Practice Guidance

The Acoustics of Sound Field Audiometry in Clinical Audiological Applications

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General foreword

This document presents Practice Guidance by the British Society of Audiology (BSA). This Practice Guidance represents, to the best knowledge of the BSA, the evidence-base and consensus on good practice, given the stated methodology and scope of the document and at the time of publication. This is to allow for a greater range of evidence to be included.

Although care has been taken in preparing this information, with reviews by national and international experts, the BSA does not and cannot guarantee the interpretation and application of it. The BSA cannot be held responsible for any errors or omissions, and the BSA accepts no liability whatsoever for any loss or damage howsoever arising.

Stakeholder consultation was undertaken in May 2018. The draft document was available via the BSA website. An electronic copy of this draft, the full list those invited to comment on the draft and the spreadsheet of comments supplied during the consultation are available on request.

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Shared Decision-Making

It is implied throughout this document that the service user should be involved in shared decision-making when undertaking audiological intervention, receiving subsequent information and understanding how it will impact on the personalisation of care. Individual preferences should be taken into account and the role of the clinician is to enable a person to make a meaningful and informed choice. Audiological interventions bring a variety of information for both the clinician and the subject which can be used for counselling and decision-making regarding technology and anticipated outcomes.

Contents

1. Purpose and Scope of this Document

Sound field audiometry is a procedure to assess the hearing sensitivity of a person in which acoustic signals are presented through one or more sound sources in a room (i.e. not through earphones).

This document is intended to provide practical guidelines and highlight some theoretical considerations in the implementation of sound field audiometry for routine clinical assessment of hearing using tonal or narrow-band noise stimuli. It does not cover the use of speech, speech-like, or speech-feature stimuli. It is not intended as a "recommended procedure" but does provide suggestions on a range of issues in order to encourage consistent practice and to promote reporting that is comparable between testers and test centres. This document also aims to suggest ways to minimise some of the errors inherent in sound field testing and to clarify some issues around the interpretation of results.

2. Information from Relevant International Standards

Two international standards are most relevant:

BS EN ISO 8253-2:2009 defines test stimuli and sound field characteristics for sound field audiometry, describes calibration and maintenance procedures for equipment, and gives brief notes about test procedures and the display of results.

BS EN ISO 389-7:2005+A1:2016 gives normative data (reference hearing thresholds, RETSPLs) for pure tones in a free sound field and one-third octave band noise in a diffuse sound field.

2.1 Types of sound field

BS EN ISO 8253-2:2009 describes three types of sound field which are defined by the allowable variation of sound pressure level produced by the output of a loudspeaker in a small space surrounding a reference point. The reference point is roughly at the midpoint of the head of a hypothetical listener and is defined as:

"The midpoint of a straight line connecting the listener's ear canal openings when positioned in the listening position in the sound field."

- In a *free sound field* the walls, ceiling and floor exert a negligible effect on the sound waves produced by a loudspeaker in the room. This condition is met only in an anechoic room and is unlikely to be available in a clinical environment.

- In a *diffuse sound field* the walls, ceiling and floor exert a substantial effect on the sound waves produced by a loudspeaker in the room. The sound energy is uniform over a defined region.

This condition is usually met only in a room which is designed to be highly reverberant and is unlikely to be available in a clinical environment.

- In a *quasi-free sound field* the walls, ceiling and floor exert only a moderate effect on the sound waves produced by a loudspeaker in the room and is the condition most likely to be achieved, in practice, for the purpose of clinical threshold measurements. The sound field is influenced by room reverberation.

Most purpose-built audiology rooms with 100mm of absorption on the walls and an absorptive false ceiling with a 300mm cavity will meet the standard for a quasi-free sound field.

2.2 Types of test signal

BS EN ISO 8253-2:2009 defines three types of test signals which may be used in sound field audiometry:

- pure tones.
- frequency-modulated tones (often referred to as warble tones).
- narrow-band noise.

In a quasi-free sound field, which is the condition most likely to be found in clinical conditions, only frequency-modulated tones and narrow-band noise should be used. Pure tones will cause marked standing waves resulting in unpredictable and unacceptable fluctuations in sound pressure level within the room.

