clause **32**).

32 Documentation

COMMENTARY ON CLAUSE ***32***

The provision of accurate documentation, which reflects the "as built" condition of the installation, is of paramount importance. Documentation is only as good as its veracity. It is in the purchaser's interests to require good and accurate documentation, even though this might come at a cost, since the faster any fault can be identified, the less it will cost to rectify.

Verification is best done by an organization independent of the incumbent contractor in order to avoid over-sight due to familiarity. Systems are often complex and it is therefore pragmatic to verify a representative sample of the data rather than the whole system. This would especially apply to loudspeaker circuits and their labelling, though to some extent the software based routing and signal processing of a DSP system is also a valid case for representative sampling.

BS 5839-8:2008 gives the basis for adequate generic records and other documentation.

32.1 General

Documentation, as a minimum, should conform to the recommendations of BS 5839-8:2008, and include:

a) a procedure for carrying out pre-event checks (see Clause **35**);

b) schematic diagrams of the system (see **32.4**);

c) details of the configuration of items such as DSP and network equipment (see **32.4**);

d) instructions for users of the system and any operational “cue cards” (see **32.2**); and

e) any certification (see Annex B).

32.2 Operations manual

32.2.1 General

The system should be as intuitive in use as possible. In addition, the Operations Manual should comprise a set of clear and concise documentation, designed to make the system easy to use. In order to provide both speed and efficiency of learning, the operations manual may be (and are preferably) divided into two parts or levels of information.

32.2.2 Level 1 – Quick reference “cue” cards

Clear user instructions using A5 or A6 laminated cards may be provided, about 2 to 10 in number (according to the application) and located in the vicinity of the “operating base” (e.g., paging panel, conference room) and specific to that operating base, i.e. for systems with a multitude of outstations, the cue cards relevant only to that location should be available at that location. The building might need 50 cue cards, but each location should only have the few which are relevant.

There should be no more than 10 cards for any location.

*NOTE If more are needed, either the systems design was too complicated in the first place, or the cards contain irrelevant material. For places with complex facilities, the operating manual (**32.2.3**) may be appropriate.*

The cue cards should be written from the point of view of the first time user, to give information for what that person is most likely to want to do. Hence, they should contain succinct headings such as: “How to make an announcement,” or “How to broadcast a pre-recorded message”.

32.2.3 Level 2 – Operating instructions

*COMMENTARY ON **32.2.3***

Operating instructions also tell the user “how to…”, but at a more detailed level, e.g. how to connect an input device, or increase the volume in particular area.

Step-by-step instructions should be provided on a location-by-location basis, so a relevant excerpt can be left at each location.

In each version of the operating instructions, details of all items, components, fittings or accessories that require adjustment, manipulation or other operation and which are necessary to ensure proper working order should be given, but these should be restricted to those which are appropriate. Irrelevant or superfluous information should be avoided.

The instructions should clearly indicate:

a) the identification of operable parts, showing the location of such parts on diagrams with the use of annotated photographs and/or screen shots;

b) routine operating procedures and sequences;

c) operating procedures and sequences for any emergency;

d) fault finding procedures; any fault observed during the routine use of the system should be rectified in accordance with the established maintenance policy (see **37.1** and **37.2**);

e) precautions, warnings and safety measures to be taken in order to comply with any legal requirements relating to the equipment.

32.2.4 Full operations manual

A copy of all the cue cards and each of the excerpts of the operating instructions should be provided as the operations manual as a complete reference document.

32.3 Maintenance instructions

Particular advice should be given on the maintenance of outdoor and/or overhanging equipment.

32.4 Schematic diagrams

COMMENTARY ON CLAUSE ***32.4***

Accurate schematic diagrams are essential for the ongoing operation and maintenance of the system.

Schematic diagrams should incorporate the following:

a) a block and/or signal flow diagram;

b) details of equipment interconnections, including cable labelling;

c) interconnections between equipment rooms; and

d) if programmable units are used, textual or graphical indication as to the basic internal functionality.

In complex systems, multiple schematic diagrams may be used to separate out the different levels of detail.

Diagrams are almost always electronically generated and should be provided as both printed and electronic copies. The electronic copies should be in both native and an easily accessible version (e.g. a PDF).

It is recommended that diagrams that might be regularly referred to are laminated.

In systems where the equipment racks are distributed around the site, interconnections between equipment rooms should be clearly shown on a permanently mounted diagram in each location.

Each rack should contain detailed schematics relating to the individual rack as well as its relationship with external signals. To assist in fault finding, cables should be identified using permanent labels at the equipment connections, and the same identification should be shown on the schematics.

32.5 Software configuration and firmware

COMMENTARY ON ***32.5***

All parties need to be mindful that software might be used for many years and the personnel writing, maintaining and using the software might come and go. Care has to be taken over storage of copies of the software, logs of software changes and all necessary passwords. Consideration ought to be given over who has the rights to any software and the rights or ability to make any changes and checks in the future.

There should be an agreement regarding the copyright, ownership and availability of any software used, in order to protect maintainability in future.

There should be a log of firmware versions currently in use in the system.

32.6 Documentation for specifically installed equipment and infrastructure

All design verification and test result documentation should be included in the maintenance manual, including but not limited to:

a) the report of the structural integrity engineer, if the recommendation in Clause **23** is relevant;

b) results of tests on any network parameters;

c) results of circuit impedance tests;

d) electro-acoustic measurement results;

e) alternative power supply duration and changeover test results.

Section 5: User responsibilities

33 Restriction of access to system controls

*COMMENTARY ON CLAUSE **33***

There are parts of a system which need to be extremely accessible, and there are others which, if accessed by someone lacking in competence, can result in compromising the system during emergencies. It is therefore useful to classify the level of accessibility.

BS EN 54-2 gives classifications for access for the "control and indicating" part of a voice alarm system. The classifications given here reflect those in BS EN 54-2, but apply them more appropriately for sports venues.

Reference to these "access levels" within this particular standard are those specifically given in Table 1.

Users of the system should be afforded different levels of accessibility ranging from full accessibility to very limited accessibility as defined in Table 2.

Table 2 **Access levels**

Access level	Typical application	Restriction
1	Visual indications can be seen by anyone in the vicinity without manual intervention, e.g. a sign saying "Microphone Live".	Most accessible, very public.
2	Not only indications but also (manual) controls are available but only by a special procedure, e.g. a locked door to an announcer's booth or a secondary paging panel within a locked cabinet. As a minimum, only persons having a specific responsibility for safety, and who are trained and authorized to operate the equipment would have access.	Selected non-technical staff including police, fire and event controllers.
3	Level 3 users have all the access of Levels 1 and 2 and also be able to prepare special parameters for an event, e.g. pre-set zones on a touchscreen for announcements according to the seating arrangements for the supporters of different teams. Access to this may be via a key or password of limited availability. Access is by persons who are trained and authorized to re-configure the operational aspects of the system.	More operationally orientated staff such as the match announcer or sound engineer.
4	Level 4 access is restricted to those who have the skill and competence required to safely alter the technical parameters of the system. This involves access by keys and passwords. Access is by persons who are appropriately trained and authorized by the manufacturer or installer to change its basic mode of operation or effect repairs. Clearing fault logs also requires authorization at this level, and the action is then appended to the new fault log.	Least accessible, usually authorized maintenance staff only.

