NAL Report No 133
January 2010

The calculation of maximum permissible ambient noise levels for audiometric testing to a given threshold level with a specified uncertainty

Warwick Williams

Senior Research Engineer
National Acoustic Laboratories

National Acoustic Laboratories
A division of Australian Hearing

Contents

ISBN 978 – 0 – 646 – 53460 - 2
ISSN 0812 8677

Enquiries concerning this publication can be made to

The Executive Officer, Research
National Acoustic Laboratories
126 Greville Street
Chatswood NSW 2067
Australia

The National Acoustic Laboratories is a division of Australian Hearing, a Commonwealth Government Authority

First published 2010

Abstract

When testing hearing threshold levels specific acoustic criteria must be applied to the ambient sound pressure levels in the space utilised for testing. This is to ensure that the measurements obtained truly represent the levels under test and not simply the ambient or background noise in the test space. International Standard ISO 8253 – 1 provides an appropriate method of either (a) calculating the ambient noise levels in order to test to specific audiometric requirements, or (b) calculating what audiometric tests can be carried out in a particular space.

Key words: maximum permissible ambient SPL; hearing threshold testing; background noise; audiometric testing; audiological testing

1. Background

The National Acoustic Laboratories regularly receives a miscellany of enquiries in connection with the establishment of audiological or audiometric test facilities. The first question asked from enquiries is *"what noise levels are required for audiological/audiometric testing?"*. After considerable discussion the second question inevitably arises *"how do I achieve these noise levels?"*. This current NAL Report addresses the former question but not the latter.

How to construct such a test space, be it a room or a booth, and what materials to utilise is a job for an acoustical consultant or and experienced architect/builder. To attempt to address the design/construction process in this document and present it as a generalised guideline would be too simplistic to do justice to the task.

Enquiries concerning background noise levels usually come from audiologists, audiometrists, practice managers, architects, builders, etc, who have commonly been assigned the peripheral task of finding out '*'whats required for a the new audiological/audiometric test area'*. As pressure comes to reduce costs from those responsible for the construction and maintenance of such test areas, those responsible for testing can find themselves in the unenviable position of trying to help minimise costs while maintaining acoustic performance standards. This can be a very difficult position. Hopefully this document can clarify the requirements and reduce that pressure.

As a direct result of these enquiries it has become more than evident that there is a need in Australia for a recognised calculation methodology for the determination of maximum permissible ambient sound pressure levels for reliable hearing threshold measurements, whatever they maybe, to within a specified accuracy. This can be provided through the use of the International Standard *ISO 8253 Acoustics – Audiometric test methods*.

It must be emphasised that this methodology, calculating the maximum permissible ambient sound pressure levels, does not solve the question of what threshold test level is appropriate, for example 0 dB, 10 dB or 15 dB. These levels can only be set by the professionals and their governing bodies responsible for that testing.

2. Introduction

When audiology was developing in Australia the Commonwealth Acoustic Laboratories (CAL) - followed by National Acoustic Laboratories (NAL: undated) and then Australian Hearing Services - developed a series of specifications or in-house 'standards' that were used for specifying acoustic conditions in test areas (AHS: 1996). These documents were primarily construction specifications but also specified an acoustic performance criterion for the room, known as the Noise Rating (NR) (AS 1469), in which a test booth with specified minimum attenuation was to be installed. These criteria were also commonly also used in the private sector.

Currently there are some very imprecise specifications in circulation that originate from combined *Australian/New Zealand Standard AS/NZS 1269.4: 1998 Occupational noise management, Part 4: Auditory assessment, Appendix D, Maximum acceptable background noise levels for workplace audiometry programs*. *AS/NZS 1269.4* specifically states that the *"specifications in this Standard are not intended for clinical purposes"* (pg 6). However, regardless of this statement the information provided by *AS/NZS 1269.4* is frequently used as a specification for ambient noise levels for clinical assessments of hearing threshold levels.

With the objective of ensuring reliable and repeatable hearing threshold level (HTL) measurements the International Organisation for Standardisation (ISO) developed the series of standards *ISO 8253 Acoustics – Audiometric test methods*. In addition to the methodology for testing, maximum permissible ambient sound pressure levels are also provided as part of *ISO 8253 – 1 Acoustics – Audiometric test methods, Part 1: Basic pure tone air and bone conduction audiometry* in *Section 11 Permissible ambient noise*. These are required to ensure that all measured hearing threshold levels are correct for the stipulated conditions. Australia has recently adopted the *ISO 8253* series of Standards as *AS ISO 8253: 2009 Acoustics – Audiometric test methods*.

