Hearing Disability Assessment

Report of the Expert Hearing Group

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1.0 Preface

1.1 Terms of Reference

In November 1997, the Department of Health and Children established an expert group to examine and make recommendations on an appropriate system and criteria for the assessment of hearing disability arising from hearing loss, with particular reference to noise induced hearing loss.

The group was to prepare a report for the Minister for Health and Children.

1.2 Members of the Expert Group

Dr Orlaith O'Reilly	*Director of Public Health, South Eastern Health Board (Chairperson)*
Mr Peter Gormley	*Consultant Otolaryngologist, University College Hospital Galway*
Mr Stephen Hone	*Senior Registrar in Otolaryngology, Beaumont Hospital, (Medical Secretary)*
Mr Vivian Kelly	*Consultant Otolaryngologist, Beaumont Hospital Dublin*
Mr Brian McGovern	*Department of Health and Children (Secretary)*
Mr Donald McShane	*Consultant Otolaryngologist, Adelaide Hospital, Dublin*
Dr Dan Murphy	*Director of Occupational Medical Services, Health and Safety Authority*
Mr Gary Norman	*Audiological Scientist, Beaumont Hospital Dublin*
Prof. Michael Walsh	*Professor of Otolaryngology, Royal College of Surgeons in Ireland*

1.3 Methodology

The Group employed the World Health Organisation definition of impairment and disability. The World Health Organisation defines impairment as any loss or abnormality of psychological, physiological or anatomical structure or function. A hearing impairment therefore represents evidence of disorder of the organs of hearing.

The World Health Organisation defines disability as any restriction or lack of ability to perform an activity, in a manner within the range considered normal for a human being. A hearing disability therefore, is the inability to hear everyday sounds, in either quiet or noisy backgrounds, in a manner that is considered to be normal for humans.

The group approached its task in the following manner.

1. An extensive review of the literature was carried out.
2. The systems of assessment of hearing disability used in other countries were documented and studied.
3. Every Consultant Otolaryngologist in practice in the country was contacted by letter, requesting details of their use of hearing disability assessment systems and their views on the issue. This was followed up by meetings as required.
4. The group met with a number of individuals with relevant areas of expertise or interest, i.e. a representative of the Faculty of Occupational Medicine, the Director, Medical Corps of the Defence Forces, the Chief Medical Advisor to the Department of Social Welfare and representatives of the Permanent Defence Forces Ordinary Ranks Representative Association (PDFORRA).
5. Internationally recognised experts on hearing assessment were identified and their advice obtained. The group met with Professor P W Alberti, General Secretary of the International Federation of Otorhinolaryngological Societies and Professor of Otolaryngology, University of Toronto, Professor Mark Lutman, Professor of Audiology, Institute of Sound and Vibration Research, University of Southampton and Professor RRA Coles, Institute of Hearing Research, Medical Research Council, University of Nottingham.

The Expert Group based each decision in developing the Irish hearing disability assessment scale on published scientific evidence.

The Expert Group met on 16 occasions during a 3 month period from December 1997. The Group engaged the services of a librarian attached to the Royal College of Surgeons in Ireland and a Statistician attached to Trinity College, Dublin to give professional support. The report was submitted to the Minister in March 1998.

1.4 Scope of the Report

The Report outlines the pathophysiology of noise induced hearing loss. It describes European legislation in the field of hearing protection and methods of screening for hearing loss. The difference between screening for hearing loss and the diagnosis of hearing impairment is clarified. The standards for clinical and audiological diagnosis of hearing loss are described. Hearing disability assessment methods from a number of other countries are documented. The proposed Irish scheme for assessment of hearing disability is described, and the scientific basis for its elements discussed. Recommendations for diagnostic testing of hearing impairment and assessment of hearing disability are made.

2.0 Introduction

2.1 Hearing Impairment or Hearing Loss

This is defined as the amount by which an individual's hearing threshold level changes for the worse as a result of some adverse influence. It implies some disorder of the structure or function of the hearing apparatus and is usually measured in decibels (dB).

There are many forms of hearing loss, which broadly divide into 3 main categories:

(a) Sensorineural hearing loss affecting the cochlea or auditory nerve;

(b) Conductive hearing loss affecting the ear canal, tympanic membrane, or ossicles;

(c) Mixed hearing loss, i.e. a combination of sensorineural and conductive hearing loss.

Sensorineural hearing loss is usually irreversible and permanent and may be caused by ageing, infections, trauma, pressure changes, poor blood supply, noise and toxic chemicals, among other causes. Conductive hearing loss is of mechanical origin and may at times be rectified by surgery.

2.2 Hearing Disability

Disability is defined by the World Health Organisation as any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being. A hearing disability therefore, is the inability to hear everyday sounds, in either quiet or noisy backgrounds, in a manner which is considered to be normal for humans (World Health Organisation 1980).

2.3 Age Related Hearing Loss

There is a natural deterioration in hearing ability with advancing years. Most elderly people have at least some degree of hearing loss. We begin life with 23,000 microscopic hair cells inside the cochlea which detect the presence of sound vibrations and send the appropriate electrical information to the brain. However, both the hair cells and the attached nerves degenerate with the passage of time. This phenomenon is known as Age Related Hearing Loss (ARHL) (Schuknecht 1993). In the elderly, this is usually known as “presbyacusis”, but since this process commences after the second decade of life, the term ARHL is more accurate.

2.4 Noise Induced Hearing Loss (NIHL)

Noise Induced Hearing Loss is due to loss of hair cells in the cochlear portion of the inner ear. These hair cells vibrate when sounds pass into the cochlea, and thereby send electrical signals to the brain which are perceived as sound. Excessive noise selectively damages some of these hair cells, causing hearing loss and sometimes tinnitus (noise in the ears)(Alberti, PW 1987a).

Damage to hearing from noise depends on a number of factors. These include the character of the noise, its frequency spectrum, its intensity and its duration. Other important aspects include the interval between the exposure and an individual’s susceptibility. Noise may be continuous or intermittent. Very short interval intermittent noise which may occur in industries such as drop forging or pile driving is described as impact noise. Impulse noise is noise of short duration and high intensity with a characteristic wave form, such as follows gunfire. If impulse or impact noise is repeated very rapidly, as may occur in a piston engine, its characteristics merge with those of continuous noise (Alberti 1987a; Hinchcliffe 1994).

Sound above a certain intensity level may cause damage to the ear. The criteria to describe the likely damage from noise are based on a concept of equivalent amounts of acoustic energy. This concept is known as the Equal Energy Concept and assumes that equal amounts of energy produce equal amounts of hearing loss (Burns and Robinson 1970). Acoustic energy may be defined as the product of noise intensity and duration. As sound intensity is measured on a logarithmic scale, an increase of 3dB equates with a doubling of energy. Accordingly exposure time should be halved for equal risk, if the intensity of the sound increases by 3dB. Noise imission levels have been computed to calculate the exposure and risks to individuals in noisy working environments. Noise in excess of 85dB (A) for a 40 hour week is considered to be hazardous and will cause hearing loss in 5% of the population. At 90dB(A) for a 40 hour week, 15% of the population will develop hearing loss due to cochlear damage (Thomas 1988; Robinson and Shipton 1977).

Excessive noise may cause a temporary or permanent hearing loss known as a temporary or permanent threshold shift. The relationship between noise induced permanent threshold shift and noise induced temporary threshold shift is not clear cut. A temporary threshold shift may blend imperceptibly into a permanent threshold shift with continued exposure to noise. Noise induced permanent threshold shift usually occurs first around 4,000 Hertz (Hz) and then progresses to involve adjacent frequencies. The hearing loss at 4,000Hz progresses over the first ten years of noise exposure and then tends to stabilise. It may take 30 years of ongoing noise exposure to involve the frequencies of 1,000Hz and below (Alberti 1987a). NIHL has a recognisable audiometric pattern with the maximum damage usually occurring at 4,000Hz, but occasionally it may occur at 3,000Hz or 6,000Hz. There is a great deal of variation in hearing loss due to individual susceptibility. It is impossible to predict in any one individual the likelihood of further progression of the hearing loss or the rate of progression with continuing exposure to noise above the accepted limits. Noise induced hearing loss tends to occur equally in both ears unless there is a particular reason why one ear is exposed more than the other. This may occur for example, while shooting a rifle in which a right handed individual would have his left ear closer to the muzzle of the gun.

The maximum loss in the higher frequencies occurs over the first ten years of exposure to noise. Damage to the lower frequencies progresses with continued noise exposure. Once exposure ceases, NIHL does not progress further. There is no reason that early indications of high-tone hearing loss should lead to disabling NIHL, in individuals who exhibit an early NIHL, provided they are protected from further excessive noise exposure. Individuals should be told that they have an early NIHL, and that they will be required to take appropriate precautions and co-operate with arrangements to prevent further exposure. Likewise, potential employers should be warned that such a hearing loss exists but that the candidate is audiologically fit for the duties required but that the arrangements must be such that any workplace noise is controlled to safe levels as required (European Communities 1990).

It is relatively easy to measure continuous noise, but less easy to measure impulse/impact noise. It has been shown that at least some impulse noise follows the Equal Energy Concept which pertains to steady state noise (Ward 1980). International Standard ISO 1999 (1990) gives a method for adding various noise exposures of an intermittent nature to produce equivalent continuous noise level (Leq) to a steady state 40 hour noise exposure measured in dB(A). The standard also quantifies the risk to the exposed population for a given noise level and takes into account the amount of hearing loss which would be expected in a similar population not exposed to noise (Alberti 1987a).

Regulations based on the Equal Energy Concept do not take into account the possibility of recovery periods in cases of intermittent noise. Occupational noise tends to be intermittent rather than continuous due to movement of the individual about the workplace and/or because the noise itself is intermittent.