34 Personnel

*COMMENTARY ON CLAUSE **34***

Personnel involved with the operation of the sound system require different skills. For pre-event testing an understanding of how the system is operated is needed. In the case of an announcer, their primary skill is a clear and distinctive speaking voice along with the ability to operate the relevant part of the system.

34.1 Prior to an event at the venue, the responsible person (see BS 5839-8:2008, Section **6**) should ensure that there is an adequate number of competent personnel who are familiar with the system to carry out their assigned tasks.

34.2 The tasks requiring such competent people include:

a) carrying out the pre-event tests (Clause **35**);

b) operating and using the equipment during the event; and

c) identifying any system shortcomings and reporting these to the responsible person.

NOTE Depending upon the size of the venue these responsibilities might need to be spread across a number of people, each with appropriate skills.

34.3 It is expected that users of the system, whether they are employed by the venue management, the Police Authority, the Fire Authority, or anyone else, should only be allowed to operate the system if the responsible person is satisfied that they have reached an appropriate level of competence. Competence is only achievable through training on the system installed in that particular venue; this is especially important in the case of announcers.

35 Pre-event checks

*COMMENTARY ON CLAUSE **35***

Sports venues have a calendar of events which are fairly regular, often seasonal, and usually predictable. It is therefore pragmatic to carry out a major check of the entire system prior to the beginning of the venue's year as an annual check, as well as an operational check prior to each event.

In addition to minimizing environmental noise issues checking the system on a zone by zone basis will also verify the operation of the routing system. Whilst checking the operation of the loudspeakers it is advisable to visually confirm the correct orientation of loudspeakers.

When corrective maintenance is required which includes some or part of the system not being available for use in an emergency, it is advisable to assess the risk to people due to the lack of the system and put alternative measures in place. Since such maintenance is likely to be carried out other than when the venue has an event taking place, the people affected are likely to be predominantly staff and in quite small numbers. Nevertheless the alternative measure might well take the form of someone assigned to monitor the fire detection system and, armed with a megaphone, go to the affected area if an alarm condition arises in order to effect the evacuation.

BS 5839-8 gives recommendations regarding the extent and regularity of maintenance for voice alarm systems as applied to a complete fire detection and alarm system.

35.1 Pre-event checks should include aural checks for correct functioning of all loudspeakers serving areas as identified within the published venue safety plan (e.g. bowl seating, concourses).

35.2 Any indicated or apparent system faults at the end of the pre-event check should be logged and the user notified prior to the event.

35.3 A maintenance regime should be put in place which ensures that the system is always available for events for both entertainment and emergency purposes. This is best assigned to a competent contractor with an agreed scope and timescale.

35.4 It is also recommended that the contract includes cover for a set number of emergency call-outs where a faster response is required, say, during an event. It may also include cover for event attendance in order to assist with the operation of the event, as well as to rectify any problems as they arise.

35.5 It is recommended that wherever possible, routine maintenance is carried out at the same time as emergency maintenance and/or event attendance in order to utilize the skill base in the most efficient manner.

35.6 The annual check should include all items in the pre-event check as well as the following list as a minimum:

a) confirmation of system initialization from an enforced and complete "power off" state;

b) operation on, and changeover to, secondary power;

c) checking of mechanical fixing of loudspeakers in accordance with the structural engineer's recommendations;

d) a spot check of sound pressure levels in each zone and the location and level documented for future reference.

36 Announcements and announcer training

*COMMENTARY ON CLAUSE **36***

As stated in the Green Guide [1], "good communications are not solely dependent on the provision of advanced equipment. This is particularly true of public address systems. The operation of the system and the skills of the operators are equally important.

"In the event of an emergency it is essential that clear, accurate information is given to spectators at the earliest possible time. It may also be appropriate to pre-record certain standard messages, for use in emergencies. It is also important that the announcer is familiar with the layout of the sports ground and the agreed evacuation procedures."

Experience has shown that some announcers become excited too easily, become inarticulate under stress, or are just incapable of translating the need into words which the public will understand and be able to act upon. Training might help to alleviate these traits.

36.1 It is recommended that the announcer practices using the public address system, while assessors comment on the audibility, tone and effectiveness of their delivery.

36.2 In particular, announcers should be trained to give a stressless, articulate and intelligible announcement, especially in emergencies when others might be under stress.

NOTE It is worth noting that intelligibility starts with the announcer, and no amount of electronics or electroacoustics will make a poor delivery better.

36.3 Messages should be positive; leaving those to whom they are addressed in no doubt as to what is required of them.

36.4 Foreseeable messages should be scripted in advance with the agreement of the police, fire authority and, where a safety certificate is in force, the local authority.

36.5 Management should ensure that for certain international events, announcers able to speak the appropriate language(s) are available at the ground, and are briefed on the use of the system and the content of any safety announcements.

36.6 The responsible person should restrict the operation of the emergency announcement facilities to those who have had proper training.

Annex A (informative) Design target matrices

A.1 General

This standard applies to all types of sports venues, not just stadiums for field sports. The spaces which require coverage vary enormously between venues. For example, a swimming pool or an indoor sporting arena has a different set of operating parameters to a predominantly outdoor venue such as a racecourse or cricket ground. It is for this reason that the original version of this standard defined the acoustically distinct areas as:

a) public audience areas;

b) areas of congregation (turnstiles, etc.);

c) areas of circulation (concourses, stairways, etc.);

d) private areas with a view of the event (executive suites, etc.);

e) areas of dispersal (forecourts, designated areas within car parks, etc.).

These were each allocated performance requirements, which varied based on the likely demand arising from the occupational parameters.

This revision of the standard takes the concept one step further and describes how the generic categories (see Table A.1) are to be expanded into a design brief specific to the venue under consideration (see Table A.2).

To aid clarity in the consultation process, Table A.3 proposes a relationship between the technical expression of "frequency response" and the form of subjective sound quality that might be expected. In each case, the likely physical manifestation of typical loudspeaker solutions is also indicated.

The process described in this annex is intended to enable the electro-acoustic designer to agree design targets and associated costs with the client and his design team budget experts. The generic area categories suggest a broad brush budget. When the operational needs of the revenue generation side of the venue are more defined, the subdivision of the broad categories allow the budget of the agreed performance requirement to be refined.

The highest priority of the electro-acoustic design has to remain the achievement of speech intelligibility requirements and a safe and reliable sound system for emergencies. Beyond that, the operational needs, which might demand system enhancement, can be added. The client needs to understand where and why that expenditure is necessary and agree to it at each stage of the design development. This is absolutely no different to any other discipline within the project, and should be afforded the same priority as other safety related disciplines.

The subject of budget and cost is addressed in this standard because shell and core often use a significant portion of the available finance, leaving specialist fit-out budgets unnecessarily squeezed, sometimes to the brink of compromising safety.

As an indication (applicable to new-build or major refurbishment projects), the design (and associated budget) refinements of the sound system would normally start at RIBA Stage C in generic terms and be completed by RIBA Stage G [1].

[1] The Stages are contained in the "Outline Plan of Work" which is published by and regularly updated by RIBA, the Royal Institute of British Architects. This is a common format used in the UK and elsewhere for the construction industry regarding the design and management process.