Before specifying performance criteria, however, we need to understand their purpose. It is a basic requirement when carrying out any sort of measurement that the measurement process does actually measure the quantity under study and that the measurement process does not in any way significantly affect the parameter under measure. We need to be assured of the accuracy, or trueness and precision, of the result (*ISO 5725*). Thus, if the objective is to measure hearing threshold levels care must be taken to ensure that it is the threshold level that is being measured and not the background or ambient noise of the measurement space where the measurement is being undertaken.

If a test signal for the determination of a hearing threshold level is presented to a subject then in order to respond the subject must be able to clearly distinguish the test signal from the ambient noise in the test space and the ambient noise in the test space must not affect the test signal. If measuring hearing thresholds to 0 dB is the objective then the ambient noise must be significantly below the sound pressure level (SPL) of the applied test signal. This is true for all octave or third-octave bands over which the test signal is to be applied and for adjacent bands depending on the affects of masking (Zwicker & Schorn: 1978).

It is also necessary to appreciate that the unit of measurement for hearing thresholds (dB) is quite different from the measurement of sound pressure level (dB re 20 μPa). The hearing threshold level for a particular test signal is the difference between the SPL at which an individual can detect the test signal 50% of the time and a given reference SPL for that particular test signal. While, alternatively, the SPL of any sound of interest is a defined ratio of the pressure of the sound of interest expressed in Pascals (Pa) to a reference SPL of 20 μPa (20×10^{-6} Pa), expressed in dB.

3. Method

ISO 8253 – 1, Section *11 Permissible ambient noise*, provides internationally agreed specifications on the maximum permissible ambient sound pressure levels desirable for both air and bone conduction audiometry. *Table 2* of ISO 8253 – 1 provides a summary of the maximum permissible ambient sound pressure levels, L_{max}, in one-third octave bands for air-conduction thresholds to 0 dB using typical supra-aural earphones[1]. For convenience *Table 1* below summarises this data in octave rather than one-third octaves as presented in ISO 8252 - 1.

[1] *The two supra-aural earphones specified are Telephonics TDH39 with MX 41/AR cushions and Beyer DT48 earphones*

Air-conduction audiometry

Octave band centre frequency *(Hz)*	***Max permissible sound pressure levels L_{max} (Reference 20 µPa)*** *(dB)*		
	Test tone frequency range *(Hz)*		
	125 to 8k	*250 to 8k*	*500 to 8k*
31.5	56	62	73
63	38	48	59
125	23	30	47
250	18	18	33
500	18	18	18
1 kHz	20	20	20
2 kHz	27	27	27
4 kHz	34	34	34
8 kHz	33	33	33

Note: Using the above values provides an uncertainty of +2 dB due to ambient noise. If an uncertainty of +5 dB for the threshold value is acceptable the L_{max} values in the above table may be increased by 8 dB.

Table 1: Maximum permissible ambient sound pressure levels, L_{max}, in octave-bands for air-conduction audiometry for hearing thresholds down to 0 dB using typical current supra-aural earphones such as the Telephonics TDH39 with MX 41/AR cushions and Beyer DT48 (adapted from *Table 2* of ISO 8253 – 1).

The supra-aural earphone combination represented in *Table 1* provides only a small attenuation of ambient SPL. Greater attenuation, if required, can be provided through the use of purpose supplied noise excluding headsets as detailed in Section 4 following. The attenuation typically provided by this earphone combination is presented in *Table 3* of *ISO 8253 – 1* and reproduced in column three of *Table 4* below.

Table 4 of ISO 8253 – 1 provides similar maximum permissible ambient sound pressure level information for bone conduction audiometry to thresholds of 0 dB. This data is summarised in octave bands in *Table 2* below.

Bone-conduction audiometry

Octave band centre frequency **(Hz)**	***Max permissible sound pressure levels L_{max} (Reference 20 µPa)*** *(dB)*	
	Test tone frequency range *(Hz)*	
31.5	47	56
50	30	39
125	20	21
250	11	11
500	8	8
1k	7	7
2k	6	6
4k	2	2
8k	9	9

Note: Using the above values provides an uncertainty of +2 dB due to ambient noise. If an uncertainty of +5 dB for the threshold value is acceptable the L_{max} values in the above table may be increased by 8 dB

Table 2: Maximum permissible ambient sound pressure levels, L_{max}, in octave-bands for bone-conduction audiometry for hearing thresholds down to 0 dB (adapted from *Table 4* of ISO 8253 – 1).

It is not uncommon for sites that carry out audiometric testing to experience ambient sound pressure levels that exceed the levels specified by the Standard. In these cases higher ambient levels may be tolerated and excluded by the use of noise excluding headsets or insert earphones. In this case as long as the attenuation of the headsets or inserts is known, new acceptable ambient levels can be calculated. These new ambient levels may be higher than those presented in *Table 1* above. Similarly if threshold testing is not required to be carried out to 0 dB higher ambient levels may be acceptable.

