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GUIDELINES ON THE ACOUSTICS OF SOUND FIELD AUDIOMETRY IN

CLINICAL AUDIOLOGICAL APPLICATIONS

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1. DEFINITION

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).

2. PURPOSE AND SCOPE OF THIS DOCUMENT

This document is intended to provide practical guidelines and highlight some theoretical considerations for 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 reporting that is comparable between test centres.

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

2.1 Unaided hearing assessments

In most cases sound field assessment of hearing is applicable to young children and clinics in which learning disabled adults are tested. It is generally accepted that, once a hearing loss has been identified, it is preferable to determine frequency-specific unaided thresholds using supra-aural or (preferably) insert phones where possible, as this provides more accurate control of stimulus level as well as enabling ear-specific measures. However, this is often not possible with young children and the principal aim of this document is to suggest ways to minimize some of the errors inherent in sound field testing and to clarify some issues around interpretation of results.

Unaided threshold measurements (minimal response levels) 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 a distraction test procedure).

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

2.2   Aided hearing assessments in hearing-aid users of all ages

These are usually undertaken with a static system as in section 4.2 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).

This function has largely been replaced by real ear measurement except in the case of special devices, such as bone-anchored hearing aids or cochlear implants, where such measures are not possible. Sound field measures are not recommended for precise measurement of hearing aid performance for fitting purposes where information about the supra-threshold performance of the aid is required.

Caution should be applied in making direct comparison between PTA 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 SPL at the eardrum may vary considerably as a result of acoustic and anatomical factors.

3.   INFORMATION FROM RELEVANT INTERNATIONAL STANDARDS

Two international standards are most relevant:

ISO 8253-2 (1998) 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.

ISO 389-7 (2005) gives normative data (RETSPLs) for pure tones in a free sound field and one-third octave band noise in a diffuse sound field.

3.1   Type of sound field

ISO 8253-2 (1998) 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 and by the inverse square law with respect to the distance between the sound source and the reference point. To ensure that measurements are satisfactorily consistent and repeatable, the requirements specified by ISO 8253-2 must be closely adhered to:

- 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 at least 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.

The room should have low ambient noise. ISO 8253-2 specifies maximum permissible ambient sound pressure levels for hearing threshold level measurements down to 0 dB HL. However, these levels are 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. This entails adding 10 dB to the specified maximum permissible ambient sound pressure levels in (see also Lutman, 1997). These levels are given in Appendix 1.

3.2   Type of test signal

ISO 8253-2 (1998) 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.

ISO 8253-2 (1998) gives specifications for frequency-modulated tones and narrow-band noise which refer to specifications in IEC 225, IEC 645-1 and ISO 266. Any audiometer which is used for sound field audiometry should comply with IEC 225 and IEC 645-1, but users must satisfy themselves that the additional requirements in ISO 8253-2 (1998) are also met.

3.3   Reference zero for equipment calibration

ISO 389-7 (2005) provides reference hearing thresholds (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 ISO 8253-2 (1998) 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 4.3).

Standard ISO 8253-2 (1998) provides guidelines on calibration procedures. These are covered in detail in section 4.5.1.

4.   PRACTICAL ISSUES TO CONSIDER IN SOUND FIELD AUDIOMETRY

4.1   The purpose of the measurements and the accuracy required

In recent years, real ear measurement (REM) has largely replaced soundfield audiometry as the primary means of hearing aid fitting verification. This is particularly the case for DSP (digital) aids where the ideal test signals are often not appropriate for behavioural threshold measurements. Generally, audiologists should be discouraged from attempting to make sound field functional gain measurements in view of the availability of REM.   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. Therefore they do not necessarily provide a suitable measure for verification of hearing aid response characteristics.

In some situations aided threshold measures can be useful as an indicator of a patient's response to sound, such as a situation 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).

The use of REM is not appropriate for the fitting verification of certain other assistive devices, notably bone-conduction hearing aids and cochlear implants. Also, it should be borne in mind that not all patients will tolerate REM procedures. In such cases aided thresholds are of considerable importance and directly indicate the availability of speech sounds to the user.

Unaided threshold (minimum response level) measurements should be made using earphones (insert phones or supra-aural) wherever possible, but until objective techniques become considerably more refined there will always be the need for unaided thresholds 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.

One main issue is ensuring that the level of the signal at the ears is what is intended. Firstly, this necessitates an agreement on which normative (reference) thresholds to use. This is addressed in section 4.5.1. It also depends on the layout and acoustic characteristics of the room, addressed below in section 4.2. Even if a reference point can be established satisfactorily sound levels are modified if additional people are present in the test room.

The other main issue is that 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).

Nonetheless, while there may appear to be no perfect solution to some of these problems, it is certainly worthwhile trying to establish guidelines so that procedures and results can be compared across centres.

4.2   The available test environment

As outlined in section 3.1 the sound field in a typical paediatric test room is best described as "quasi-free", at least in the area around the reference point. In this situation, loudspeakers are likely to be 1-1.5m from the reference point, so that the inverse square law will be applicable, but also with a moderate effect of reverberations. 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. For this reason various steps should be taken to minimise these potentially confounding influences. The following points should be considered when setting up a sound field testing facility.