A.2 The generic design target matrix

Early in the design process, the designer is advised to produce a generic matrix in a similar format to that shown in Table A.1. This identifies the minima required by the standards as well as any enhancement required by the operational proposals of the client. From this, an initial budget can be produced which, together with the performance requirements, will enable the client and his project team to approve the design in principle.

In the case of the electro-acoustics (loudspeakers and their associated amplifiers) the performance might need to be enhanced for the bowl seating area of the stadium (which forms the public audience areas) as well as the restaurants/conference centres/banqueting halls. These areas might require improved bass and high frequency signal level capabilities (beyond that essentially required for emergency purposes) for suitable reproduction of music.

It is important for a client to give approval at this "generic" stage since the performance is related to cost, and the cost to the revenue generation ability of the system. For example, if a venue, which has deep overhanging balconies, is used for pop concerts it might be difficult for a touring sound company to provide sufficient coverage to the back of those overhangs with any front-of-house (FOH) system. If the under-balcony coverage of the "house" sound system is of sufficient quality and power, it can provide show sound without compromising audience expectations, or incurring further rental equipment (often a compromise solution in itself).

A.3 Specific design target matrix

A.3.1 General

The matrix in Table A.2 is given purely as an *example*. The purpose of the matrix is to define the Target SPL, the associated percentage of coverage, and the required frequency response. The sub-divisions of the venue and the value of the design parameters are the outcome of a detailed technical briefing process. The resultant matrix is the cornerstone of the subsequent electro-acoustic design.

A.3.2 Unoccupied and occupied ambient noise levels

NOTE Where the sports venue already exists, it is fairly easy to establish base level data by measurement. However the more usual scenario is one where the building is undergoing major structural change over a considerable timespan. In the process, the purpose and use of the spaces, together with their acoustic properties, is likely to change. In other words, probably no different to a new build – one does not know what the noise levels will be.

An appropriate assessment of noise levels may be derived from an equivalent space in an existing venue. It is advisable to ask the client what venues and their spaces could be considered similar to that which he is trying to achieve. Then, a measurement of ambient noise may be taken and used for the base data for the project in hand.

The part of the event where the measurements are taken will affect the data taken, e.g. a bar area in a concourse at half time will be considerably noisier than during the match, so there is no point in using the quieter measurement. Since one cannot be everywhere at the same time, measurements might need to be taken on a number of occasions.

Table A.1 **Example form of generic design target matrix for a sports venue**

Area	SPL requirement[A)]	STI requirement[B)]	Coverage[C)]	Design frequency response[D)]
Public audience areas				
Areas of congregation 1: turnstiles etc.				
Areas of congregation 2: banqueting halls, etc.				
Areas of congregation 3: bars, etc.				
Areas of circulation 1: internal concourses				
Areas of circulation 2: external concourses, stairways				
Private areas: suites, restaurants, etc.				
Areas of dispersal: forecourts, car parks, etc.				
Pitch				

A) Project specific SPL requirements, both to meet speech intelligibility requirements for emergency purposes, and any higher grade requirements as appropriate to purpose, e.g. for musical entertainment.

B) STI: for example, category F, G or H as per **19.2**.

C) Coverage: this figure is likely to be between 80% and 95% and is used to temper the criteria to allow for the pragmatic necessity to serve unusable as well as usable space within any area.

D) Project specific requirements (see also Table A.3).

There are no specific guidelines concerning where and when to take measurements because it depends upon what is going on at the time of that measurement, what type of venue is being assessed and what type of event is either going on or about to go on. Sports venues are typically multi-purpose venues not only for sporting events but also concerts, exhibitions, or even accountancy exams.

A.3.3 Signal to noise ratio

This is amount which the resultant system can generate over and above the occupied and operational noise criterion. As a guide, and subject to specific acoustic conditions (e.g. RT), the nominal figure of 10 dB is likely to be a minimum requirement to secure an acceptable level of speech intelligibility; however BS EN 60268-16 gives further guidance, especially regarding high SPLs.

A.3.4 Target SPL

This is the resultant sound pressure level requirement derived from the design noise level and the required signal-to-noise ratio.

A.3.5 Target STI

This is the required category (e.g. F, G, or H) of the design (see **19.2**).

A.3.6 Target coverage

This is the percentage of the area where the designer considers he can exceed or at least meet the performance parameters stated. For periphery or masked areas, the performance would at best be slightly reduced as a result of being merely off-axis to a primary sound source (loudspeaker).

A.3.7 Target frequency response

This is the frequency response considered to be appropriate for each sub-division of the venue. Typical characteristics for a given frequency response are given in Table A.3.

A.3.8 Noise measurement metric

It is considered that the $L_{A10,t}$ is the most useful metric for ambient noise measurements over longer periods. However a short term L_{Aeq} would be more appropriate for spaces where the extraneous noise is confined to short bursts. The duration of the measurement needs to be appropriate to the venue and its usual activities.

Table A.2 **Example of a specific design target matrix for a sports venue**

Area/room	**Un-occupied ambient noise** dBA	**Usage noise head-room** dB	**Signal to noise ratio** dB	**Target SPL** dBA	**Target STI** Cat.	**Target coverage**	**Target frequency response**
Levels 1 and 2 concourses	77	6	10	93	G	80%	300 Hz to 6 kHz ±5 dB
Levels 3 and 5 concourses (suite corridors)	70	3	10	83	G	80%	200 Hz to 6 kHz ±3 dB
Stadium bowl	60	32	10	102	H	95%	125 Hz to 12 kHz ±3 dB
Directors lounge	70	20	10	100	G	80%	125 Hz to 12 kHz ±3 dB
Executive suites	70	20	10	100	G	80%	125 Hz to 12 kHz ±3 dB
Banqueting hall	70	22	10	102	G	95%	125 Hz to 12 kHz ±3 dB
Toilets	60	9	10	79	G	80%	300Hz to 6 kHz ±3 dB
VIP entrance lobby	73	6	10	89	G	90%	300 Hz to 6 kHz ±3 dB
Bar lounge	65	25	10	100	G	80%	300 Hz to 6 kHz ±3 dB
Speciality restaurant	65	9	10	84	G	80%	300 Hz to 6 kHz ±3 dB
Conference room	70	6	10	86	G	95%	125 Hz to 12 kHz ±3 dB
Meeting room	70	6	10	86	G	95%	125 Hz to 12 kHz ±3 dB
Offices	60	15	10	85	H	80%	300 Hz to 6 kHz ±5 dB
Car park and external concourses	65	15	10	90	H	80%	300 Hz to 6 kHz ±5 dB