Section 11 of ISO 8253 - 1 provides a method for calculating maximum permissible ambient sound pressure levels for testing with noise excluding headsets and inserts and to hearing threshold levels other than 0 dB. This calculation must take into account not only the attenuation provided by the chosen noise excluding headset or ear but also the attenuation provided by the usual test headset. Importantly, the attenuation of the noise excluding headsets must come from a recognised, standard test procedure.

4. Specific example of the calculation procedure

Consider the case where audiometric testing needs to be carried out at a location where the ambient noise is greater than those levels specified in ISO 8253 – 1. Under these conditions it will be desirable to make use of a noise excluding headset of known attenuation. It should be noted here that the attenuation data normally supplied with the ear muffs when used as personal protectors may not be applicable. In most applications the shells of the earmuff will have been modified to allow for the insertion of the earphones. This may include, for example, drilling holes to allow the passage of cabling between the audiometer and the earphone. Also just the simple fact of mounting the earphone within the shell may significantly vary the attenuation performance of the device.

For the current example, consider that a headset has been supplied which consists of earphones (TDH39) mounted within a typical noise excluding ear muff. Typical attenuation characteristics of the earmuffs when used in such a manner are provided by the manufacturer or supplier and are outlined in *Table 3*.

***O/B centre frequency** (Hz)*	*125*	*250*	*500*	*1k*	*2k*	*4k*	*8k*
***Mean attenuation** (dB)*	8	13	25	34	29	30	32

Table 3: Mean attenuation characteristics in octave bands for the noise excluding ear muff used in the given example.

To calculate the required ambient levels when using a different headset from those specified, Telephonics TDH39 with MX 41/AR cushions and Beyer DT48, the process is to simply add the extra attenuation of the intended headset to that provided by the typical specified headsets. Alternatively, if the attenuation values are less the values are subtracted.

Octave band centre frequency (Hz)	*Max ambient using typical supra-aural H/S* (dB)*	*Typical attenuation of supra-aural H/S** (dB)*	*Mean attenuation of H/S proposed for use† (dB)*	*Difference between proposed H/S and typical supra-aural‡ (dB)*	*Max ambient when using proposed H/S☻ (dB)*
	A	B	C	(C – B)	A + (C –B)
31.5	56	0	0	0	56
63	38	0	0	0	38
125	23	3	8	5	28
250	18	5	13	8	26
500	18	7	25	18	36
1 kHz	20	15	34	19	39
2 kHz	27	26	29	3	30
4 kHz	34	32	30	-2	32
8 kHz	33	24	32	8	41

Notes: * Value from ISO 8253 – 1, *Table 2*
** Value from ISO 8253 – 1, *Table 3*
† Obtained from supplier data
‡ Difference between the mean attenuation of the proposed headset and the typical supra-aural headset attenuation
☻ Sum of maximum ambient using typical supra-aural and difference between supra-aural and proposed headsets

Table 4: Table summarising the calculation required to estimate the maximum permissible ambient sound pressure levels (L_{max}) in octave bands using a proposed headset of given octave band attenuation for hearing threshold measurements down to 0 dB from 125 to 8k Hz with a maximum uncertainty of +2 dB.

The mechanics of this process are provided in *Table 4* for a noise excluding headset that has the attenuation characteristics to provide threshold testing to 0 dB over the range 250 to 8k Hz. The final column provides values for the permissible ambient sound pressure levels. Conversely, this process may be reversed if the ambient levels are known to calculate the desired attenuation of the required noise excluding headset.

If it is now desired to provide facilities capable of testing to a different minimum threshold and not to 0 dB then using the process outlined in ISO 8253 – 1, the difference between the new minimum threshold level and 0 dB is simply added to all of the given permissible maximum ambient values for 0 dB to obtain the maximum permissible ambient noise levels values. Thus if it is desired to test to a minimum threshold of 15 dB the new ambient sound pressure levels are given in *Table 4*:

Octave band centre frequency (Hz)	***Maximum ambient when testing to 0 dB with proposed new H/S maximum uncertainty +2 dB (dB)***	***Maximum ambient when testing to15 dB with proposed new H/S maximum uncertainty +2 dB (dB)***	***Maximum ambient when testing to15 dB with proposed new H/S maximum uncertainty +5 dB (dB)***
	A	(A + 15)	(A + 15 + 8)
63	38	53	61
125	28	43	51
250	26	41	49
500	36	51	59
1 kHz	39	54	62
2 kHz	30	45	53
4 kHz	32	47	55
8 kHz	41	56	64

Table 4: An example of the maximum permissible ambient sound pressure levels, L_{max}, in octave bands for threshold testing to 0 dB and 15 dB from 125 to 8k Hz for the proposed noise attenuating headset with a maximum uncertainty of +2 dB or + 5 dB.