1. The room should be of adequate size (minimum dimensions for practical clinical applications 3m x 3m; preferred minimum dimensions for paediatric assessment 6m x 4m)

2. The room should have low ambient noise (ISO 8253-2 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 (DHSS, 1974)

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

   - A description of the instrumentation used in the test environment and for calibration

   - 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 and intensity for each loudspeaker and for each signal type.

7. 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.

8. 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 at least 1 m in order to minimize the effects of the inverse square law near the reference point.

9. On occasions it is not possible to use a fixed test room arrangement in order to accommodate, for example, children and their parents or wheelchair users. It must be noted that room calibration will, in such a case, be invalidated to an unpredictable extent and an alternative measurement method should be used, such as real time measurement with a SLM, preferably with remote microphone. During informal trials, variability of

signal levels by up to 15 dB from the calibrated level at the reference point have been noted when "extra" adults have been in the test area.

Fig 1 is taken from the recommended VRA test protocol from the English Newborn Hearing Screening Programme (Day 2002). It shows a typical room layout for soundfield 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 usually feasible to deliver the sound signals frontally, so loudspeakers are usually placed at 45° or 90° azimuth.

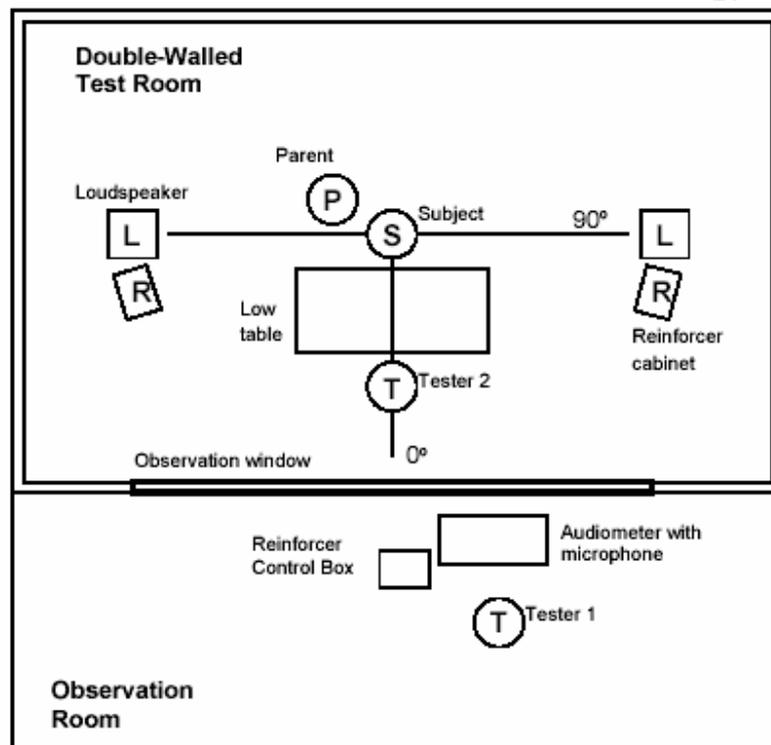The reader is referred to Day (2002) for a clinical protocol for performing VRA.

Fig 1: Typical test room layout for VRA, incorporating a separate observation room housing the audiometer and reinforcer controls. (Reproduced from Day, 2002)

4.3   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 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).

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 sound level meter (SLM) with filters is available. Measurements in dB SPL have an advantage in that they are often required in the use of hearing aid prescription formulae. However, as discussed above (section 4.1) current practice now favours the use of REM measures for most procedures of hearing aid fitting and verification. For this reason the calibration of sound fields in dB SPL does not appear to offer any important advantages.

dB HL

In principle dB HL is what is required as it is referenced to normative threshold measures (for adults) made in the sound field. It is comparable (in principle) to dB HL measured using earphones and can be plotted on a standard audiogram form. Unfortunately, however, ideal normative data are not readily available. The most recent relevant British Standard (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 3.1) 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 ISO 389-7 (2005) are reproduced in Appendix 2. Inspection of the data shows that these are very similar over the frequencies normally used 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

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 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. Obviously, this is not clinically important.

Correction factors are available from ISO 8253-2 (1998) 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.

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 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. In these cases, for practical purposes measurements will have to be made using SLMs 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 ISO 389-7 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.

4.4   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 thresholds with earphones or static loudspeakers. For this purpose calibration is obviously 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.

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 as the generator is likely to be used in a variety of positions. Also, variability is introduced as the influence of the tester holding the device is likely to be significant and unpredictable. The pragmatic approach is therefore to check the sound level produced by the device (probably at several distances) using a sound level meter set 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 minimized by standardizing distances and positions as much as possible.