Table A.3 **Typical characteristics for a given frequency response**

Target frequency response	Quality descriptor	Technical comment
300 Hz to 6 kHz ±5 dB	"Voice alarm" Intelligible, but nothing more. Possibly acceptable for background music. Marginally better than telephone quality.	This is a lower quality and would be the sort of musicality associated with an inexpensive 4" or 8" speaker fed via constant voltage system using inexpensive transformers. It is possible that its frequency response is limited by a lack of volume (air) in the back can/box, and/or low mass in the magnet of the driver. Re-entrant horns would also be included in this descriptor.
200 Hz to 12 kHz ±3 dB	"Speech quality" Suitable for speech reinforcement and a better quality of background music. Equivalent to a portable stereo or radio.	This is a medium quality and would be the sort of musicality which is recognisably "better than usual". The response would be associated with an 8" driver with good quality transformer (if not at low impedance) and with a suitably sized back can/box and a high mass magnet. "Music horns" would also be included in this descriptor, but so would co-axial ceiling loudspeakers, and many more esoteric formats of speaker. This would also include some of the active line arrays.
125 Hz to 12 kHz ±3 dB	"Music quality" This is quite a high standard for public places, but would not be considered satisfactory by hi-fi enthusiasts or audiophiles, however, it is a reasonable cost-benefit marker for most venues.	This is a high quality and would be the response from a driver which has a low frequency component, probably of at least 12" diameter, augmented by at least one other component if not two (i.e. 2- or 3-way system). It is preferable not to drive these from constant voltage lines in order to preserve quality in terms of transformer saturation distortion and frequency response. These are intended to be able to reproduce a good bass sound without the need for augmentation and consequently are physically large. They are intended to be able to produce a lot of sound and therefore require a dedicated power amplifier of approximately 300 W per driver.
60 Hz to 18 kHz ±3 dB	"Professional live audio quality." This is a quality typically provided by rental companies serving international concert tours.	Such systems are characterized by large numbers of low-frequency and sub-bass drivers. Also in this descriptor would be discrete component multi-way arrays and hence highly controlled dispersion arrays, full range line arrays and the like.

Annex B (informative) Testing and commissioning method statement

NOTE The following text is a generic description of the testing and commissioning process provided in this annex as an engineering note for information.

B.1 Order of works

B.1.1 Loudspeaker operation

This is a check that all loudspeakers on every circuit are actually functioning. This test proves that the cabling and termination is correct and that the loudspeaker itself is functioning.

NOTE In environments where the access to the loudspeaker is difficult, it is advisable to check loudspeaker functionality prior to installation.

Broadcast a sound and check that the correct loudspeakers are working on a circuit by circuit basis at a relatively low sound pressure level. This is often practically achieved by using a test amplifier to connect to the circuit under test at the installed amplifier position. This can be done by feeding the source directly into the amplifiers before connecting them to the routing and distribution part of the system. It can even be done using a single amplifier which is temporarily connected to the loudspeaker circuit.

B.1.2 Routing and zoning

Most systems of any size have multiple zones which can be selected to receive different sources, possibly simultaneously. Therefore it is still necessary to prove that all available sources can be routed to all relevant zones.

Connect a sound source at low level into an input and route it to each zone on a zone by zone basis. Repeat for all other inputs.

In the case of a system which is capable of routing multiple sources to multiple diverse zones simultaneously, the systems engineer should use different sources at low level and route them to appropriate zones. The sound engineer should then visit each acoustic space to check the validity of the routing.

It is very unusual that routing systems are wrong, but especially in these days of programmable signal processors, there can easily be slip-ups which go undetected until tested in reality.

B.1.3 Maximum level – Part 1

This is an adjustment necessary if there is a primary signal control, such as a digital signal processor, which is responsible for protecting the loudspeakers under load by means such as limiting and/or compression.

NOTE 1 This also applies for systems where the protection is provided within the amplifier hardware and, obviously, the spirit of the wording, rather than the order of the wording has to be applied.

Using a suitable source such as speech and/or music, with any gain control on/in the amplifiers set to full power, increase the gain on the DSP until the correct SPL is achieved in that area on those circuits (bearing in mind that the circuits are likely to be interleaved) according to the electro-acoustic specification. This may require the interleaved circuits to be set for relative level prior to setting the maximum level. Set the compression and limiting to be capable of producing that level only as a maximum.

*NOTE 2 The final levels might need further adjustment (see **B.1.8**).*

B.1.4 Relative level

This is an alignment necessary when there are multiple circuits in the same acoustic space. This might be simply a matter of interleaved circuits in a voice alarm system but in addition it could be because of time delay with respect to a focal point source.

With a feed level considerably below maximum but at a level which is 6 dB above ambient as a minimum, send a pink noise signal to a pair of adjacent areas. Measure the SPL in those areas and check that they are the same or adjust until they are. Progress on to the next adjacent area and repeat the measurement, having muted the previous area, until all acoustically linked areas have been covered.

B.1.5 Equalization

This may be done in the same visit as relative level.

This alignment is to adjust the response of the sound system to its acoustic environment with respect to the loudspeakers' ability to reproduce at all relevant frequencies.

Check the response using a real time analyser and make any equalization adjustments if necessary.

Acoustically similar spaces may be anticipated and the system engineer might be able to make the equalization adjustments in advance to save time.

B.1.6 Output delay

Output delay might be required in order to align the arrival of a sound from different loudspeaker circuits. This is dependent upon the distances between the circuit devices and whether they acoustically interfere.

NOTE Where interleaved circuits (A&B) are deployed for integrity reasons, the A and B circuits are considered as one for this purpose.

B.1.7 Source delay

Where areas are served by more than one source, the delay needs to be placed at the front end of the system and each source set for each location.

B.1.8 Maximum level – Part 2

It is quite possible that the preceding adjustments will have altered the overall maximum level available to be below that required in the specification. For this reason, spot checks should be made and adjustments made accordingly.

B.1.9 Quality

Having aligned the system it is appropriate to use trained ears to subjectively assess the system for overall intelligibility and quality. This is usually achieved by listening to messages first and then to music. Preferably listen at relatively low sound pressure levels when checking the whole site, but lastly definitely at full power in selected areas, if not the whole site.

B.2 Certification

Sound systems used for emergency purposes (be that fire, civil order, bomb alert, etc.) usually require certification that they meet certain standards, and that measurements have been taken to prove that this is the case.

It is not advisable to measure any system until it has been properly and fully aligned as given above. There is no point. If a system is required to be intelligible and the delays have not been set properly, it will not be intelligible.

Care ought to be taken to ensure that where a system is used as the voice alarm part of a fire detection and alarm system, any commissioning of the fire system which triggers the voice alarm is not carried out until the sound system has been fully aligned. Even so, when the voice alarm is finally connected to the fire system, the latter will, of its very essence, cause sounds to be made at maximum sound pressure level and this will surely upset neighbours and fellow workers if it is allowed to continue unabated.

Measurement of verification of compliance is described in Clause **33**. Intelligibility measurements are quite a lengthy and rigorous exercise which requires knowledge and experience. Give due consideration to neighbours and fellow workers by measuring only in those output zones required to cover the relevant acoustic space.

The contractor is advised to produce a template for the commissioning and verification processes which reflects the specific requirements of the venue. This will contain the relevant specification and/or standard clause numbers and headings against which the measurements or ratification of cause and consequence can be entered. The latter might need to be manifold in order to cover the various zones of the project. It is advisable that this is not merely a bureaucratic exercise, but forms part of the maintenance manual whereby the system can be re-tested on an annual basis. Another use would occur when the system is re-aligned following modification or expansion, and that in turn would lead to re-certification.

Annex C (informative) Assessments for acceptability and verification

C.1 General

There are different forms of contractual arrangements which give rise to different approaches to this topic. On the one hand the specialist (design-build) contractor satisfies himself and then invites the purchaser to agree that everything is acceptable. The next level might include a consulting engineer as the specifier and approver for the client, and finally (usually in the event of a dispute) there is an independent expert who will verify whether the contract conditions (specification) has been met. The guidance below is generic for all versions of contractual arrangements with some guidance being more appropriate to one version than others.

This standard recommends that the parameters of the tests and measurements are set out at the design stage.