BS EN ISO 8253-2:2009 gives specifications for frequency-modulated tones and narrow-band noise which refer to the specifications in BS EN 61260-1:2014, BS EN 60645-1:2017 and BS EN ISO 266:1997. Any audiometer which is used for sound field audiometry should comply with the above standards but users must satisfy themselves that the additional requirements in BS EN ISO 8253-2:2009 are also met.

FRESH™ noise is a narrowband stimulus suitable for threshold estimation in sound field audiometry. It is calibrated in dB HL, unlike the narrowband noise specified above. As of the 2014 review of BS EN ISO 8253-2:2009 it has not been included in the standard.

2.3 Reference zero for equipment calibration

BS EN ISO 389-7:2005 provides RETSPLs for calibration purposes derived from a large group of laboratory studies in different countries. Reference thresholds are provided for the following two specific conditions and are reproduced in Appendix 2:

- pure tones heard binaurally under free-field conditions with the subject facing the sound source.
- one-third octave bands of noise heard binaurally in a diffuse sound field.

Correction factors are provided by BS EN ISO 8253-2:2009 for the increase in sound pressure at the ear closest to the loudspeaker when the sound is incident from 45° or 90° and are reproduced in Appendix 3. These may be required in some test situations but not others (see Section 3.3).

BS EN ISO 8253-2:2009 provides guidelines on calibration procedures. These are covered in detail in Section 3.4.

3. Practical Issues to Consider in Sound Field Audiometry

There are two main applications of sound field audiometry in clinical audiology:

3.1 Aided hearing assessments

These are usually undertaken with a static system as is detailed in Section 3.3 and have historically been used to provide a measure of the aided hearing of the user, or the functional gain of the user's hearing aid(s). However, real ear measurement (REM) and/or coupler-based measurement has largely replaced sound field audiometry as the primary means of digital hearing aid fitting verification because the ideal test signals are often not appropriate for behavioural threshold measurements. Functional gain measures give information at a very limited number of frequencies and do not characterize the input/output function of the aid or the maximum output levels in the patient's ear. In addition, they do not provide a valid estimate of how a hearing aid will work at conversational speech level and digital signal processing may result in underestimation of the functional gain levels. Therefore, they do not provide a suitable measure for verification of hearing aid response characteristics. Generally, audiologists should be discouraged from attempting to make sound field functional gain measurements in view of the availability of REM unless implantable/semi implantable devices are involved.

Despite this, aided threshold measures can be useful as an indicator of a patient's response to sound in some situations, such as where REM target gains cannot be met. They may also be used to demonstrate the utility of aiding to carers or others as part of the rehabilitation/information-giving process and, as such, may be useful as an outcome measure for discussion with parents of hearing-impaired children, for example (Scollie & Seewald 2002).

Walker et al (1984) advise that caution is required when making direct comparison between pure-tone audiometry results using supra-aural or insert earphones and sound field aided thresholds obtained using narrow band stimuli. Often, different dB scales will apply and the actual sound-pressure level (SPL) at the eardrum may vary considerably as a result of acoustic and anatomical factors.

3.2 Unaided hearing assessments

In most cases sound field assessment of hearing is applicable to young children and clinics in which adults with learning disability are tested. It is generally accepted that, once a hearing loss has been identified, it is desirable to determine frequency-specific unaided thresholds (minimum response level) using supra-aural or (preferably) insert phones where possible. This provides more accurate control of stimulus level as well as enabling ear-specific measures. However, until objective techniques become considerably more refined there will always be the need for minimum response levels to be measured in the sound field for some young children.

In this situation the audiologist is faced with several difficulties affecting the accuracy of the measures. It is vital that the level of the signal at the ears is what is intended, within an acceptable margin of error. This necessitates an agreement on which normative (reference) thresholds to use (addressed in Section 3.4). It also depends on the layout and acoustic characteristics of the room (addressed in Section 3.3).

Threshold measures generally provide information on the sensitivity of the better hearing ear only, which obviously limits the value of the results. Furthermore, if both ears are not the same then the results will indicate a slightly exaggerated hearing loss as the reference thresholds available are for binaural listening (more sensitive by 1- 3 dB depending on frequency; Stream & Dirks, 1974).

3.3 The test environment

Unaided threshold measurements may be undertaken in various ways, but predominantly by:

(a) Hand-held audiometer, usually with the signal-generating circuitry and a single loudspeaker in the same unit (most often used in the distraction test procedure).