From these values the maximum uncertainty of the threshold values will be +2 dB. If, however, it is acceptable to allow an uncertainty of up to +5 dB then a further 8 dB can be added to the maximum permissible ambient sound pressure levels. The results are presented in column four of *Table 4* above.

It should be noted that ISO 8253 – 1 does not specify if the parameter L_{max} should be measured with the sound level meter on 'F' (fast or 0.125 s) or 'S' (slow or 1 s) time weighting. It has been the convention in Australia and New Zealand to use the slow time weighting 'S' which gives the meter a response time of one second. It is recommended that this convention of using slow time weighting be retained as described in *AS/NZS 1269.4: 2005*, Appendix B. If this is the case then the L_{max} parameter should more correctly be specified as $L_{S,max}$.

5. Discussion

The above work is offered as a solution to the present rather confused state of knowledge and procedures that seem to present when dealing with the estimation of maximum permissible ambient sound pressure levels required for audiometric testing in Australia. It is anticipated that the above examples and accompanying explanation can serve as a tool for audiologists, architects, builders and acoustic consultants when designing acoustic spaces required specifically for the testing of hearing.

Using this template developed from *ISO 8253 – 1 Acoustics – Audiometric test methods – Part 1* the maximum permissible ambient sound pressure levels can be calculated to ensure satisfactory hearing level testing to the intended level and to a specified uncertainty of either +2 dB or +5 dB.

6. Maximum ambient sound pressure levels for audiometric testing

The above work shows the use of the tool to calculate the necessary maximum permitted ambient sound pressure levels for pure tone audiometric threshold testing. The threshold level to which testing should be carried out is determined by the needs of the client under test and the requirements of the test diagnostic procedure. For example, the test requirements for testing young children will vary significantly from those required for older adults or compensation claimants. When testing young children testing will need to be carried out to zero dB threshold levels where as this may not be required for an older person.

Lower threshold measurements mean lower ambient noise requirements which in practice translate into lower ambient noise levels and more stringent location and construction requirements for the test facility and direct financial costs.

While financial costs are a significant consideration when setting up a test clinic or selecting a test site the decision as to what threshold level should be tested and the associated degree of uncertainty are decisions that must be made by hearing health providers and their associated professional bodies.

7. A further note of caution about calibration

The use of a noise excluding headset does not necessarily automatically guarantee you are measuring correct hearing threshold levels.

For example, if the audiometer to be used has been correctly calibrated for use with TDH 39 earphones and cushions then there may be difficulties when these earphones and cushions are mounted inside a noise excluding headset. This difficulty will arise because during the calibration procedure it is assumed that the earphones will be positioned over the ear such that there is close physical contact between the earphone and the ear. In fact the earphone usually rests directly against the pinna. The process of mounting the earphone inside the cup of the noise excluding headset may, and usually does, cause the earphone to be retained in such a position so as to create a physical gap between the earphone and the ear. In this case the audiometer will no longer be calibrated to produce correct hearing threshold levels and the equipment will need to be recalibrated.

If in any doubt please refer questions about equipment to the manufacturer, supplier or calibration laboratory.

8. References

AS ISO 8253: 2009 Acoustics – Audiometric test methods, Standards Australia, Sydney

Australian Standard AS 1469: 1983 Acoustics – Methods for the determination of noise rating numbers, Standards Australia, Sydney 1983

Australian/New Zealand Standard AS/NZS 1269.4: 2005 Occupational noise management, Part 4: Auditory assessment, Standards Australia, Sydney, 2005

Australian Hearing Services (1996) *Guidelines for establishment of AHS Hearing Centres*, Australian Hearing Services, Chatswood

ISO 5725 Accuracy (trueness and precision) of measurement methods and results, International Organization for Standardisation, Geneve, Switzerland

ISO 8253 – 1 Acoustics – Audiometric test methods, International Organization for Standardisation, Geneve, Switzerland

ISO 8253 – 1 Acoustics – Audiometric test methods – Part 1: basic pure tone air and bone conduction threshold audiometry, International Organization for Standardisation, Geneve, Switzerland

National Acoustic Laboratories (undated) *Guidelines for establishment of NAL hearing centres*, Commonwealth Department of Community Services and Health, Canberra

Zwicker, E & Schorn, K (1978) Psychoacoustic Tuning Curves in Audiology, *Audiology*, 17: 120 - 140