The reasons for this are manifold.

- The degree and complexity of the tests will dictate the manpower and equipment required and therefore the cost.
- The cost needs to be included in the budget which is approved by the client.
- These resources need to be included in the specification so that the costs can be included in the contract.
- The amount of time required will probably be indicated in this process and this could and ought to be included in the correct place in the programme of works so that all other trades co-ordinate and the job can be done properly and on time.

Not all such matters go to plan, but it is advisable to identify potential problems well in advance and agree the practical and acceptable route with the client so that there are no surprises at the end of the day.

The chosen assessment could consist of "if you can hear something, it is time to walk away" at one end of the scale, whereas a "scientific" assessment defendable in court is at the other end of the scale.

Indeed, "acceptability" has been defined in this standard as a subjective assessment, whereas verification of conformity has been defined as an objective assessment. Having completed the testing and alignment of the system, what is probably the right amount of assessment is demonstrating the coverage, the loudness and quality to the client and subsequently a successful first public event.

If anything is found to be missing, inadequate or distorted or unintelligible, when clearly it ought not be so, then the contractor needs to rectify the situation and the assessment be repeated.

If the client is still not satisfied, that is when it is advisable to call for independent verification of whether or not objective measurements can prove the case. Such measurements are at the client's expense until they prove a failing of the contractor, so they tend to be a rare occurrence in practice.

C.2 Degree of assessment

It is easy to concentrate on the prime area, such as the bowl of a stadium or the steppings of a racecourse grandstand, plan to assess that in great detail and compare it against the computer predictions at the design stage. However, the banqueting hall, the supporters' bar and the public concourses, not to mention the parade ring or production kitchens, are all part of the same system and they have minimum standards which also have to be met for operational reasons let alone life safety.

When planning the assessment process, due regard has to be taken of the testing and alignment process. There is no escaping testing and alignment: without it, the system is not fit for purpose. for the process of alignment proves acceptability, so the witnessing process after a successful alignment process, in effect, duplicates the exercise.

Even if it has produced a duplication (or partial duplication) the client obviously expects to witness personally (being the paymaster) so it is as well to have the witnessing process as the minimum degree of assessment.

NOTE The testing and alignment process is collectively referred to as "commissioning" by the contractor. It has become popular that the subsequent witnessing process has been carried out by independent "commissioning" companies, especially in relation to fire detection and alarm systems in large buildings. The certification of conformity is usually issued by the contractor and witnessed by the commissioning contractor where appropriate. Recently, the Football Licensing Authority has taken on the mantle of witnessing the conformity to official guidance (standards and the Green Guide [1]), not only of stadiums, but also racecourses. Indeed they also have monitored designs as well as implementation.

Whatever the hierarchy of the acceptance process, the guidance given in **C.3** to **C.5** is aimed at those who are familiar with the technical, scientific, and practical needs of a sports venue, rather than a lay person.

C.3 Evenness of coverage

Before undertaking any objective measurements the tester is advised to familiarize themselves with the system performance by walking through the spaces and listening to check each "audience" position both on- and off-axis.

Especially when dealing with the prime spaces, such as the bowl of a stadium, one it is advisable to look at the location and spacing of the speakers and imagine how the sound is likely to beam out from the transducer to the audience. Listen to the system in one stand. This will identify any "gross errors" but more importantly will allow one to define how the measurements are to be taken and where.

Measurements are handy for an informal assessment, but critical for a formal verification.

Once individual loudspeakers have been confirmed as operational as intended, where the spaces are physically repeated, such as a rectangular bowl of a stadium, a detailed check of one stand is needed and then a confirmatory sample can be sufficient for its mirror image counterpart. Indeed, the adjacent stand might have only a length differential and that might reduce the measurement count as well.

The spaces which are "likely to meet spec" (e.g. those on axis and relatively close to a speaker) are really irrelevant, other than a reference as to the best measurement, and therefore these can be ruled out of the remaining measurement process. That will eliminate 50% to 75% of the measurements which would otherwise be taken.

That leaves two categories to check, namely:

a) the spaces which are likely to be "marginal" (e.g. those on axis but a long way from the speaker supposed to be serving them) and here, if verifying conformity, full measurements would be needed; and

b) the spaces which are likely to be "unlikely to meet spec" (e.g. those off axis and a long way from the speaker supposed to be serving them) and here, if verifying conformity, sample measurements only would be needed just to prove the worst case.

NOTE The degree to which measurement of evenness of coverage is necessary or even desirable is often driven by cost. Pragmatism also dictates whether any root and branch corrections are indeed possible, even at a commensurately high cost. It might well be desirable to continue measurements by a sampling method as described below.

The prime spaces are important, but so are all the spaces. A similar diligence ought to be shown to all parts of a sound system.

Typically in a stadium bowl it is likely that between 50 and 100 measurements would be taken, but 200 is not unusual for more complicated architectural configurations.

Within that process it is advisable to identify whether any failings are rectifiable or inherent to the design. Corrective works are always possible, but not always necessary or desirable (see **C.5**).

When considering what percentage of an area meets the specified performance, the spaces least likely to be occupied, or easiest to escape from, are the first to be included in the mitigating percentile. After that, any spaces which are critical, such as corner seats in a group of seating rows bounded by walls ought to be checked, since these might be the most difficult from which to escape. Attention also ought to be paid to adjacent areas that might impact on the evacuation, in this example the adjoining seats leading to the gangway also ought to be included. The latter are unlikely to be acceptable if the sound is unintelligible. Such considerations are unable to be defined prescriptively in any standard or guide. It is very much a matter for the safety team at the venue to indentify such areas *at the design stage* in order for them to be treated with due importance.

The percentage of an area meeting a criterion might be stated within a specification, but due regard ought to be given to flexibility in applying this when it comes to defining acceptability.

C.4 Intelligibility

In general terms, acceptability is judged by the listeners, and listening tests are a positive and practical way to assess whether the audience both likes and understands what they hear. A client would be wise not to make a final judgement one way or the other until the first event has been held and listening tests have been carried out during that event.

NOTE The client and his senior staff are very unlikely to be assessing the sound system during the first event since their role is to manage the event overall, rather than micro-manage just one aspect. It is therefore the results and report following the listening tests which would be used as the benchmark, together with the overall opinion of the audience, often voiced directly or by word of mouth (see Annex H).

Uneven coverage makes lack of coverage likely, i.e. there will be areas which have predominantly a lack of level, and also frequency response. It is those areas which, logically, will be less intelligible.

When carrying out verification of conformity measurements, it is likely that the number of measurements required would number well into the hundreds. Indeed, just as a matter of project management, even an informal assessment may take over 100 measurements in a stadium bowl alone.

The process of taking intelligibility measurements can take a number of forms, some of which require post-processing for extrapolation of an occupied space. If such a method is proposed, the time needed for measurements is greatly increased since many more "marginal" area measurements are needed and even the "unlikely" areas need greater definition. Indeed the whole post-processing activity is a huge time resource which has to be budgeted for at the beginning.

C.5 Corrective works and liabilities

Acceptability does not necessarily mean that everything is perfect, it just means that the client is satisfied.

Checks or measurements might show that there is a deficiency in coverage or intelligibility. Such a deficiency would probably mean a very expensive and time-consuming exercise in rectification, followed by a test, re-alignment, and acceptance process. The decision as to whether the corrective works have to be carried out depend upon two things, namely:

a) whether the contractor accepts that he is contractually liable; and

b) whether the client is sufficiently upset that he insists the work is done; that is a matter for local agreement.