(b) Static systems, usually with separate signal-generating circuitry and one or more loudspeakers (most often used in visual reinforcement audiometry).

As outlined in Section 2.1 the sound field in a typical paediatric test room is best described as “quasi-free”, at least in the area around the reference point. The sound field is also influenced by the inverse square law with respect to the distance between the sound source and the reference point.

3.3.1 Room layout

To ensure that measurements are satisfactorily consistent and adhere to that specified by BS EN ISO 8253-2:2009 the room layout should be as follows:

- The loudspeaker should be at head-height of the seated listener and directed towards the reference point. The distance from loudspeaker to reference point should be **a minimum** of 1 m in order to minimise the effects of the inverse square law near the reference point.

- In the absence of the test subject and chair, the sound pressure levels 0.15 m above, below and to the left and right of the reference point should not deviate from that at the reference point by more than 2 dB. In addition, the levels 0.1 m in front and behind the reference point should not vary by more than 1 dB from those predicted by the inverse square law. However, in clinical practice, deviation of up to 5dB can occur (which is clinically insignificant, see below).

- The room should have low ambient noise. BS EN ISO 8253-2:2009 specifies maximum permissible ambient sound pressure levels for hearing threshold level measurements down to 0 dB HL which is usually achievable by the commission of a purpose-built audiology room. However, these levels can be difficult to achieve and, for practical purposes, it is reasonable to accept ambient sound pressure levels that are adequate for measuring hearing threshold level measurements down to 10 dB HL, still only achievable through specialist audiology room design. This entails adding 10 dB to the specified maximum permissible ambient sound pressure levels (see also Lutman, 1997). These levels are given in Appendix 1.

Subject head movement within the sound field is unavoidable. The variation in SPL within 30 cm (in all axes) of the reference point is statistically significant but clinically insignificant (a maximum variation of +/-5 dB; Beynon & Munro 1995, Shaw & Greenwood 2012).

The goal of setting up the test environment is to establish appropriate and consistent sound levels at the reference point. Unfortunately, pragmatic considerations will sometimes introduce sources of variability, e.g. additional people in the vicinity of the reference point, patients in wheelchairs etc. It must be noted that room calibration will, in such a case, be invalidated to an unpredictable extent.

Figure 1 is the recommended Visual Reinforcement Audiometry (VRA) test layout from the British Society of Audiology guidelines (2008). It shows a typical room layout for sound field audiometry where the speakers are at 90° azimuth and with a pair of reinforcers close to the loudspeakers. Due to the position of Tester 2 it is not feasible to deliver the sound signals frontally, so loudspeakers are usually placed at 45° or 90° azimuth.

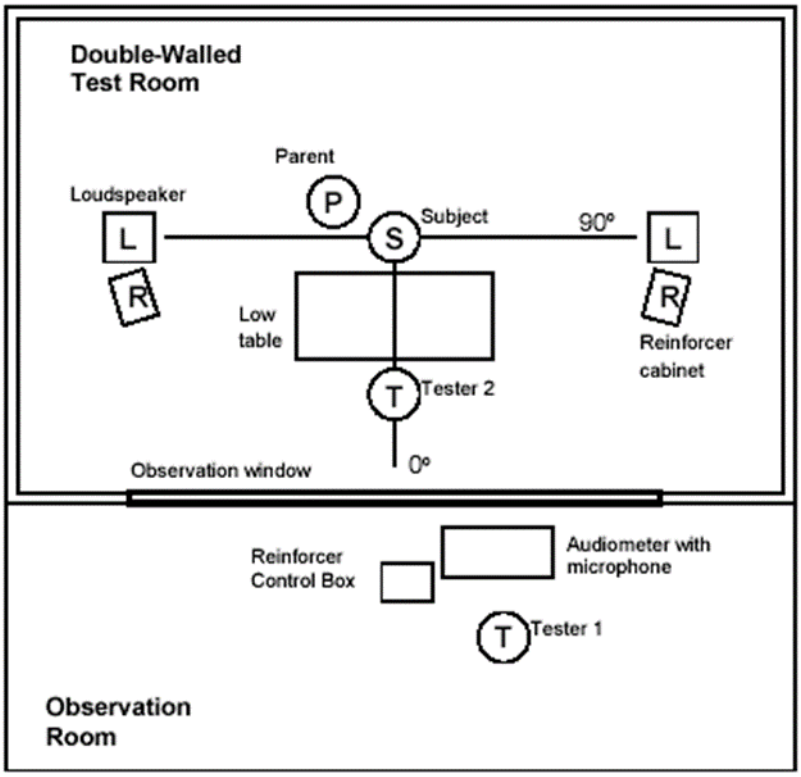


Figure 1: Typical test room layout for VRA, incorporating a separate observation room housing the audiometer and reinforcer controls. (Reproduced from BSA 2008).