2.5 The effects of noise on hearing (historical perspectives)

Coppersmith's Deafness was first reported in 1713 by Ramazzini. Admiral Rodney became deaf for a fortnight following the firing of 80 rounds of cannon from his ship *HMS Formidable* in 1782. This is one of the first descriptions of a noise induced temporary threshold shift (Alberti 1987a). An officer is reported to have been made permanently deaf due to the noise from a nearby cannon at the Battle of Copenhagen in 1801. Boilermakers Deafness was recognised first in 1886 (Barr T 1886). The site and histopathology of damage to the ear was first described by Haberman in 1890 (Haberman 1890). He examined the temporal bones of a man who had worked as a blacksmith for 20 years. Damage to the organ of Corti in the inner ear was found with the destruction of hair cells. Most damage occurred at the basal turn of the cochlea. Atrophy of the cochlear nerve with degeneration of the spiral ganglia was also noted. Fosbroke in 1831 coined the expression "Blacksmith's Deafness" giving an accurate description of noise induced deafness in blacksmiths (Alberti 1987a).

It was not until the onset of the Industrial Revolution in the 19th Century that occupational hearing loss became much more widespread. This was perpetuated during a second industrial revolution that occurred following World War II. Since then other groups of 'at-risk' workers were recognised. These included those working in heavy engineering, ship building, the aircraft industry and military personnel. More recently it has been recognised that many leisure activities such as shooting, motorcycling, car racing and listening to loud music may also put the hearing at risk.

Following the introduction of audiometry over 60 years ago, it became possible to measure hearing accurately. In 1939 Bunch was responsible for publishing one of the first audiometric data demonstrating the high frequency loss occurring in those exposed to noise (Bunch 1939). It was in 1938 that an effort was made by the medical profession to study the relationship between noise exposure and hearing loss. At that time, the American Academy of Ophthalmology and Otolaryngology established a sub-committee to study noise in industry (Anon. 1947; Glorig 1980).

Despite the publication of accurate audiometric data on people with noise induced hearing loss in 1939 (Bunch 1939), it was a number of years before it was possible to measure the sound pressure level of noise. It was only with the development of the sound level meter and the octave band analyser that accurate measurements of individual sound exposure were possible. Since then many reports on the relationship between hearing loss and noise have been published.

2.6 Illustration of Noise Intensities of Common Sounds

The following illustration (Table 1.) shows the sound pressure levels (dB) of common sounds. It compares these to percentage hearing disabilities computed by the Irish formula, given a symmetrical hearing loss.

Table 1. Illustration of Noise Intensities of Common Sounds

Percentage Hearing Disability		***Sound Pressure Levels (dB)***
	140	Pain Threshold
	130	
		Jet engine take-off at 100m
	120	
	110	Average disco or Walkman at full volume
100%	100	Pneumatic drill
	90	
		Shouted speech
	80	Average street traffic
	70	Telephone
56%		Business office
	60	
		Conversational speech
	50	
25%	40	Living room
19%		Whispered speech
	30	
0%	20	
		Woodland noise
	10	
	0	Threshold of hearing

3.0 Noise Legislation in Ireland

3.1 1975 Noise Regulations

Legislation introduced in 1974 for industrial workers was replaced in 1990 by legislation covering all workers.

The Factories Act, 1955 set out requirements in relation to safety, health and welfare which were applicable in factories and industrial situations such as building sites and included enabling provisions for Regulations. There were no provisions in relation to noise in the Act. In 1975 Regulations on noise were made under the 1955 Act. These were the Factories (Noise) Regulations, 1975 (S.I. No. 235 of 1975) and were therefore applicable in the same situations as the 1955 Act. These Regulations required that persons employed should not be exposed to sound pressure levels in excess of 90dB(A) unless either:

(a) The duration and level of exposure is controlled so that its cumulative effect is unlikely to cause harm or

(b) ear protection is provided.

The Regulations also required that barriers or warning notices be erected in areas where the noise level exceeded 90dB(A). In effect, these Regulations required employers to provide ear protection if the working environment had noise levels above 90dB(A). These Regulations were enforced by the former Industrial Inspectorate of the Department of Labour. While there was a general requirement in the Regulations to control the duration and level of exposure so as to be unlikely to cause harm, the provision and use of ear protection was given equal weight with any other control method. Inspectors visiting noisy factories following the enactment of the Regulations would recommend, inter alia, the provision of ear protection and encourage employees to use them, in particular if measurements indicated the level was above 90dB(A). The use of ear protection, ear plugs and ear muffs has increased since the 1975 Regulations came into force.

The Safety, Health and Welfare at Work Act, 1989, ushered in a prevention based system covering all employees, in which hazard identification, risk assessment and preventive measures became the norm.

3.2 1990 Noise Regulations

On 1st July 1990, the European Communities (Protection of Workers) (Exposure to Noise) Regulations, 1990 (S.I. No. 157 of 1990) came into force. These Regulations implemented an EC Directive on Noise (86/188/EC). The Regulations set out a comprehensive legal framework for a hearing conservation programme. They are accompanied by a guidance booklet and a leaflet, available from the Health and Safety Authority (1991 and 1992). These Regulations require the following actions where exposure exceeds 85dB(A):

1. Measure noise levels
2. Provide ear protectors and training in use
3. Inform workers of the risk
4. Make hearing checks available.

In addition, where exposure exceeds 90dB(A):

1. Identify the cause of the problem
2. Reduce the noise at source if possible
3. Ensure that areas where noise exceeds 90dB(A) are clearly marked
4. Ensure ear protectors are available and worn
5. Workers must be informed of the potential damage to hearing and wear the protection provided.

3.3 Audiometry in the Regulations

Workers who are exposed to a noise level at or above 85dB(A) (whether or not hearing protection is used) are entitled to have their hearing checked. The purpose of this hearing check is to detect any early hearing loss. The employers must make the necessary arrangements to have the hearing checks carried out by a registered medical practitioner (or a person acting on his/her responsibility). The audiometric tests carried out for the purposes of these Regulations shall comply with the specifications of ISO 6189:1983, supplemented by a measurement of the hearing threshold at 8,000Hz.

It is stressed that the Regulations and the guidelines on audiometry are for screening purposes only. The final diagnosis of NIHL should be made by a specialist with expertise in the area, using clinical diagnostic audiometry which is a more extensive and comprehensive testing than screening audiometry (Health & Safety Authority 1991).

It is inappropriate to use the warning levels or referral levels in Annex 2 of "The Guidelines on Hearing Checks and Audiometry" as levels of disability (Health & Safety Authority 1991). These levels indicate the need for the exposed worker to take more stringent precautions as regards exposure to noise, the wearing of hearing protection and more frequent audiometric testing. The referral level indicates a requirement to refer to a specialist for diagnosis of the cause of hearing loss, disability assessment if appropriate, and treatment where possible.

4.0 Audiology

4.1 Concepts Of Auditory Threshold

4.1.1 Sensitivity Of The Ear

Research has been done to establish what sound level is just audible in the “normal” ear. These levels are obtained with highly trained individuals in the area of psychoacoustics, using quite complex scientific psychophysical procedures. When the sound pressure presented to the ear is reduced, the loudness of the sound decreases, but this is only true down to a certain level: below a certain sound pressure “the minimal audible pressure” the sound is not heard at all. The psycho acoustical measurement of any hearing threshold is based upon a statistical probability; as the intensity of a sound decreases, the probability of detecting a correct response diminishes. As the intensity of a sound increases, the probability of obtaining a correct response increases (Durrant and Lovrinic 1984). The threshold is usually based upon a minimum 50% correct detection. There is therefore no “absolute threshold level” above which one will always obtain a response and below which one will never get a response.

4.1.2 Sound Range Of The Ear

The human ear responds to a very wide range of sound intensities, in a ratio of about 100,000,000,000,000 to 1 from the threshold of pain to threshold of hearing, making such a scale highly inconvenient to use. Therefore a logarithmic scale is used. If the logarithm to the base 10 is taken, the units of the scale are called Bels, after Alexander Graham Bell. This is a small unit, so the scale is expressed in decibels or dB.

The Sound Pressure Level (SPL) in dB = 20 $\log_{10\ (P/Po)}$

The reference pressure (Po) was taken so that 0 dB SPL represented the average absolute threshold, for a 1000 Hz pure tone, 20 micro pascals. Levels referred to this are known as pressure dB SPL. The measured sound pressure level is P. The shape of the curve relating auditory threshold to frequency has been established. Fig 1. is an example of the measurement of absolute threshold as a function of frequency. Sounds of different frequencies, at a constant SPL (e.g 60 dB SPL) do not evoke equal loudness sensations. For example, the reference taken is usually 1,000Hz at a fixed intensity level (60 dB SPL in this case). The listener then adjusts the intensity of a comparison tone of a different frequency to equal loudness (the units are in phons) (Durrant and Lovrinic 1984). For this particular intensity the equal loudness contour would be the 60 phon contour. The ear is more sensitive to the mid frequencies (1,000 – 5,000Hz) and less so at the low and high frequencies as shown in Fig 1. The loudness of a pure tone therefore depends not only upon its SPL but it also varies with frequency.

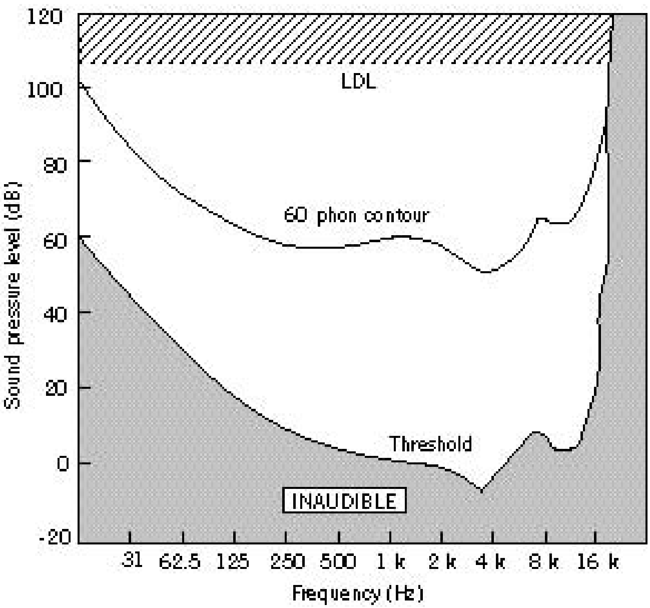


Figure 1. The threshold of audibility (minimum audible field curve averaged from a group of otologically normal young adults). Also shown is the 60 phon loudness contour and loudness discomfort levels (adapted from Davis and Silverman 1978).