Where proof of contractual liability is needed, the verification process is a useful tool. It is therefore of critical importance that the subject of the performance specification and the assessment procedures are defined at the design stage. A client could be considered negligent in not allowing the time or resources identified at the design and contract stages of the project, if he later came to rely upon that as evidence in arbitration or legal proceedings.

Annex D (informative) Electro-acoustics – Concepts and clarification of scope

D.1 Introduction

Electro-acoustics, in the context of this standard, refers to technologies, equipment and acoustical conditions that are necessary to achieve stated performance requirements from an audio system broadcasting into an acoustic environment.

Electro-acoustics combines parameters of both hardware and audio content as well as acoustic elements.

D.2 Audio elements

D.2.1 General

Hardware and audio elements include:

- loudspeakers;
- amplifiers;
- audio signal processors;
- installation infrastructure;
- microphones;
- announcement content.

D.2.2 Loudspeakers

The loudspeaker has to be able to produce a clear sound level output of appropriate level. In the case of spectator areas, this often means the ability to produce a sound level higher than that of the current ambient, which might be significantly higher than typical in other public address applications, and over a large area, without noticeable distortion. The loudspeaker selection and locations also affect how the acoustic environment is excited during a broadcast; devices with directivity patterns that match well to their associated coverage areas serve to improve the ratio of direct to reverberant sound to the benefit of intelligibility.

Electro-acoustic factors to consider include:

- output directivity patterns;
- continuous sound level output capability;
- transient signal handling capability;
- frequency response.

D.2.3 Amplifiers

The design or topology of amplifiers vary. Certain topologies clip the output signal to different degrees and in different ways. Signal limitation (clipping) might occur consistently above a certain drive level or might only start to occur when reserves of short term energy are exhausted, i.e. some amplifiers are more capable of transient response than others. Other factors such as protective compressor and/or limiting circuitry might also be a feature of an amplifier design.

It has been shown that signal limitation in the amplifier stage, for whatever reason, is not immediately responsible for a loss of intelligibility. However care has to be taken by systems designers that the intelligibility of which the overall system is capable is not compromised by a disregard of headroom capability.

D.2.4 Signal processors

This includes spectrum equalizers, cross-overs, compressors and time delays. Equalizers are used to optimize clarity and level in difficult acoustic conditions, allowing a subjective balance judgement between naturalness and speech intelligibility (as well as musical quality, where appropriate). A cross-over is used to control the spectral range of a each branch of an audio signal path that is split between loudspeaker drivers intended for operating in different parts of the audible spectrum, e.g. bass, middle and high frequency components. Compressors and limiters are useful in controlling the dynamic range of the speech signal before it is amplified, allowing overall signal level to be maximized while controlling maximum signal levels to avoid distortion. Time delays are used to align arrival times of the same audio signal broadcast from more than one physical loudspeaker location simultaneously.

D.2.5 Microphones

This includes the microphones (and associated local electronics) whether the primary purpose of the microphone is for emergency purposes or not.

D.2.6 Message generator

This includes the recording process as well as the replay electronics.

D.2.7 Announcement content

This includes the choice of text and wording used in the messages, as well the announcers' clarity and delivery skills.

D.3 Acoustic elements

D.3.1 General

Acoustic elements include:

- reverberation time;
- room geometry;
- boundary surfaces;
- signal-v-noise levels.

D.3.2 Reverberation time

Reverberation time is a measure of the time taken for a sound to fall in level by a specified amount, usually 60 dB. It is influenced by the volume of the space and the efficiency of surface finishes in absorbing, scattering and reflecting sound. Where more sound absorbing finishes are present, reverberation time is reduced. Late arriving sound such as sound reflections, reverberance and echoes can mask direct and useful early sound and reduce speech intelligibility.

Also remember that operation of the system might be needed in times of particularly low occupation by the public. In large stadiums or bowls the reverberation time might increase significantly in times of low occupation as the number and area of bare reflective surfaces increases. Satisfactory operation at or near full occupancy might not necessarily translate to satisfactory operation at very low levels of occupancy.

D.3.3 Room geometry

The (air) volume of the "room" has a significant effect on the acoustic response of that space. Larger spaces will tend to have higher reverberation times. Semi-open "rooms" such as stadium terraces are effectively a room with one or more virtual walls of infinite acoustic absorption. This does not preclude reflections since these might be caused by the remaining surfaces.

D.3.4 Boundary surfaces

More absorption within a room will lead to fewer reflections and therefore lower reverberation times.

D.4 Signal versus noise levels

In order for a sound to be intelligible, it requires sufficient audibility and clarity.

Audibility is the ability of the desired sound to be heard clearly over all other sounds. This is expressed as a signal-to-noise ratio.

The background noise in any venue changes with time, audience numbers, and the degree to which that audience is excited. Measurements at existing venues can usefully be studied in order to establish the baseline against which the sound system maximum SPL (sound pressure level) is to be designed.

Measurements of the L10 have proven valuable in this regard, and the data should be expertly interpreted in terms of rationally determining the baseline noise figure. The rationale should be recorded within the project documentation.

Together with the capability of the electro-acoustic system to deliver the required SPL on axis, the system designer also has to take account of the off-axis response and where it joins the dispersion of an adjacent loudspeaker. This will determine the "evenness of coverage". Ideally the system will be designed to provide the required SPL evenly across the whole of the audience area. In practice it is often necessary to design for optimization in the off-axis response areas.

When considering SPL and evenness of coverage, due consideration ought to be given to the fact that the dispersion characteristics of a loudspeaker are frequency dependent. This means that the coverage has to be achieved in all frequency spectra which are critical to intelligibility (nominally the 500 Hz through to 4 kHz octave bands).

D.5 General synopsis

Insufficient attention to the treatment of a "room" to achieve the necessary acoustic environment will pose a problem which no amount of audio hardware can resolve.

Inappropriate selection of audio hardware and loudspeaker location will undo even the most perfect acoustic environment.

Success can only be achieved by a harmonization of the correct hardware and the appropriate acoustic environment.

Intelligibility starts with the talker, so to complete the task of communication, the user has to be competent.

Annex E (informative) Speech intelligibility

In the context of this standard, speech intelligibility is a conceptual quality that refers to the ease with which the words in broadcast speech can be received. It says nothing about the comprehensibility of the verbal content carried or of the language or cognitive skills of the listener employed in extracting meaning from the received words. It is a quality of the overall transport mechanism from the talker's mouth to the listener's ear.

The speech intelligibility needed is such that speech messages, when broadcast, are of sufficient audibility and clarity to the intended audience that they are capable of being understood by average listeners. The responsibility for ensuring that the messages are meaningful to the listeners lies with the user of the system (see Clause **37**).

It is not practicable to apply rigorous, truly behavioural, intelligibility tests of the system performance in the context of an occupied venue nor is it normally practicable to test the system under true emergency conditions. Moreover, such tests would be of limited value as design tools. However, general behavioural tests are important as a continuous evaluation of the effectiveness of the announcer, the correctness of the adjustment of the sound system controls and the continuing operational status of the equipment. It is envisaged that these tests might conveniently take the form of listening tests (see Annex H).