4.5   Periodic calibration of the test stimuli

4.5.1   Static (loudspeaker) sound sources

ISO 8253-2 (1998) 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: every 5 years of after any change in room layout or external noise levels

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

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 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).
- 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

This is to ensure that the equipment meets appropriate standards, including those of ISO 645-1:

- Frequencies and characteristics of FM tones
- Attenuator steps (linearity)
- Harmonic distortion

In addition to these checks (ideally every 3-6 months) the sound pressure level at the reference point should be checked at least every 3 months. The sound levels at the reference point should be recorded and compared with those in ISO 389-7 (Appendix 2 of this document). The audiometer calibration system should then be adjusted to give dial readings in dB HL for each frequency or dial reading correction factors calculated.

Stage C

Initial set-up of a sound field test facility involves two main tasks in addition to the actual calibration. These are checks of the ambient noise level (covered in section 4.2) and on the uniformity of the field around the reference point (covered in section 3.1). Room reverberation times should also be checked. Once these have been established they need only to be checked every 5 years of whenever the room layout or equipment is changed or if it is suspected that ambient noise levels have changed.

4.5.2   Hand-held sound generators

The principles behind Stage A and B checks hold for hand-held systems as for static loudspeaker systems.

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).
- Listening at higher output levels (60-70 dB HL) to check for distortion, proper functioning of interrupter switches etc.

Stage B

This periodic calibration/check should be performed annually and would normally be carried out by the manufacturer or supplier. 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.

It is not straightforward to reproduce this calibration in the typical clinic, but it is possible to establish a "reference" data set by coupling the device to a 6 cc coupler and microphone using a supra-aural headphone cushion. The electroacoustic characteristics thus measured will not reflect accurately those achieved at the reference point of the test room, due to acoustic impedance differences, but it will be possible to check whether the output of the device has changed over time, should this be suspected.

It should be emphasized 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.

5.   SYMBOLS AND PRESENTATION OF RESULTS

Suggested symbols for recording Soundfield results in dB HL are to be found in
ISO 8253-2, 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:
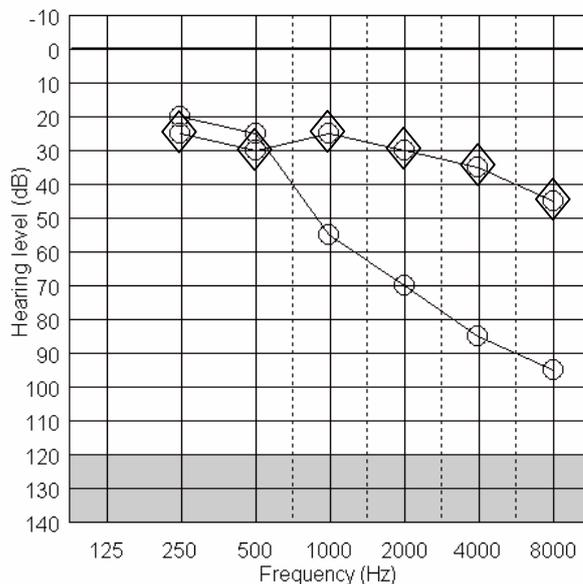
In this example the right ear is assumed to be isolated in the unaided condition (e.g. by plugging
the L ear). If either ear could be contributing to the response then the threshold must be indicated
by a "B" symbol on the audiogram.   NB: if computer-generated audiograms are being produced,
these symbols may not be available. A key should therefore be provided which clearly identifies
the meaning of all symbols used.

6.   APPENDICES

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

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

6.2   Appendix 2: Reference thresholds for equipment calibration (from 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
1 000	2	0.5
1 250	1.5	0
1 500	0.5	− 1
1 600	0	− 1
2 000	− 1,5	− 1.5
2 500	− 4,0	− 3
3 000	− 6	− 4
3 150	− 6.5	− 4.5
4 000	− 6.5	− 5
5 000	− 3	− 3.5
6 000	2.5	− 0.5
6 300	4	0.5
8 000	11.5	5.5

6.3   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 requires first 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

7.   References

Beynon G, Munro K (1993): A discussion of current sound field calibration procedures. *Brit J Audiol* 27, 427-435.

Day J (2002): Visual reinforcement audiometry testing of infants – a recommended test protocol. www.nhsp.info

DHSS (1974): *Hospital E.N.T. Services: A Design Guide*. Department of Health and Social Security, 1974

ISO 8253-2 (1998):   *Acoustics – Audiometric test methods – Part 2: Sound field audiometry with pure tone and narrow-band test signals.* International Organization for Standardization

ISO 389-7 (2005):   *Acoustics - Reference zero for the calibration of audiometric equipment – Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions.* International Organization for Standardization

Lutman, M.E. (1997): *Planning your new audiology clinic.* Newsletter of the British Association of Audiological Scientists, number 29

McDermott JC & Hodgson WR (1982): Auditory thresholds in children for narrow-band noise and warble tone in sound fields. *Br J Audiol* 16, 221-225

Morgan DE, Dirks, DD, Bower, DR (1979): Suggested sound pressure levels for frequency modulated tones in the sound field. *J Speech Hear Dis*. 44, 37-54.

NHS Estates (1994): *ENT and audiology clinics. Hearing aid centre.* Health Building Note 12, Supplement 3. HMSO

Scollie SD, Seewald RC 2002): Evaluation of electroacoustic test signals I: comparison with amplified speech   *Ear & Hearing* 23(5), 477-487

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