3.3.2 Considerations when planning a testing facility

The following points should be considered when setting up a sound field testing facility:

1. The room should be of adequate size (preferred minimum dimensions for paediatric assessment 4m x 6m, plus a separate control room).

2. The room should have low ambient noise. BS EN ISO 8253-2:2009 specifies maximum permissible ambient sound pressure levels for hearing threshold level measurements down to 0 dB HL. These levels are given in Appendix 1.

3. The room should have low reverberation times below 0.25s (HTM2045, 1996).

4. There should be a defined layout of furniture, furnishings and equipment.

5. There should be defined positions for people in the room during testing.

6. There should be a physical demarcation of the calibration reference point. This could be a mark on the ceiling or floor indicating where the patient should be seated.

7. The test environment should be clearly documented. This documentation should include:

   - A description of the instrumentation used in the test environment.
   - Instrument settings.
   - A written description of the physical test environment and positions of all moveable and permanent fittings and furniture.
   - Diagrammatic description of the test environment allowing three-dimensional location of the reference point and all furniture, fittings and equipment.
   - A description of the calibration procedure.
   - Tables showing:
     a) Typical ambient noise levels across frequency.
     b) Lowest testable threshold levels across frequency.
     c) Dial corrections / sound pressure level recordings across frequency for each loudspeaker and for each signal type.

8. Preferably, the room should have the audiometer and control equipment for the sound field stimuli in a separate and adjacent control room, with an observation window between the two rooms.

9. The loudspeakers should be at the head-height of the seated listener and directed towards the reference point. The distance from loudspeakers to the reference point should be at least 1 m.

3.4 The measurement scale to be used

There are currently three different measurement scales that are used in sound field audiometry and each has advantages and disadvantages according to the particular test procedure being carried out. It should be noted that dB HL calibration is used in the majority of cases. It is possible to calibrate a sound field reference point using any of these scales (i.e. so that the audiometer dial reading corresponds directly to one particular scale).

3.4.1 dB SPL

This is the fundamental sound pressure level (referenced to 20 μPa) and is not derived from any normative sound field threshold measurements. Calibration in dB SPL is very straightforward as long as a suitable SLM with filters is available. Measurements in dB SPL have the advantage that they are often required in the use of hearing aid prescription formulae. However, as discussed above in Section 3.1, current practice now favours the use of REM measures for hearing aid fitting and verification. For this reason, the calibration of sound fields in dB SPL does not appear to offer any significant advantages.

3.4.2 dB HL

dB HL is reference to normative sound-field threshold measures (for adults) which should make it an ideal scale for testing. It is comparable (in principle) to dB HL measured using earphones and can be plotted on a standard audiogram form. Unfortunately, ideal normative data are not readily available. BS EN ISO 389-7:2005 provides RETSPL values for pure tones in the free field (directionally dependent) and for 1/3 octave noise bands in the diffuse sound field (binaural listening in both cases).

As previously discussed (Section 2.1) a typical audiology department test room is likely to have characteristics of a "quasi free" sound field. This has certain characteristics of a free sound field (directionally dependent and following the inverse square law) and others of a reverberant field. As most test rooms are different the exact characteristics achieved will vary.

The two sets of RETSPLs from BS EN ISO 389-7:2005 are reproduced in Appendix 2. Inspection of the data shows that these are very similar over the frequencies used routinely in audiometry. Differences are 2 dB or less at all frequencies up to 4 kHz and increase significantly at higher frequencies. This means that adopting either data set when using warble tones in a quasi-free sound field probably does not result in errors that are clinically significant. There have been attempts to measure RETSPLs for conditions that more closely match those encountered in normal audiology settings (e.g. Morgan et al. 1979) and these are also similar to the data from BS EN ISO 389-7:2005. However, these were derived from relatively small subject numbers and are not incorporated into any national or international standards.