A design target of system performance needs to be based upon objective measurements which can be practically carried out upon completion. Speech transmission index (STI) measurements have been successfully employed as a metric of subjective evaluations of speech intelligibility (see BS EN 60268-16).

BS 5839-8:2008 for voice alarm systems recommends an STI value of 0.5 in general. It continues to recommend conditions and likely areas where variation may then be allowed when agreed by interested parties. By default, the recommendation to achieve objective measurement of 0.5 STI will prevail for all areas of a sports venue. However, it is acknowledged that each specific venue will have characteristics which might require more detailed considerations, exemplified in:

- the arrangements and constraints formed by the accommodation provided for spectators;
- the acoustic properties of the built environment in which the sound system has to operate, e.g. reverberant spaces;
- the dominance of ambient noise which might in turn require high sound levels from the installed system; and
- the roles of signage, stewards and other forms of communication in the emergency management strategy.

The design parameters of the overall sound system will vary with zoning and acoustic requirements for each space, let alone the practicality factors exemplified above. For this reason alone it might be unnecessarily or impracticably onerous to apply the same criteria to all spaces. For example the temporary inclement weather enclosure at racecourse might be perfectly acceptable with 0.5 STI over only 50% of the area whereas the bowl seating area of a football stadium might require 95% intelligibility measured as 0.5 STI minimum. The sort of generic descriptions used as guidance for these parts of a venue include:

- areas of congregation;
- areas of circulation; and
- areas of dispersal.

The methods and metrics of objective measurement of speech intelligibility have developed greatly over recent years and, at the time of writing, the STIPA variant is favoured for application at sports venues or by derived impulse response methods. (see BS EN 60268-16). Proposals to use other metrics ought not to be precluded provided that a reasoned argument is included within the documentation (e.g. O&M manuals) kept at the venue.

Objective speech intelligibility measurements are only really practicable when the venue is empty. In general, it is not possible to make measurements when the venue is occupied for an event, let alone under true emergency conditions. Experts will normally either simulate operational conditions using an ambient noise simulation or convert data obtained under “venue empty” conditions. The latter requires the expert to contaminate the recorded data with spectrum shaped noise in order to predict the performance that would be obtained under emergency conditions.

The system performance design target for intelligibility is applied to each space or zone according to the density of audience, their risk of danger and the pragmatic ability of systems to deliver that performance without being onerous. it is advisable to give such criteria in a table or matrix (see Annex A) and should be fully documented as a fundamental part of the design process. This may be agreed by all interested parties prior to committing to a specification, supply, or installation process.

The objective measurement of intelligibility forms part of the verification of compliance process. This process consists not only of objectively measurable parameters for each fundamentally different part of the venue, but also the tolerance of those parameters. It is advisable that the collection of data and its interpretation in order to replicate real world conditions only be entrusted to a recognized expert. The resultant report includes a full description of the equipment and method used in order to substantiate the results obtained.

Following repairs, routine maintenance or modification, listening tests are carried out to ensure that the performance parameters have been upheld or improved. If the results of the listening tests are unsatisfactory or inconclusive, objective tests are carried out. If these prove that improvements are necessary, improvements ought to be carried out and the test procedure repeated.

Annex F (informative) Intelligibility – The integrity of the signal being measured

Intelligibility measurement per se is outside the realms of this standard (see BS EN 60268-16. There are many different approaches and equipment used in making intelligibility measurements. However most of the common methods cannot measure with any accuracy if the signal is distorted in the level domain by compression.

Sound systems may employ automatic gain controls (AGCs) and/or compression. An AGC is characterized by sufficient gain in the control loop to hold the steady-state amplifier output current substantially constant for values of sinusoidal source e.m.f. above a threshold value, and a release time-constant in the control loop of one second or greater. AGC does not, when correctly implemented, change the subjective quality of the programme signals.

Compression (amplitude compression) is characterized by gain in the control loop set so that the steady-state amplifier output current increases with source e.m.f. less than proportionally for values of sinusoidal source e.m.f. above a threshold value, and a release time-constant in the control loop of the order of milliseconds. Compression changes the subjective quality of the programme material.

For both techniques, the attack time-constant in the control loop is usually of the order of milliseconds.

However, the system is not being measured in the state in which it is designed to be used if these circuits are bypassed. In fact, since the measurements are being made at full output level, loudspeaker drivers might be blown up if this protection is removed.

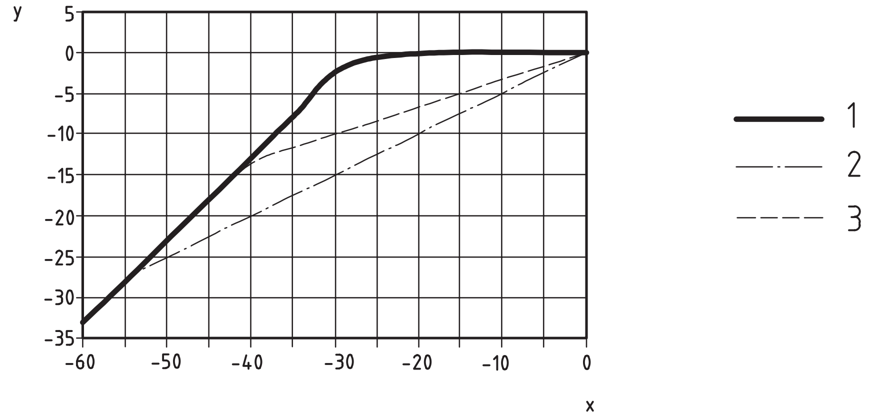
The intelligibility of a sound system starts with the talker in the acoustic domain and finishes with the listener in the acoustic domain. It is therefore logical that a measurement of intelligibility starts with the source in the acoustic domain (artificial mouth) and finishes with the microphone of the meter and/or recorder in the acoustic domain. The latter is common, but the former is rare.

To bypass the microphone and insert the test signal at line level using a different input channel to the system; or even worse, inject it effectively at the amplifier input, is to defeat the object and render the measurement void. However, it is possible that this method of false measurement has been used in the past.

It is as well to consider, and even specify, how the intelligibility measurements is to be used as the design process such that if verification of compliance is required, it is carried out in an appropriate fashion.

Figure F.1 shows typical steady-state output/input characteristics.

Figure F.1 **Typical steady-state output/input characteristics**



Key

1	AGC	x	Input level dB reference rated source e.m.f.
2	Compression 1	y	Output current dB reference rated output
3	Compression 2		

Annex G (normative)

Speech intelligibility objective measurement

G.1 The measurement should follow the recommendations of BS EN 60268-16.

G.2 The type of verification of compliance measurements and the methods to be employed should have been determined at the time of the systems design and agreed with all interested parties, as should the number and location of those measurements.

G.3 The methods to be employed should have confirmed that the measurements are to be taken in an unoccupied venue and the results contaminated with noise by one of the preferred means in order to arrive at a credible and justifiable extrapolation of the data for a venue-occupied condition. The level and spectrum of the contamination noise should preferably have been established, and agreed by the interested parties to be suitable, at the design stage.

G.4 The contamination noise should preferably have been determined by examination of the level and spectrum of an equivalent audience at either the venue concerned, or at another venue of similar operational nature. The data should be studied for a period (or an average across multiple periods) where the noise could be considered to be typical of the primary use of the venue when an emergency could have arisen. This may be as short as the pre-match entertainment plus one half of a football match, or as long as the whole of a horse race meeting. It is essential for the designer to judge the most appropriate period within the data logged, agree this with interested parties, and record this rationale within the design documentation as a specific report.