For clinical purposes the measurement of hearing thresholds requires a procedure which is not too complex for an individual, provides a reasonable level of accuracy and can be completed in a reasonably short period of time by a trained operator. A technique called pure tone audiometry (PTA), which is a behavioural or subjective test has been developed to clinically measure hearing acuity. In this procedure a voluntary conditioned response is required by a patient to an acoustic stimulus. Various factors including extrinsic and intrinsic variables affect the reliability and accuracy of this test. Stephens (1981) listed some 38 sources of variability in audiometric testing. The extrinsic variables can essentially be controlled, particularly those of the physical environment i.e. temperature, humidity, light, ambient background noise. All equipment should function in accordance to relevant appropriate International Standards. Procedures and instructions used for the measurement of hearing thresholds are given in ISO 8253-1:1991 for diagnostic assessment and EN 26189:1991 for hearing screening purposes.

The intrinsic variables which could potentially affect the measurement of auditory sensitivity include; intelligence, motivation, attention, fatigue, judgement criteria, familiarity with procedure, comprehension of instructions, financial motivation, state of health, real fluctuation in hearing sensitivity etc. Therefore, audiometric tests should be performed by appropriately trained audiologists experienced in the assessment of patients exhibiting traits of non-organic/feigned hearing loss. Otherwise the “true” hearing level of a person claiming compensation is elevated during such conventional tests and is often undetected.

Physiological activity, such as from vascular, digestive and respiratory functions can produce internal noise which interferes with signal detection. Spontaneous or random neural or acoustic activity within the auditory system, including tinnitus, can contribute to this noise (Yantis 1985). Individuals can frequently give inconsistent responses during audiometry to varying degrees. This is because they are not trained like subjects undergoing psycho acoustical research who are required to give a high degree of accuracy and repeatability.

4.2 Pure Tone Audiometry (PTA)

Routine hearing evaluation measures hearing sensitivity (threshold of hearing) by PTA. This is performed using an audiometer; a device used to produce tones of specific frequencies. The typical range of test frequencies are 250Hz, 500Hz, 1,000Hz, 2,000Hz, 3,000Hz, 4,000Hz, 6,000Hz, 8,000Hz. The tone is amplified and presented at a known (calibrated) intensity level. This can range from -10dB to 120dBHL and is adjusted using an attenuator dial. The tonal signal is passed to a silent switch which allows it to pass to the output transducer, either a headphone or bone conductor. A range of audiometers exist varying in complexity from simple screening devices (types 4 & 5) which present only pure tone air conduction signals, to complex diagnostic audiometers for use in medical assessment (type 1,2,3). Specifications are given in EN 60645-1:1994. Audiometers may be manual, automatic or computerized. They use intensity step sizes of 5dB, which introduces a standard error of ±5dB. The tolerances given in EN 60645-1:1994 allow intensity levels to vary by ±3dB of sound pressure level (or force level for bone conduction) from 125Hz to 4,000Hz and ±5dB at 6,000Hz and 8,000Hz. The above two sources of error can potentially expand the standard error to 10dB or more.

The results of PTA may be presented in a tabular format which is often useful in screening audiometry to compare serial tests. More conventionally however, they are plotted on a graph termed an audiogram (Fig. 2) constructed for an individual's hearing levels over the frequency range assessed.

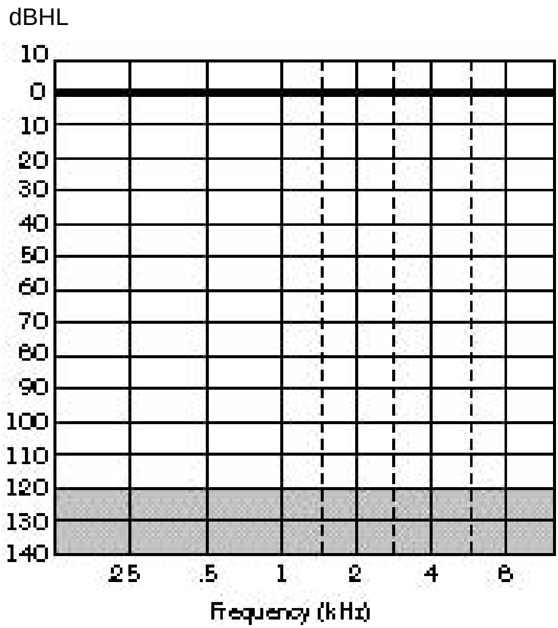


Figure 2. The Pure Tone Audiogram

The unit dB HL is not the same as dB SPL, Fig. 1 indicates the minimum audible pressure curve for normal hearing as previously defined. This scale has generally been considered to be too cumbersome to use when portraying hearing loss. The values shown on the SPL scale can be plotted on a more convenient scale, called the dB Hearing Level (dBHL scale). The basis or reference of this scale is the modal threshold of hearing for a group of otologically normal individuals in the age range of 18 – 30 who have not had significant noise exposure using pure tone audiometric techniques (EN ISO 389:1997). These reference threshold levels (RETSPLs) are therefore used as correction factors built into audiometers so that at each frequency the 0 dBHL level represents the modal threshold of hearing for the normal group.

A graph of sample hearing levels using the SPL scale is shown in Fig 3. The same levels are plotted in Fig 4 using HL values. As an example of the difference between the two units, the RETSPL at 1,000Hz is 7.5 dBSPL, therefore 0 dBHL of the audiometer will produce an output of 7.5 dBSPL, whilst at 30 dBHL the headphone output would be 37.5 dBSPL.

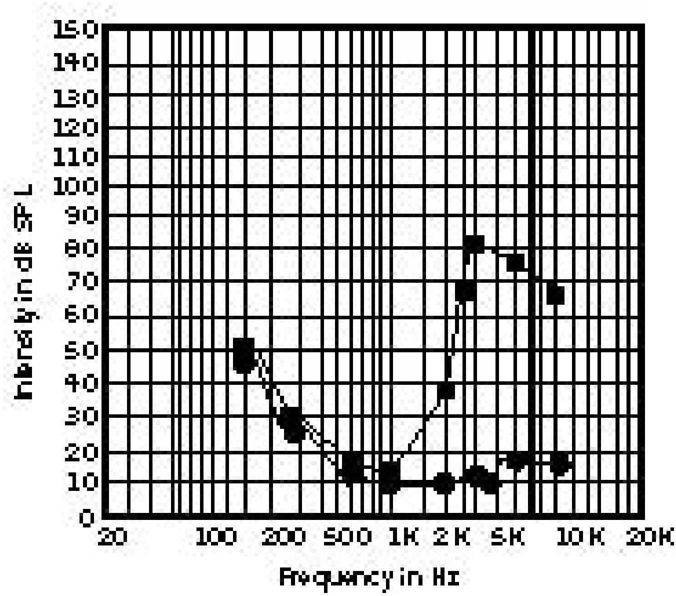


Figure 3. Hearing on the dBSPL scale

(From Introduction to audiometry and amplification. Starkey tech - nical services division)

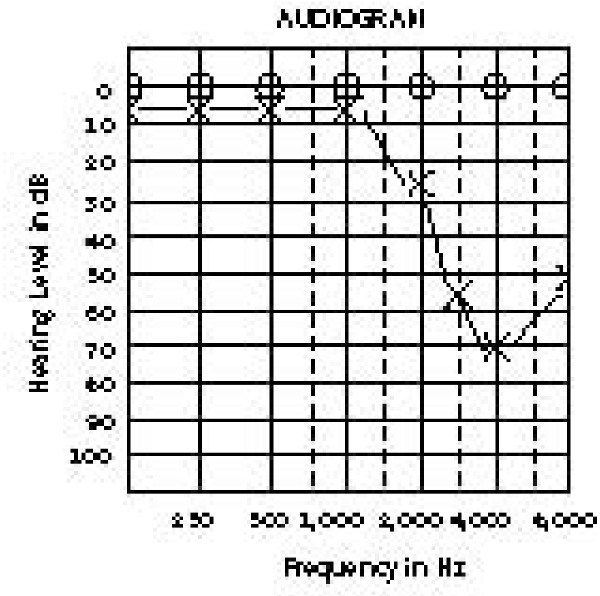


Figure 4. Hearing on the dBHL scale

(From Introduction to audiometry and amplification. Starkey technical services division)

The variation in threshold obtained in ISO 7029:1990, should be noted. These values are for “normal individuals” and the hearing levels range from -10 to approximately 20 dBHL. The 0 dBHL is not an absolute normal level, it is primarily designed for calibration purposes to ensure similarity of function of audiometers from clinic to clinic.

It is important to note that the 0 dBHL line is based on the auditory sensitivity of a specific population, that of a highly screened young group of individuals with no history of ear abnormalities or excessive noise exposure. Comparing hearing threshold levels of older individuals with those obtained for such a group used to define the 0 dBHL is inappropriate. There is a wealth of scientific research which has demonstrated that hearing levels deteriorate progressively with age. This is known as ARHL and the effect predominantly occurs in the higher frequencies, affecting the outer hair cells in the basal region of the cochlea. ISO 7029:1990 details the changes which occur in hearing with age as a percentile of the normal population. It is therefore more appropriate to perform a “peer comparison” using age-matched normative data when comparing auditory thresholds.

4.3 The Audiogram

The intensity of sound (loudness) is plotted on the y-axis as dB Hearing Level. If a hearing loss is present, the threshold of hearing will be elevated and a greater intensity signal will be required to reach the auditory threshold. The greater the hearing loss, the further down the audiogram the results will be. Both the degree and configuration (shape) of hearing loss can be recorded on the audiogram (Fig 5).

The frequency (pitch) of the pure tones is along the x-axis with low frequency (bass) sound on the left of the audiogram and increasing in frequency from left to right (treble or high frequency region). The audiogram is constructed such that octave frequencies from 125 to 8,000Hz are plotted along the ordinate, interoctave frequencies should be indicated by broken lines (EN 26189:1:1991).