The RETSPLs from BS EN ISO 389-7:2005 were derived from binaural listening conditions with the sound source in the frontal position (0° azimuth). Both these factors introduce a source of measurement error. Thresholds for binaural listening are about 2-3 dB more sensitive than for the monaural condition (Stream & Dirks, 1974) which means that if the two ears have asymmetrical hearing thresholds then the result (presumed as applicable to the better ear) will appear worse by this amount.

Correction factors are available from BS EN ISO 8253-2:2009 for loudspeakers placed at 45° or 90° azimuth (rather than 0°), but for normal clinical purposes use of these is not recommended. When sound is incident from a lateral direction there is a frequency-dependant increase in sound pressure at the ear closest to the loudspeaker. However, for assessment of minimal response levels where the better ear is not known then these should not be applied as there is an equal chance that the better ear is away from the loudspeaker and therefore subject to reduced sound level relative to the calibration. In principle, under certain specific conditions the correction factors can be taken into account (i.e. when the better ear is known, or when testing aided thresholds for a cochlear implant etc.). However, it would be necessary to subtract about 3 dB as it would be a unilateral situation, making the overall correction very small at most frequencies.

3.4.3 dB(A)

This is the scale usually used for broad-band stimuli such as speech sounds. It is referenced to an approximation of normal hearing thresholds in a sound field but is based on the 40 phon equal loudness contour and is smoothed to ease technical incorporation into SLMs. Its derivation is therefore different from that of dB HL. Also, unlike dB SPL and dB HL this scale is not used in other audiological applications. It therefore differs from dB HL and in principle results in dB(A) should not be presented on a standard audiogram form (but see note on conversion below).

From the above considerations it is recommended that sound fields using static loudspeakers are calibrated using RETSPLs provided by BS EN ISO 389-7:2005. As the signals most commonly used are warble tones it is further suggested that of the two alternatives the data set for 1/3rd octave noise bands (in the diffuse field) is the more appropriate (Appendix 2).

For example, with reference to the right-hand column in Appendix 2, audiometer output would be adjusted so that a 60 dB dial setting (i.e. 60 dB HL) produces a level of 63.5 dB SPL at 500 Hz and 55 dB SPL at 4 kHz.

While the majority of sound field audiometry can be performed using static loudspeakers and narrow-band stimuli there will always be situations where natural stimuli or hand-held sound generators are used (see Section 3.5). For practical purposes, measurements in these cases will have to be made using a SLM set to A weighting. It is recommended that results are then presented in tabular form. Alternatively, conversion from dB(A) to dB HL is possible in which case results in dB HL can be entered on a standard audiogram form. Factors for converting between dB (A) and dB (HL) are provided in Appendix 3. The adoption of the RETSPLs from BS EN ISO 389-7:2005 results in mainly small conversion factors. Indeed, over the usual audiometric frequencies these are all less than 3 dB, apart from at 4 kHz and 8 kHz, where they are 4 and 4.4 dB respectively. This means that for most practical purposes dB(A) and dB HL can be used interchangeably.

It should also be borne in mind that the published RETSPLs have all been derived from testing of adult subjects. There is considerable evidence that the lowest obtainable behavioural response levels of children may be different to those of adults (McDermott & Hodgson, 1982). For this reason, it is probably more appropriate to use the term “minimal response level” rather than “threshold” when testing children too young for performance audiometry. These differences can be considerable and will vary with age of the child and the test methodology. Obviously, these cannot be incorporated into test facility calibration but should be considered by audiologists when interpreting test results.

3.5 The use of hand-held sound generators

The use of hand-held systems is regarded as inherently unreliable for measurement of minimal response levels and it should be stressed that wherever possible VRA should be carried out (using a static speaker

setup or, preferably, using insert phones). However, there are clinical situations where hand-held sound generators are useful or even necessary. These include:

- training young children to respond to tonal or narrow-band noise signals prior to measuring their minimum response levels with earphones or static loudspeakers. For this purpose, calibration is not critical.
- distraction testing in clinics (e.g. community) where VRA facilities are not available. This also includes "modified" distraction testing, where a child will not remain at the reference point of a dedicated paediatric test room but opportunistic distraction testing may provide limited but very useful test results (BSA 2018).