G.5 The process of logging data and studying it as described above should be done in numerous locations if the building is complex and therefore the electro-acoustic treatment is particularly diverse.

G.6 Having established the baseline for the intelligibility measurements, the locations should have also been determined, and therefore the scope of the measurement process should be complete.

G.7 The results of the measurements should be provided in a report which can be bound into the O&M manuals (in hard and soft copy formats) so that it is available for reference in the future.

NOTE Remember that the requirements of O&M manuals for the construction industry are likely to be in addition to the needs of the client in respect of actual operation of the venue.

G.8 It should be noted that the acceptability of the system can be determined both by measurements using steady state sources (as described in **G.1** to **G.6**) and also using dynamic sources; one is not preclusive of the other in terms of acceptability.

G.9 The acceptability of a sound system should always remain the subjective quality perceived by human experience en masse, supported by objective measurements.

Annex H (informative)

Listening tests

In the context of the overall standard, listening tests are the predominant method of checking that the sound system is functioning correctly and forms a valid form of communication. In their crudest form they consist of listening to a sound source of unspecified type or content. In relation to testing for effectiveness, the methodology has to be more like a controlled experiment.

The acceptability of a sound system is always the subjective quality perceived by human experience en masse, supported by objective measurements.

Listening tests are not an acceptable alternative to objective measurements in terms of the verification of conformity with the agreed design parameters set out in the contract, as described in Clause **34**.

Listening tests are however a valid means of the ongoing assessment of the effectiveness of the sound system and typically consist of a comparison between a message from the announcer and what a listener hears in different parts of the venue. As such, the use of staff messages or winning ticket numbers reported back to event control (or equivalent) are acceptable. It is advisable to log the content of all such messages broadcast and the corresponding results in order that potential gaps in intelligibility can be assessed and investigated.

Where only a guide is required, it is possible to carry out simple checks to confirm system performance. Caution is essential with regard to the interpretation of the results because simple uncontrolled checks are unreliable.

Such checks usually involve the reading of a simple sentence which carries specific information, for example: "The winning ticket number is 413" where the number 413 cannot be predicted.

Numbers are, however, relatively easy to understand and those less than 10 all sound different. Hence an element of guessing or judgement may reduce the validity of the results. Some vowels and consonants, when masked by noise, are more easily understood than others. For example, the number 66 (sounded sixty six) is more readily understood in the presence of low frequency background noise than 34 or 54.

The advantage of these checks is that they can be carried out with minimum disturbance under occupied conditions.

The results are best not expressed in percentage terms, but including the words and messages used, the listener positions, and the number correctly identified by each listener. These ought to be kept in a log in order that trends can be spotted over a period of time.

Where matters of dispute are involved, it is advisable that only objective measurements of intelligibility are used.

Annex I (informative) Measurement definitions associated with sound

dBA — The sound pressure level, expressed in dB, referred to 20 μPa, measured with a defined frequency weighting, known as A-weighting (see BS EN 61672-2).

$L_{A10,T}$ — The A-weighted sound pressure level, in dB, exceeded for 10% of a given time interval.

$L_{A90,T}$ — The A-weighted sound pressure level, in dB, exceeded for 90% of a given time interval.

$L_{Aeq,T}$ — The value of the A-weighted sound pressure level, in dB, of continuous steady sound that within a specified time interval T has the same mean-square sound pressure as a sound that varies with time. It is given by:

$$L_{\mathrm{Aeq,T}} = 10\log\left\{\frac{1}{T}\int_{t_1}^{t_2}\frac{p_a^2(t)}{p_0^2}dt\right\}$$

that is: the equivalent continuous A-weighted sound pressure level, in dB, determined over a time interval $T = t_2 - t_1$.

p_0 — the reference sound pressure (20 μPa).

$p_a(t)$ — the instantaneous A-weighted sound pressure (μPa) (see BS 4142).

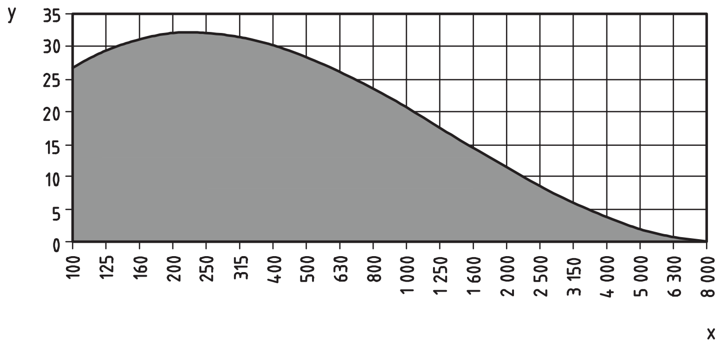
Annex J (informative) Speech-spectrum shaped noise signal

The signal specification given in Table J.1 and plotted in Figure J.1 is that originally produced for BS 7827:1996. The basis of the signal is white noise which is subsequently shaped in accordance with the parameters shown below. As a result, it was not readily available for practitioners and was rarely used. It is therefore only provided here for information if a practitioner prefers to use it.

Table J.1 **Speech-spectrum shaped noise signal**

1/3 octave centre Hz	1/3 octave band response dB	Frequency response dB	Tolerance of frequency response dB
100	–18.4	–5.7	±2
125	–14.5	–2.8	±1
160	–11.7	–1.0	±1
200	–9.7	0 (ref)	0 (ref)
250	–8.7	0	±1
315	–8.3	–0.6	±1
400	–8.6	–1.9	±1
500	–9.4	–3.7	±1
630	–10.7	–6.0	±1
800	–12.3	–8.6	±1
1 000	–14.2	–11.5	±1
1 250	–16.3	–14.6	±1
1 600	–18.3	–17.6	±1
2 000	–20.4	–20.7	±1
2 500	–22.2	–23.5	±1
3 150	–23.9	–26.2	±1
4 000	–25.1	–28.4	±1
5 000	–25.9	–30.2	±1
6 300	–26.2	–31.5	±1
8 000	–25.8	–32.1	±2

Figure J.1 **Speech spectrum shaped noise**



Key
x Frequency, Hz y Level, dB

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For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 4142, *Method for rating industrial noise affecting mixed residential and industrial areas*

BS 5839 (all parts), *Fire detection and fire alarm systems for buildings*

BS 8887-1, *Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – Part 1: General concepts, process and requirements*

BS EN 54 (all parts), *Fire detection and fire alarm systems*

BS EN 54-2, *Fire detection and fire alarm systems – Part 2: Control and indicating equipment*

BS EN 60268-3, *Sound system equipment – Part 3: Amplifiers* [IEC 60268-3]

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BS EN 61672-2, *Electroacoustics – Sound level meters – Pattern evaluation tests*

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ISO 7240-19, *Fire detection and alarm systems – Part 19: Design, installation, commissioning and service of sound systems for emergency purposes*

Other publications

[1] *The Guide to Safety at Sports Grounds*. Department for Culture, Media and Sport. (commonly referred to as the "Green Guide") Fifth Edition. 2008. (http://www.culture.gov.uk/images/publications/GuidetoSafetyatSportsGrounds.pdf)

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