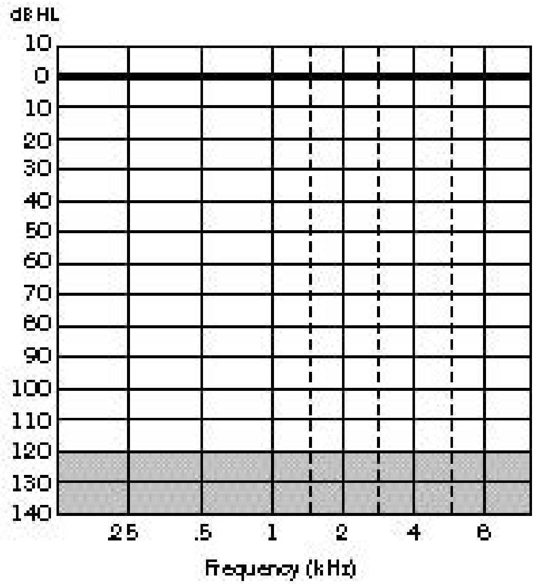


Figure 5. The Pure Tone Audiogram

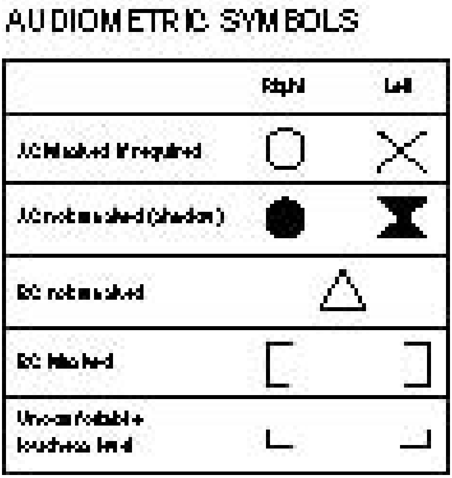


Figure 6. Symbols used in Audiology

4.3.1 Audiometric Symbols

There are standardised symbols which should be followed for consistency in interpretation. For air conduction (AC) of the right ear the symbol is an “O”, whilst for left ear it is an “X”. For audiometric screening these are the only measurements that are required. However, for more complex assessments other symbols are required. The triangle represents bone conduction (BC) from the better hearing cochlea (this could be either ear). The open brackets represent masked BC thresholds: these represent responses from the cochlea of a particular ear. If the bracket is open to the right [, this response is from the right cochlea. If the bracket is to the left], this response is from the left cochlea. If no response is obtained either for AC or BC stimulus at the maximum level available on the audiometer then an arrow is drawn pointing downward, indicating that the threshold is worse than the maximum level available. Audiometric symbols for audiometric presentation of threshold should meet the requirements of EN 26189:1991;ISO 8253-1:1991; British Society of Audiology, 1989.

For medico legal audiometric reporting, the following information should be available:

- Type(s) of Audiometers used

- Type(s) of Transducers used
- Audiometric standards to which transducers are calibrated
- Certificate of calibration, less than 12 months old at time of assessment
- Audiometric procedures performed for AC/BC and masking
- Certificate of compliance with background noise criteria
- Qualifications and experience of operator

4.4 Audiometric Measurements

In view of the differences in the causes, attributes and management of conductive hearing loss (CHL) and sensorineural (SNHL), it is a requirement to separately determine the loss of hearing at the cochlea and the overall hearing of the ear. The conductive loss is the difference between the two. The integrity of the entire auditory system, which is the normal route by which sounds are heard is measured using headphones. The AC stimulus will pass via the external auditory meatus (ear canal) - Tympanic Membrane (ear drum) - Middle Ear - Inner Ear (Cochlea) - Central Nervous System to the auditory cortex of the brain.

To measure the sensitivity at the cochlea requires a stimulus which bypasses the outer and middle ear and stimulates the cochlea directly. This is achieved by presenting a vibratory stimulus to the skull, (usually the mastoid), assuming that the vibration will travel directly through the bone of the skull to the fluids within the cochlear partitions, independently of the outer and middle ear. This is referred to as BC. The headphone is changed for the bone vibrator and the audiometer switched to bone conduction. The vibrations of the skull essentially bypass the outer and middle ear, directly stimulating the cochlea and is therefore (with limitations), a measure of the integrity of the sensorineural system. If the hearing loss is due to a sensorineural hearing impairment, i.e. affecting the cochlea or nerve of hearing, then the AC and BC thresholds should be similar.

If a blockage occurs in the external ear, a perforation or a defect within the middle ear, then there will be a difference between the

AC and BC thresholds - an Air Bone Gap (ABG). This is caused by attenuation of the AC signal but not the BC signal. The greater the conductive hearing loss the greater the ABG. It is also possible to get a combination or mixed hearing loss where there is a combined conductive and sensorineural hearing impairment.

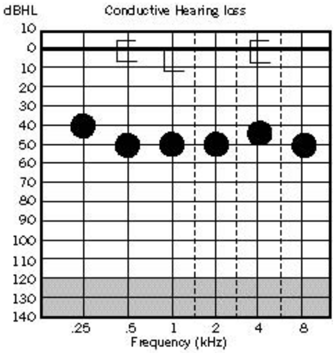
4.5 Masking

Although headphones allow sound to be presented to each ear separately (monaurally), it should not be assumed that the test ear is the one actually responding. When the threshold of hearing is very different between the two ears (asymmetrical loss) it is possible that when testing the worse ear, the better ear detects the signal. This is termed cross hearing / cross over and the recorded hearing levels for the worse ear may be a “shadow” of the better ear and not the true hearing levels. The attenuation is referred to as transcranial transmission loss.

There is a marked individual variation in this phenomenon. It is around 60 dB when using conventional earphones but can be as little as 40 dB. With bone conduction there is little or no transcranial transmission loss, i.e. 0 – 20 dB. When the difference in thresholds is greater than the transcranial transmission loss, the involvement of the better ear must be excluded by “masking” the cochlea of the better ear. This is done by presenting masking noise (narrow band noise) to the better ear. If a significant asymmetry exists, then assessment will require a full diagnostic audiogram. The procedure for masking is documented in ISO 8253-1:1991. It is recommended that masking charts (British Society of Audiology 1986) are maintained for medico legal cases which may be referred to, should any discrepancy in masked threshold levels occur. Further information regarding the requirement for masking and procedures employed are given by the British Society of Audiology (1986). This is however not required for screening purposes but would be routinely employed in diagnostic audiometry.

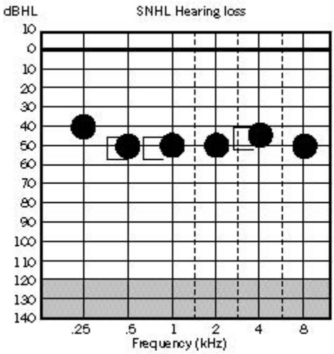
4.6 Audiometric Interpretation

Fig. 7 illustrates the three main categories of hearing impairment with associated audiometric patterns.

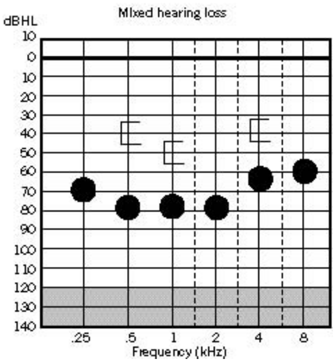


If there is a difference in AB/BC there is an Air Bone Gap.

Conductive hearing loss in the right ear.



If AC=BC, there is Sensorineural Hearing Loss in the right ear (no ABG).



Here there is a Sensorineural Hearing Loss and Conductive Hearing Loss.

Mixed hearing loss, right ear.

Figure 7. Audiometric examples of hearing impairment

4.7 Audiometric Equipment

Audiological assessment will require a range of equipment, the complexity of which will depend upon whether the hearing measurements are being made for a screening or diagnostic reason.

4.7.1 Audiometers

Audiometers are classified according to the range of stimuli and facilities available. Those used for diagnostic assessment have a high specification with a minimum of air and bone conduction facilities. These are classified types 1,2 and 3. Audiometers with only air conduction, used for audiometric screening are classified as types 4 and 5 (EN 60645-1:1994). Audiometers should meet the specifications given in EN 60645-1:1994.

Air conduction stimuli should meet the specifications of EN ISO 389:1997.

Bone conduction stimuli should meet the specifications of EN 27566:1991.

Narrow band masking noise used in diagnostic audiometry should have the characteristics as defined in EN 28798:1991.

4.7.2 Electric Response Equipment

Currently the only standard available for Auditory Evoked Potential (AEP) measurement relates to test stimuli parameters, EN 60645-3:1995.

4.8 Calibration Of Audiometers

The correct function of audiometric equipment is essential for accurate measurement of hearing function. It should be recognised that equipment will not maintain its electrouacoustical performance indefinitely. Consequently periodic monitoring and maintenance is required.

For audiometers, a three tier check procedure is recommended as detailed in ISO 8253-1: 1991 and EN 26189:1991. A brief summary is given below.

Stage A- Routine daily subjective checks

This is essentially a test of normal working function in the normal working environment.

Stage B- Periodic objective checks

This level checks a number of functions of the audiometer. It requires specific equipment for measurement of audiometer output, along with the appropriate technical skills to use and interpret results. The equipment required and applicable standards are given in ISO 8253- 1:1991. This should be performed at least on an annual basis.

Stage C- Basic Calibration

Full scale basic calibrations are required at a minimum on an annual basis. However, should there be a suspicion that stage A / B checks have failed, a full calibration is required. This procedure has to be performed by a competent organisation with appropriate traceability and a certificate of compliance with appropriate standards, such as a National Accreditation on Measurements and Sampling (NAMAS). A certificate indicating that equipment meets appropriate standards should be issued and retained by the Audiologist for proof of compliance.

4.9 Audiometric Threshold Procedures

Accurate measurement of HTLs is a prerequisite for medico-legal assessment. It is important to ensure consistent audiometric practice and therefore minimise those errors which can occur if different techniques are employed.

4.10 Screening Audiometry

Only basic unmasked air conduction threshold measurements are required. The procedure for screening audiometry is given in EN 26189:1991.

4.11 Diagnostic Audiometry

A procedure for diagnostic audiometry, i.e. AC/BC and masking is documented in ISO 8253-1:1991. Centres utilising alternative strategies, such as those given by British Society of Audiology (British Society of Audiology 1981; British Society of Audiology 1985; British Society of Audiology 1986) or other variations employed by departments with specialist knowledge of audiometric assessment, should document their methodology.