In principle, the sound field from hand-held sound generators around a reference point can be calibrated in the same way as static loudspeaker systems. In practice, however, this is complicated by the generator being used in a variety of positions. Significant and unpredictable variability is also introduced by the tester holding the device. Great care should be taken to ensure that the sound generator is pointing directly at the subject to minimise variability (because it is acting as a point source so will not perform to the inverse square law). The pragmatic approach is therefore to check the sound level produced by the device (probably at several distances) using a sound level meter weighted to dB(A). However, it must always be remembered that this measure will not be exactly the same as the level actually generated at the child's ear, largely due to the influence of the tester holding it.

It should also be appreciated that bringing the sound generator close to the ear can be very useful. When a remote sound source is used in a free field, or in a diffuse field, left-right differences are usually very small, especially for low frequencies. Distraction testing depends on head turns stimulated by sound localization. This can be made much easier if the sound source is close to the head. In this case, due to the inverse square law, significant left-right differences (in the order of 5-10 dB) can be generated, increasing the likelihood of a positive head turn. It must be considered, however, that such practice necessitates greater care over measurement of the level at the test ear as intensity will drop off rapidly with increasing distance.

From these considerations it should be clear that the use of hand-held systems is inherently unreliable, but unavoidable in certain situations. Errors can be minimised by standardising distances and positions as much as possible. Reference should be made to the BSA recommendations for distraction testing (2018).

3.6 Periodic calibration of the test stimuli

3.6.1 Static (loudspeaker) sound sources

BS EN ISO 8253-2:2009 outlines three calibration stages:

- Stage A: routine examination and listening test (weekly).
- Stage B: periodic electroacoustic test (intervals not more than 12 months).
- Stage C: Initial room setup, and after any significant change in room layout or external noise levels.

The reader is referred to BS EN ISO 8253-2:2009 for details of the recommended calibration checks, but these are summarized below:

Stage A (weekly)

This is routine checking to ensure that equipment is functioning normally and that the calibration has not altered noticeably and involves the following steps:

- Check of equipment connections, cables etc.
- Check of approximate audiometer output and ambient noise by a listening check at just audible levels for a subject with normal hearing (for all appropriate signals on both left and right channels).
- Listening at higher output levels (60-70 dB HL) to check for distortion, proper functioning of interrupter switches etc.
- Check of subject response and monitor circuits.

Stage B (annually)

This is to ensure that the equipment meets appropriate standards, including those of BS EN 60645-5:2017:

- Frequencies and characteristics of FM tones.
- Sound pressure levels at the reference point, as detailed in Appendix 2 and Section 3.3.1.
- Attenuator steps (linearity).
- Harmonic distortion.

Stage C (room commissioning)

Initial set-up of a sound field test facility involves three main tasks in addition to the actual calibration. These are checks of the ambient noise, the reverberation times and of the uniformity of the field around the reference point. Once these have been established they only need checking if the room layout or contents are significantly changed.

3.6.2 Hand-held sound generators

The principles behind Stage A and B checks hold for hand-held systems as for static loudspeaker systems. It should be emphasised that the source of variability in measurements made using hand-held devices is not usually due to technical limitations of the actual device but is due to variability in device and tester positioning. Even changing the angle of the transducer relative to the ear being tested can change the sound level at the ear significantly. Care should therefore be taken to try to minimise these sources of variability.

Stage A

This is routine checking to ensure that equipment is functioning normally and that the calibration has not altered noticeably and involves the following steps:

- Check of approximate output by a listening check at just audible levels for a subject with normal hearing (for all appropriate signals) or at the minimum output, whichever is lower.
- Listening at higher output levels (60-70 dB HL) to check for distortion, proper functioning of interrupter switches etc.

These checks should be performed with the sound generator at “test distance” (0.5 – 1m from the ear).