4.12 Speech Audiometry

A wide variety of speech audiometry tests, especially speech discrimination testing have been used to assess disability from NIHL. In order to mimic difficulty in hearing in background noise, speech discrimination tests may be carried out in the presence of a generated background noise. However there are practical problems. There are major difficulties in developing appropriate speech tests that are a realistic measure of everyday listening situations, such as: the time spent in noise and quiet, the level of background noise, the familiarity with the subject being tested and local dialects. The list of variations is legion (Robinson et al. 1984).

Equipment for speech discrimination and/or speech reception threshold measurement should comply with EN 60645-2:1997. No international standards are available. It is therefore recommended that departments performing such tests document their methodology.

4.13 Hearing Handicap Questionnaires and Self Assessment

Some individuals with identical audiograms may experience different degrees of disability from hearing loss. It is possible that these differences may be attributed to differences in frequency resolution, temporal resolution or other non-audiometric factors such as current age, age at onset of the hearing loss, social support and individual needs. Accordingly hearing disability has been assessed by asking questions such as; does your hearing loss make it difficult for you to talk with your fellow workers? Using a number of such questions, validated questionnaires have been developed which allow a meaningful measure of handicap

(Ewertsen and Birk Nielsen 1973; Noble and Atherly 1970). Pure tone thresholds have been found to correlate significantly with these hearing handicap questionnaires (Schow and Tannahill 1977). The one major disadvantage however remains that it is impossible to objectively verify the result of a hearing handicap questionnaire as it is with PTA.

A review of previous research carried out comparing hearing handicap questionnaires and speech identification revealed surprisingly poor correlation (Tyler and Smith 1983). However work by Tyler and Smyth (1983) revealed excellent hearing handicap correlation within three distinct sentence tests in noise. They found that both hearing handicap questionnaires and sentence identification scores, when carried out in noise, were highly correlated to pure tone sensitivity. The best correlation between frequencies chosen and hearing handicap as measured by questionnaire and sentence identification in noise was found for 500Hz, 1,000Hz, 2,000Hz and 4,000Hz, though this group of frequencies was not significantly better than the other group of frequencies selected.

4.14 Sources Of Error In Pure Tone Audiometry

The audiometric assessment of an individual’s hearing using AC and BC measurements is essential in the evaluation of hearing loss due to noise exposure or other forms of injury. Identification of key features in the audiogram such as sensorineural notches occurring in the AC audiogram between 3,000Hz and 6,000Hz are central to the diagnosis, for example of NIHL. It is however important to appreciate that there are limitations in the measurement by AC and BC, particularly when the interpretation of the audiogram will be used in a medico-legal context.

4.14.1 Reliability of threshold measurement

The supra aural type cushions (e.g. MX 41 AR) used on earphones such as TDH 39,49 or 59 are a major source of unreliability during audiometric measurement. The transmission of sound from the earphone to the ear canal is dependent upon the accurate positioning of the transducer with respect to the ear canal. The retest reliability is lowest for low frequencies, especially 500Hz due to leakage of sound, whilst at 6,000Hz subtle changes in ear canal resonances due to placement of the earphone leads to decreased reliability (Yantis 1985). Threshold measurement at the frequencies 1,000Hz, 2,000Hz and 3,000Hz appear to be most repeatable. A number of studies have assessed the reliability of AC threshold measurement in order to establish the difference (in dB) which must occur between two audiograms at a particular frequency to be reasonably confident that the difference is arising due to hearing loss. If two audiograms demonstrate a difference of 13 dB at one frequency then one can be 95% confident that a genuine change in threshold has occurred for that frequency (Tempest and Bryan 1990).

Normative population studies have demonstrated a high prevalence of audiometric notches occurring at 6,000Hz. Lutman (1998), therefore examined the possibility that the audiometric zero defined by ISO 389 is not correct at this frequency. He identified that the "apparent" notch occurring at 6,000Hz was in fact due to a specific interaction with the IEC 303 coupler used for calibration with the common earphones, TDH 39 and TDH 39 P. Consequently when these earphones have been used, interpretation of small notches of 5 to 10 dB at 6,000Hz should be done with caution.

4.14.2 Limited Accuracy of BC Assessment

The presence of air borne radiation by bone conductors is well documented (Lightfoot 1979; Lightfoot and Hughes 1993). At frequencies at and especially above 4,000Hz, the bone vibrator radiates sound which can be heard louder by the air conduction route rather than via the intended bone conduction route. This can lead to erroneous air bone gaps which could potentially confuse diagnosis. Some of the higher specification audiometers now have the facility to provide BC at 6,000Hz and 8,000Hz. Additionally EN 27566-1991 provides an international standard for these frequencies. However, in view of this technical problem, it is advised that BC assessment does not proceed above 4,000Hz (King et al 1992; Lightfoot 1993). Since the possibility of a false ABG can occur at 4,000Hz, it is recommended that an ear plug be used in the test ear, if there is an apparent ABG at that frequency, and the BC measurement at 4,000Hz repeated.

For the diagnosis of a conductive element from the pure tone audiogram, in view of the technical difficulties, an averaged ABG of 15dB or more should be present at the frequencies 500Hz, 1,000Hz, 2,000Hz, 4,000Hz.

4.15 Indications Of Non-Organic Hearing Loss (NOHL)

Where there is evidence of inconsistencies on audiometric testing, individuals should be referred for objective hearing assessment. Audiometric inconsistencies include:-

1) Variable Audiometric Responses

Some individuals, particularly those feigning hearing loss, often give varying and inconsistent responses during audiometric testing.

2) Flat Audiometric Configuration

Individuals exhibiting bilateral non-organic hearing loss often present with pure tone thresholds which have a relatively flat audiometric configuration (Coles and Priede 1971). This is due to the individual adopting an imaginary supra threshold “target loudness level”. A pure tone stimulus having a loudness below the patients chosen “criterion” will not elicit a behavioural response whilst a stimulus that approaches it will (Gelfand and Silman 1993). In some cases there will be an underlying hearing impairment, with the additional non-organic element superimposed. The magnitude of the non-organic component has been demonstrated to be inversely related to the degree of hearing loss at each frequency (Gelfand and Silman 1993). This is believed to be due to the phenomenon of loudness recruitment. This phenomenon results in the “target loudness level” being reached at lower sensation levels for frequencies having greater loss. These are typically the higher frequencies.

3) Hearing Ability

The degree of hearing impairment recorded on the audiogram should be a reasonable reflection of an individual’s hearing ability. If the audiogram suggests a loss of 90 dBHL bilaterally but it is possible to converse with the individual in a reasonably quiet voice without visual cues, then there is strong reason to doubt the audiometric validity.

4) Low Frequency Loss

Noise exposure and age related changes generally cause SNHL over the frequencies from 3,000Hz to 8,000Hz (basal region of the cochlea). The low frequencies (apical region of the cochlea) are generally not affected to a significant degree. ISO 7029-1990, indicates that for a male aged 70 years the 10th percentile hearing level at 500Hz is 23 dB HL. Therefore if the audiogram has a loss at 500Hz greater than or equal to 25 dB HL, the individual should be referred for objective hearing threshold assessment for validation purposes (King et al 1992).

5) Physiological Inconsistencies

Individuals with unilateral hearing loss should display certain audiometric characteristics. Both AC and BC threshold measurement when performed on the side of the suspected total loss should give a “shadow”. For AC this can occur between 40 -70 dB HL above the threshold of the “good” ear whilst for BC it should occur at a level between 0 – 20 dB HL. This is due to the sound stimulus being heard at the cochlea of the good ear. The Stenger test is a useful test to detect the presence of unilateral NOHL and estimate the left/right hearing difference at the frequency of test (Coles and Priede 1971; King et al 1992). If the shadow is absent in a case of suspected total unilateral loss, then the results are physiologically inconsistent.

The BC thresholds should be equal to, or better than the AC thresholds. Audiograms with negative ABGs of more than 10 dB should be regarded as spurious. The acoustic reflex test measures the intensity required to cause the contraction of the stapedius muscle when an acoustic signal is presented to the ear either ipsilaterally (same side as stimulus and recording) or contralaterally (stimulating on one side and recording response on the opposite side). The reflex occurs when an acoustic stimulus is sufficiently loud, at levels of 85 dB HL or more (Lutman 1987). If the reflex is present in the probe ear at an intensity within 5 to 10 dB of the given auditory threshold at that test frequency, then there is a suspicion of NOHL. If the acoustic reflex is at the same level as the hearing threshold there is strong evidence of non-organic hearing loss. If the acoustic reflex occurs at a level below that of the hearing threshold it indicates definite NOHL since this is physiologically impossible (Ballantyne et al. 1993).

6) Speech Reception Threshold

Speech audiometry is used to estimate the speech reception threshold. This is the intensity level at which 50% of the speech material is correctly repeated by an individual. The speech reception threshold (SRT) or half peak level elevation (HPL) should be within 10 dB of the best two average hearing thresholds of the PTA over 250Hz to 4,000Hz (Lutman 1987). If the SRT is greater than, or equal to 20 dB better than PTA average then an element of NOHL is probable and objective threshold estimation is required (King et al 1992).

4.16 Requirement For Background Noise

The background noise within an audiometric test facility should not exceed certain values in order to avoid non-required “masking” of the test signal which would raise the true hearing threshold. For AC measurements, the headphone gives a certain degree of attenuation of the ambient background noise (ISO 8253-1:1991; EN 26189:1991). This however, does not apply to BC.

Test facilities should be assessed for compliance with background ambient noise, using a sound level meter with 1/3 octave band filters, meeting specifications in ISO 8253-1:1991. The background sound level should be assessed at a typically representative time of the day and should meet levels as specified in ISO 8253-1:1991; EN 26189:1991 by an appropriate agency or qualified personnel and a certificate of compliance issued.

Noise excluding ear muffs should not be used for diagnostic purposes as there are significant uncertainties in their fitting and a potential to give rise to a false conductive hearing loss (King et al 1992).

4.17 Additional Diagnostic Tests

4.17.1 Tympanometry

Tympanometry is an objective test which provides a recordable measure of the status of the eardrum and middle ear system. This test may be used as an adjunct to clinical assessment by the otolaryngologist. There is no international standard for performing tympanometry. However the British Society of Audiology provides a set of guidelines for clinical good practice (1992). The equipment used for measuring the acoustic characteristics of the middle ear, including stapedial reflexes, should comply with EN 61027:1993.

4.18 Electric Response Audiometry For Objective Assessment

Electric response audiometry (ERA) is a well established method for the objective assessment of hearing acuity in patients who are unable or unwilling to perform the traditional behavioural or subjective tests (Hyde et al 1986; Coles and Mason 1984). ERA itself is an umbrella term covering a variety of different responses which can be recorded from various levels along the auditory pathways using appropriate stimulation and recording conditions (Fig 8).

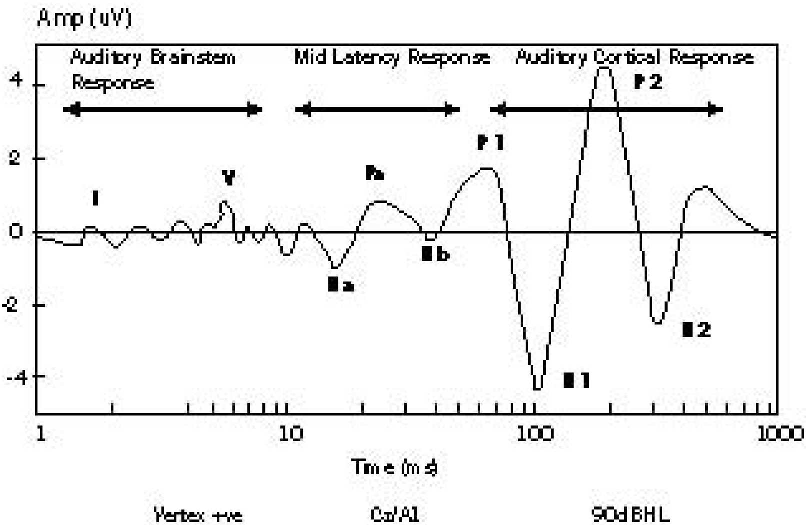


Figure 8. Schematic of Auditory Evoked Potentials

The choice of response recorded depends upon a variety of factors such as maturation of the brain, age and the type of information required.

The ERA tests themselves are non-invasive and safe. They involve the placement of four standard Ag/AgCl recording electrodes on the scalp (forehead, top of the head and behind each ear). Prior to placement, the skin is cleaned and rubbed lightly with an abrasive paste and the electrodes are applied to the scalp in a conductive medium such as a paste or gel. These are connected to an electrode amplifier to increase the level of the minute electrical changes occurring in response to an auditory signal. The responses are averaged and recorded on a Auditory Evoked Potential (AEP) computer.

The most frequently recorded response is the Auditory Brainstem Response (ABR) also known as Brainstem Evoked Response (BSER). This is often used in paediatric populations since this response is resistant to anaesthetic and sedative agents. This robust response arises from the cochlea and brainstem hearing pathways in response to an acoustic signal. It occurs within the first 10 miliseconds following stimulation, and is often categorised as an early potential. Its amplitude is quite small, in the order of nano volts, requiring a relatively large number of sweeps, typically 1,000 replications. In order to provoke this response a short duration stimulus is required. Conventionally a short duration electrical pulse producing an acoustic “click” is used in order to synchronise neural firing. A major disadvantage of the ABR as an objective audiological assessment tool is the limited frequency specificity associated with the click stimulus needed for this test.

The most appropriate test is the Cortical Evoked Response Audiogram (CERA) also known as the Slow Vertex Response (SVR). This is one of the few AEPs which originate rostrally (in the non-specific polysensory primary frontal cortex) (Fig 9). It essentially assesses the integrity of the entire auditory system and consequently is expected to have a high degree of validity for estimating behavioural thresholds (Hyde et al 1986). For this test, short duration tones, similar to those used in PTA are used to elicit a response. Therefore, the major advantage of this test for medico-legal assessment is that is it is possible to produce an objective audiogram, assessing the loss at each frequency for AC and BC, not relying on the reliability of the individual as in conventional audiometric assessments.

This test can therefore indicate whether an individual’s hearing loss is genuine or not and if not, can give an estimate of the true auditory threshold. At present, the commonest and most reliable procedure is direct determination of response presence or absence at various intensities until the response is just detectable in the averaged record. Clinically this parallels the conventional audiometric procedure, substituting response detection of the evoked response for the individual’s behavioural response.

An example of such responses for one frequency (1,000Hz) for an ear is given in Figure 9. The threshold in this case would be taken as 5 dB. The accuracy of these results is accepted as being within 10 dB of true auditory threshold, but this does depend on the experience of the tester.

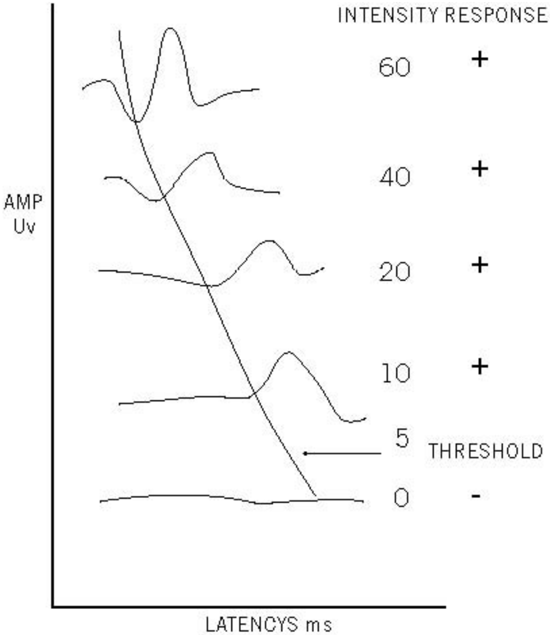


Figure 9. Schematic of Cortical Evoked Response Assessment

If the difference between the objective and subjective technique is less than ±10 dB, then the subjective thresholds should be used as the CERA test has verified the behavioural responses.

If the CERA results are better than the subjective results by more than 10 dB then there is a strong possibility of NOHL and the CERA results should be used for the appropriate assessment of hearing threshold.

4.19 Training And Qualifications

The level of training and expertise required by personnel performing hearing tests depends upon whether the audiometry being performed is for screening or diagnostic purposes. It is important to differentiate between these two categories of assessment.

Screening audiometry is often referred to as Industrial or Occupational Screening Audiometry and the testers are referred to as Industrial Audiometricians. Screening audiometry is a very basic hearing test, only measuring air conduction threshold responses for the two ears. An air conduction audiogram is required from 250Hz – 8,000Hz, in accordance with Second Schedule Part II on audiometry (S.I. no.157, 1990; European Communities (Protection of Workers) (Exposure to Noise) Regulations 1990). It should be performed by an adequately trained person.

The purpose of screening audiometry is to monitor hearing levels in employees where daily personal noise exposure equals or exceeds 85dBA or peak pressure greater than 200 daPa, thus providing an early warning system for workers at risk of NIHL.

4.19.1 Qualifications Of Personnel For Diagnostic Audiometry

Persons assessing hearing levels for medico-legal assessment should be diagnostic audiologists. They should have a minimum qualification of the British Association of Audiology Technicians (BAAT) course, with appropriate clinical experience i.e. 2 years in post with supervised training during acquisition of parts I & II, plus an additional 2 years following qualification. Personnel with equivalent qualifications from other countries would be acceptable. The audiologists should therefore be able to provide proof of examination and clinical training. Higher academic qualifications such as the MSc in Audiology or an MSc in Technical Audiology, or Diploma in Audiology are acceptable provided there is proof of supervised clinical experience.

5.0 Clinical Assessment

5.1 Introduction

Assessment of individuals with suspected NIHL should be carried out by medical practitioners with specialist training in diseases of the ear and audiology. In any individual case, the diagnosis of NIHL is based on a combination of history, clinical examination and pure tone audiometric findings. In many cases because of the latent period between noise exposure and assessment, the age of the individual, the co-existence of other ear pathology, the unknown factor of socio-acusis and the varying individual susceptibility to noise damage, the diagnosis is one of probability rather than certainty. In the assessment of a person with hearing loss, it is important to consider all possible causes of the damage. It is important to consider such causes as ear infections, trauma, ototoxic drugs, genetic causes, ageing and other diseases as the cause of hearing loss.

5.2 History

Where there is a long time interval between exposure to noise and the clinical assessment, it is particularly important to have a detailed medical and occupational history. Where possible, the history must establish that the individual has been exposed to the damaging effects of noise, exceeding the established damage risk criteria. There are techniques available for apportioning hearing loss to different episodes of noise exposure, but these depend on a full occupational and social history and may require sound exposure measurements to be taken in the workplace(s).

To be included in the history taking are the following topics:

1. Hearing Loss

(a) Has the individual noticed any hearing difficulty?

(b) Is the hearing loss present in one or both ears; if so, which ear is worse?

(c) When was the hearing loss first noticed?

(d) How did the individual become aware of the hearing loss?

(e) Was the onset of hearing loss gradual or sudden?

(f) When is the individual especially affected by the hearing loss, e.g. one to one conversation, in a group, listening to TV, on the telephone etc.?

(g) How has it affected the individual's performance of their occupation, or access to employment?

2. *Tinnitus*

(a) Is tinnitus present?

(b) If present, how does it trouble the individual?

(c) Is it constant or intermittent; if intermittent how often does it occur and how long does each bout last?

(d) How long has it existed?

(e) It is unilateral, bilateral or central?

(f) How severe is it e.g. slight, mild, moderate or severe?

(g) Did tinnitus start at the time of noise exposure?

(h) Is it noticeable in the presence of background noise, or in quiet?

(i) Does it interfere with sleep?

(j) Has the individual sought medical advice?

(k) Has the individual had any treatment?

(l) Does it interfere with normal lifestyle activities?

3. *Past Medical History of Ear Disease*

(a) Is there any history of a previous ear disease or ear surgery?

(b) Are there any other aural symptoms e.g. ear discharge, vertigo, fluctuating hearing loss, aural fullness, pain in the ear?

4. *Other Aspects of past Medical History such as:*

(a) History of head injury

(b) Exposure to ototoxic drugs, e.g. aminoglycoside antibiotics

(c) Treatment for Tuberculosis (may have been treated with ototoxic drugs)

(d) Frequent episodes of otitis media in childhood

(e) Other relevant diseases.