Stage B

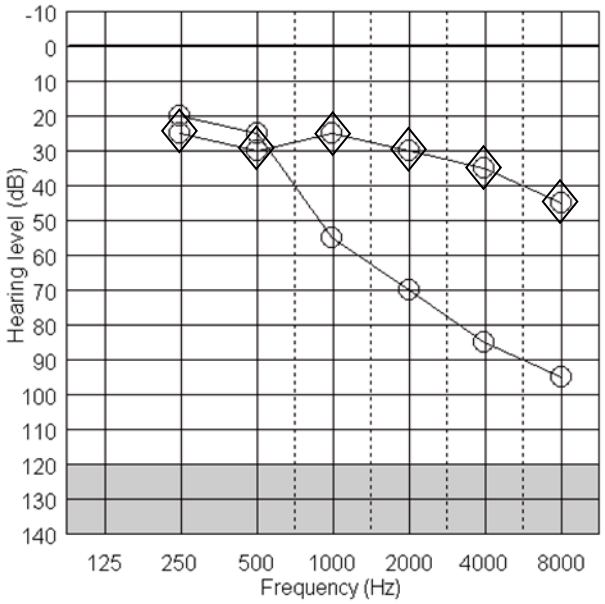
This periodic calibration/check should be performed annually and would normally be carried out by the manufacturer, supplier or independent calibration service. It will include adjustment of output levels so that dial settings are achieved in a quasi-free sound field at the recommended distance (usually 0.5m or 1m), but will also include checks of distortion, linearity and frequency.

4. Symbols and Presentation of Results

Suggested symbols for recording sound field results in dB HL are to be found in BS EN ISO 8253-2:2009, and are as follows:

Test conditions	Symbol
Monaural, left ear	X
Monaural, right ear	O
Binaural	B
Monaural, left ear aided	◇X
Monaural, right ear aided	◇O
Binaural, aided	◇B

In the case of minimal response levels, these will usually be binaural. It should always be noted on the audiogram form whether symbols represent thresholds or minimal response levels. An example of results plotted on an audiogram form is given below:



In this example the right ear is assumed to be isolated in the unaided condition (e.g. by plugging the left ear). If either ear could be contributing to the response then the threshold must be indicated by a "B" symbol on the audiogram. If computer-generated audiograms are being produced these symbols may not be available. A key should therefore be provided which clearly identifies the meaning of all symbols used.

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Appendix 1: Maximum permissible ambient sound pressure levels (from BS EN ISO 8253-2:2009)

The ambient SPLs given in the table below are the maximum that should be present when testing down to 250 Hz and to 0 dB HL. In practice, it is more realistic to aim to test down to 10 dB HL, in which case 10 dB can be added to these figures.

Mid-frequency (Hz)	Maximum permissible level (dB SPL)
31.5	60
40	53
50	46
63	41
80	36
100	32
125	25
160	18
200	12
250	10
315	8
400	6
500	5
630	5
800	4
1000	4
1250	4
1600	5
2000	5
2500	3
3150	1
4000	-1
5000	1
6300	6
8000	12

Appendix 2: Reference thresholds for equipment calibration (from BS EN ISO 389-7:2005)

Free-field thresholds are for pure tones and frontal incidence. Diffuse field values are for one-third octave noise bands.

Frequency (Hz)	Free-field (dB ref. 20 µPA)	Diffuse field (dB ref. 20 µPA)
125	22	22
160	18	18
200	14.5	14.5
250	11	11
315	8.5	8.5
400	6	5.5
500	4	3.5
630	2.5	1.5
750	2	1
800	2	1
1000	2	0.5
1250	1.5	0
1500	0.5	– 1
1600	0	– 1
2000	– 1.5	– 1.5
2500	– 4.0	– 3
3000	– 6	– 4
3150	– 6.5	– 4.5
4000	– 6.5	– 5
5000	– 3	– 3.5
6000	2.5	– 0.5
6300	4	0.5
8000	11.5	5.5

Appendix 3: Factors for conversion of dB(A) to dB HL

Frequency (Hz)	Conversion Factor (dB)
250	2.4
500	0.3
750	-0.1
1000	0.5
1500	-0.1
2000	-0.3
3000	-2.8
4000	-4
6000	-0.5
8000	4.4

Conversion from dB(A) to dB HL first requires subtraction of the dB(A) weighting to give a measurement in dB SPL, followed by the subtraction of the appropriate RETSPL values to convert to dB HL. In the above table the RETSPL values for third-octave noise bands from ISO 389-7:2005 are used.

The above values need to be subtracted from the dB(A) value to obtain dB HL, e.g.:

45 dB(A) at 250 Hz = 42.6 dB HL

60 dB(A) at 4 kHz = 64 dB HL