5. *Family history of hearing loss.*

6. *Social history including:*

(a) History of recreational shooting, motorcycling etc.

(b) Playing in a band

(c) Continuous wearing of “walkman” type headphones, listening to excessively loud music, etc.

(d) Usage of noisy D.I.Y. tools such as drills, grinders, mechanical hammers.

7. *Occupational History*

(a) All periods of employment to present day

(b) Some assessment should be made of the noise levels on a daily basis, the number of hours per day exposed to noise, whether any hearing protection or other noise abatement measures were employed, whether workers had to shout loudly to communicate

(c) Because the inner ear may recover during quiet periods, it may be necessary to record the noise-free intervals during an average week - taking into account social as well as industrial noise exposure

(d) When exposed to weapons, it is important to record the length of service in the organisation, the frequency of firing, the type of weapons discharged and the approximate number of rounds fired. When was ear protection provided, what type, and when was it used? Was it worn at all times?

(e) Any measures implemented to reduce noise exposure

(f) Symptoms of temporary hearing loss and/or tinnitus.

5.3 Clinical Examination

Clinical examination of the individual should include full examination of the pinna and skin over the mastoid process to exclude scars from previous surgery. The entire external auditory canal should be visualised, the full tympanic membrane should be visualised - using the operating microscope where required (Sadé 1979). The middle ear should be examined to establish if there is any evidence of acute or chronic middle ear disease which may have potentially attenuated the effects of environmental noise, i.e. a central eardrum perforation or a potential cause of toxic damage to the inner ear i.e. the presence of chronic inflammatory middle ear disease. Pneumotoscopy should form part of the standard examination of every ear.

Testing should include standard tuning fork tests (Rinne & Weber) and clinical assessment in response to conversational and whispered voice.

The nose and throat should be examined to rule out any co-existing pathologies which could potentially affect the middle ear, i.e. eustachian dysfunction secondary to nasal polyps which may exacerbate the hearing loss and tinnitus. If the tinnitus is described as pulsatile, the major vessels in the neck should be auscultated to rule out a transmitted bruit. Unilateral pulsatile tinnitus should always be appropriately investigated.

5.4 Audiological Findings

The pure tone audiometric findings must be correlated with:

A. The type and duration of noise exposure

B. The age of the individual

C. Co-existence of other ear pathologies

The classic audiometric evidence of early noise induced damage to the inner ear structures is the appearance of a notch on the audiogram between 3,000Hz and 6,000Hz with the maximum notch usually at 4,000Hz. A notch is defined when the hearing threshold level is 10 dB or greater at 4,000Hz than at the adjacent frequencies, or at least 15 dB or greater if the notch is at 6,000 Hz.

The following audiograms (Figs 10, 11 and 12) show the typical patterns of NIHL with continued noise damage.

As degeneration continues, the pattern closely resembles ARHL. As the hearing thresholds increase at the 8,000Hz frequency due to advancing age (ARHL), the notch disappears from the audiogram. This tends to occur after the age of 40 years.

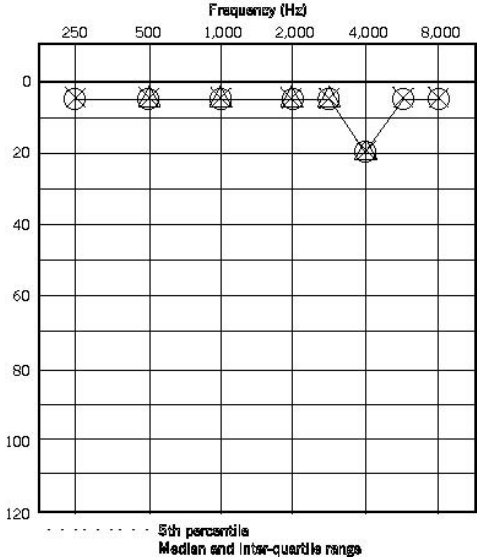


Figure 10

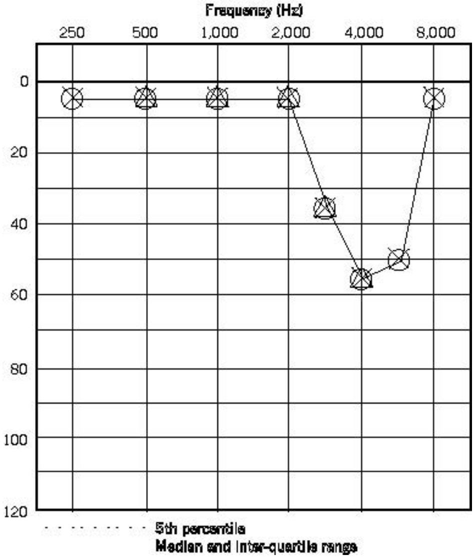


Figure 11

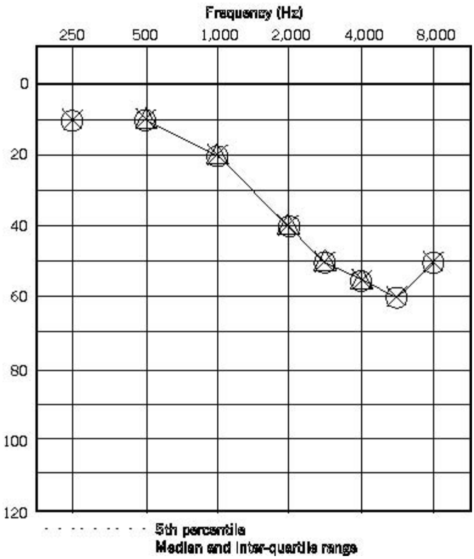


Figure 12

5.5 Atypical Audiograms

Patterns other than described above may result from varying types of noise exposure i.e., if the individual has been exposed to excessive levels of low frequency impulse noise, the effects may be more damaging initially at the lower frequencies.

5.6 Summary of Diagnosis of NIHL

1. A history of noise exposure.
2. Absence of other pathology causing hearing loss.
3. Hearing loss is always sensorineural, affecting the hair cells in the inner ear.
4. Hearing loss is usually bilateral, but may be asymmetrical if due to asymetric noise exposure, i.e. to shooting. Audiometric patterns are usually similar bilaterally.
5. Noise almost never produces a profound hearing loss. Usual low frequency limits are about 40dB and high frequency limits about 75dB.
6. Once the exposure to noise is discontinued, there is no significant further progression of hearing loss as a result of the noise exposure.
7. Previous NIHL does not make the ear more sensitive to further noise exposure. As the hearing threshold increases, the rate of loss decreases.
8. The earliest damage to the inner ear reflects loss at 3,000Hz, 4,000Hz and/or 6,000Hz. There is always far more loss at 3,000Hz, 4,000Hz and 6,000Hz than at 500Hz, 1,000Hz and 2,000Hz. The greatest loss usually occurs at 4,000Hz. The higher and lower frequencies take longer to be affected than the 3,000-6,000Hz range.
9. Given stable exposure conditions, losses at 3,000Hz, 4,000Hz and 6,000Hz will usually reach a maximum level in about 10-15 years.
10. Continuous noise exposure over the years is more damaging than interrupted exposure to noise, which permits the ear to have a rest period.

6.0 Hearing Disability Assessment Systems Used In Other Countries

The Expert Group reviewed a number of systems for the assessment of hearing disability that are used internationally. These will be briefly outlined.

6.1 The British Association of Otolaryngologists and British Society of Audiology System, 1983 ("Blue Book")

The "Blue Book" was set up by the Councils of BAOL-BSA and was published in 1983 in the British Journal of Audiology (Anon. 1983). The aim of the "Blue Book" was to provide an acceptable method for assessment of hearing disability in the United Kingdom based upon pure tone thresholds. The guidance from this book was based on scientific data available at that time, along with extensive clinical experience from experts in the field of assessment of hearing loss due to noise. The frequencies selected for this system were 1,000Hz, 2,000Hz and 4,000Hz. The subject was considered to have a disability if the average of these frequencies was greater than 20dB.

As the relationship between the hearing impairment measured at the averaged frequencies 1,000Hz, 2,000Hz and 4,000Hz disability was not linear but sigmoidal in nature, the percentage disability was calculated as rising by 1% for each decibel from 20dB to 40dB. This was increased to 2% for each decibel from 40dB to 75dB. For each decibel from 75dB to 100dB disability was increased by 0.4% per dB. To allow for the possibility of difference in hearing level between ears, a 4 to 1 ratio in favour of the better ear was suggested for calculating binaural disability. The "Blue Book" provides a presbyacusis correction for males over the age of 66 and females over the age of 74. The correction values are obtained from the median presbyacusis figures (Robinson and Sutton 1978).

6.2 Inter-Society working Group on Hearing Disability system - United Kingdom (King et al 1992 - "Black Book")

Subsequent to the publication of the "Blue Book" new research data became available from two primary sources:

1. The Institute of Sound and Vibration Research of the University of Southampton

2. The Medical Research Council Institute hearing research.

Owing to the availability of this new scientific data, a working party examined the new information with a view to reconsidering the recommendations for accessing hearing disability previously made in the “Blue Book”.

The final frequencies decided on for assessing hearing disability were 1,000Hz, 2,000Hz and 3,000Hz (King et al 1992). The authors looked at various combinations of frequency averages in order to try to maximise correlation with other measures of hearing disability. Most studies indicate that there is a high correlation with self-rated disability no matter what combination of frequencies are chosen, as long as they are within the speech frequency range. 500Hz was left out of this system as it was designed only for the assessment of Noise Induced Hearing Loss. A further reason for leaving out 500Hz was that this frequency is more prone than the others chosen to test re-test error. Reasons for not including 4,000Hz were that a notch may occur at this frequency which may be narrow and deep and lead to inflated characterisation of the average hearing levels. Other reasons were that the bone conduction accuracy reduces above 3,000Hz and that 3,000Hz contains more speech information than 4,000Hz.

The “Black Book” decided not to use a specific low fence at which disability was deemed to occur. The reason given is that there appears to be a smooth transition of disability from zero to finite values. The system involves comparing the calculated disability with the disability expected in an individual of similar age and sex with no history of noise exposure. Binaural weighting is addressed by the “Black Book” based upon clinical and theoretical considerations, i.e.

1. Loss of binaural sensitivity.

2. Loss of binaural faculty, spatial localisation, and stereo effects.

This is expressed in Table A2 of the “Black Book”.

The “Black Book” recommends a method for correction for presbyacusis using the median values specified in ISO 7029:1990 for otologically normal persons of the same age and sex as the claimant.

A major element in the rationale of the assessment scheme is that differences between the (exposed) individual being assessed and the notional (non-exposed) median individual are computed in the domain of disability rather than impairment. Thus, in order to calculate the attributable disability, first the measured impairment of the individual concerned is converted to a disability estimate. A corresponding conversion is then made for a notional individual, or ‘control’. The control has the median hearing impairment expected in a individual of the same age and sex, plus any additional components of hearing impairment from non-attributable causes that have been measured in the individual concerned. The attributable disability of the individual is the difference between these two estimates.

The “Black Book” attempts to address many of the difficulties in setting up a hearing disability assessment system using pure tone audiometry. However, it does this at the expense of simplicity. For this reason, many experts continued to use the older “Blue Book” system.

6.3 Department of Health and Social Security (DHSS) system - United Kingdom

The System of Assessment under the National Insurance Act (Industrial Injuries) Act 1965 (UK) is as follows:

1. The disease to be defined in terms of deafness which is substantial, permanent and of the sensorineural type and which is due to, or results from exposure to noise in the course of a prescribed occupation.
2. Occupational cover to be limited to a limited number of processes.
3. Minimum period of 20 years employment to be required in the prescribed occupations.
4. Claims to be allowable only if made within one year of the date of the last employment in the prescribed occupation.
5. The degree of disablement to be assessed by reference to the results of pure tone audiometry.
6. Benefit to be awarded only where the hearing loss in the better ear is 50dB or more, averaged over the frequencies 1,000Hz, 2,000Hz and 3,000Hz.

7. The date of development of the disease to be taken as the date of benefit in a successful claim.

8. A presumption of occupational origin to be given.

9. A presbyacusis correction to be made by means of 0.5% deduction from the disability assessment at age 65, with a further deduction of 0.5% for each year over 65.

10. No regard to be had to the use of hearing aids or the ability to lip-read.

11. The assessment should not be reviewed for a period of 5 years from the date of award; a similar limitation to apply to repeat claims and unsuccessful claimants, unless in the circumstance of the case, the Medical Board consider that a shorter period would be justified.

As can be noted above, the point of entry in which benefit becomes payable is high at 50dB. However, the Report emphasises that this constitutes a point which is considered to represent an assessment of the order of 20% disablement. In other words, the low fence for the purposes of this system is, in reality, 40dB with a 2% disability percentage added for each decibel in excess of that. The weighting for the better ear to establish binaural disability is a 4:1 ratio. This scheme has been updated since 1973 and is currently undergoing a further revision. No mechanism is given in this scale for the assessment of tinnitus (National Insurance (Industrial Injuries) Act, 1965).

6.4 Danish Hearing Disability Assessment System

The procedure for compensation of occupational induced hearing loss in Denmark, is based on an extensive evaluation which includes scaling the reduction in hearing and communication ability (Salomon & Parving 1985). The scaling combines self-assessment and speech audiometric measurement. These methods are used to estimate the degree of hearing handicap (HH) and communication handicap (CH). On the basis of these, a National Board of Industrial Injuries decides on whether or not a subject is entitled to compensation.

Information concerning comprehension in three listening situations is obtained.

1. *Situation A:* Optimal Listening Conditions. The speech signal is given a normal conversational level in the presence of negligible background noise.

2. *Situation B:* Reasonable Listening Condition. The speech signal is given at normal conversational level against a background noise 10dB below the speech signal.

3. *Situation C:* Poor Listening Conditions. The Speech signal is given in a background noise equal to, or more intense than the speech signal.

The ability to communicate in each of these 3 situations varies according to the visual support given by lip-reading. Accordingly, these are performed under normal lighting conditions. Audio-visual communication ability is evaluated by the speaker who directly faces the client. Hearing Handicap is classified on the basis of these tests as none (0), slight (1), mild to moderate (2), considerable (3), severe (4) and total (5).

Hearing Handicap Degree 0: Can understand speech without hearing aid in listening situations A & B, but not in C.

Hearing Handicap Degree 1: Can understand speech without hearing aid in listening situation A, but not B & C.

Hearing Handicap Degree 2: Can understand speech with hearing aid in listening situations A & B, but not C.

Hearing Handicap Degree 3: Can understand speech with hearing aid in listening situation A, but not in B & C.

Hearing Handicap Degree 4: Can not understand speech with hearing aid in listening situations A, B or C.

Hearing Handicap Degree 5: Has no speech perception with hearing aid.

Communication Handicap is based on observations of the performance of an average lip-reader with the above mentioned degrees of handicap. Communication handicap is graded as none (0), slight (1), mild to moderate (2), considerable (3), severe (4) or total (5).

Communication Handicap Degree 0: Can perceive audiovisually without hearing aid in situations A, B & C.

Communication Handicap Degree 1: Can perceive audiovisually without hearing aid in situations A & B but not in C.

Communication Handicap Degree 2: Can perceive audiovisually with hearing aid in situations A, B & C.

Communication Handicap Degree 3: Can perceive audiovisually with hearing aid in situation A & B but not in C.

Communication Handicap Degree 4: Can perceive audiovisually with hearing aid in situation A, but not in B & C.

Communication Handicap Degree 5: Can not perceive audiovisually with hearing aid in situations A, B & C.

The above handicapping scale, made on the basis of an interview assessment, will be useful only if it can be supported audiologically. Further testing is carried out using discrimination scores obtained from audio and audio-visual phonetically balanced mono-syllable word lists. These tests can be performed with background noise to simulate situation B. It is found in most cases that the two methods of scaling, namely by interview or by discrimination tests, are identical. The scaling from 0-5 is not linearly proportional to the percentage or degree of disability. In order to obtain reasonable percentages for damages, handicapping scales were fitted to a sigmoidal curve. The minimal limit for compensation under Danish law is 5%, where communication handicap 5 with hearing handicap 5, equates with 75% (table 2).

TABLE 2. Percentage Disability (5) calculated from different combinations of HH and CH

	HH 0	HH 1	HH 2	HH 3	HH 4	HH 5
CH 0	0	5	13			
CH 1		7.5	16.5	31		
CH 2		13	20	35	50	
CH 3			31	40	55	66
CH 4				50	60	70
CH 5					66	75

CH = Communication Handicap
HH = Hearing Handicap
Modified from Salomon & Parving 1985

Correlation between this system with the “Blue Book” (BAOL/BSA) is extremely poor. A 7.5% Danish disablement may range from a disability percentage of 10% to 70% on the “Blue Book” system depending on audiogram configuration (Salomon & Parving 1985).

6.5 The American Medical Association System of Hearing Assessment

The American Medical Association formula is based on the system described in 1959 by the American Academy of Ophthalmology and Otolaryngology (AAOO) and the American Medical Association. In 1959, the system used the frequencies 500Hz, 1,000Hz and 2,000Hz. The inclusion of 3,000Hz was discussed at great length and it was decided that when conversation was conducted in quiet conditions, 3,000Hz did not contribute very much to speech understanding. Therefore, 3,000Hz was not initially included (Glorig 1980). In 1976, the formula was re-evaluated. It was decided in order to allow for difficulty in a background of noise that 3,000Hz should be included. It was considered that on the basis of a number of studies using specific consonant-weighted word lists, that 3,000Hz provides valuable information for hearing conversation in a noisy environment. The adjusted formula was recommended by the American Academy of Otolaryngology Committee on Hearing & Equilibrium to the American Medical Association and was published in the Journal of the American Medical Association in May 1979 (Anon 1979). The formula now uses the frequencies 500Hz, 1,000Hz, 2,000Hz and 3,000Hz. Hearing threshold levels are averaged. A low fence of 25dB was decided, for each decibel above 25dB, 1.5% disability was added, reaching 100% disability at 91 dB. If one ear scores better than the other ear, the better ear disability is scored 5 times over the poorer ear disability, i.e. a weighting of 5 to 1 for binaural hearing. The better ear percentage is multiplied by a 5:1 ratio, added to the percentage disability in the poorer ear. This is divided by six to give a binaural disability percentage. The system does not include weighting for presbyacusis or for tinnitus. It is important to note that the system was designed not just to evaluate the effects of noise induced hearing loss but also other causes of hearing loss. There is a difference in nomenclature between America and the World Health Organisation. Hearing handicap in the American system equates to hearing disability as defined by the WHO.

6.6 South African Hearing Disability Assessment System

Under the terms of the Compensation for Occupational Injuries and Diseases Act 1993 (South Africa), hearing impairment as a result of excessive noise is a scheduled occupational disease. A system for assessing disability was introduced from the 1st March 1994 and is similar to that of the American Medical Association.

Average hearing threshold is taken of the four frequencies 500Hz, 1,000Hz, 2,000Hz and 3,000Hz. The low fence is 25dB. Hearing disability is calculated as 1.5% for each decibel above the low fence. The formula used for determining binaural hearing disability is a 5:1 ratio. There is no presbyacusis correction. Further information however, is required to enable the Compensation Commissioner to consider cases of hearing impairment as a result of noise exposure in an employee's work place. These are as follows:

1. The period of service during which the employee was exposed to excessive noise.
2. The duration of the daily exposure to excessive noise.
3. Technical details of the noise levels to which the employee was exposed in his workplace.

4. A full report by an ENT Specialist confirming the diagnosis and excluding other possible causes.

5. Two audiograms are taken within a 24 hour interval and only after the employee is removed from his noisy occupational environment for at least a weekend, or two intervening shifts. In cases where the hearing impairment is claimed as a result of acoustic trauma, an ENT Surgeon should certify that the impairment found is compatible with the nature of the injuries sustained (Van der Merwe JM 1996).

6.7 Canadian System for Hearing Disability Assessment

One of the most commonly used systems in Canada is the system used by the Workers Compensation Board of Ontario (Alberti PW 1981). This system takes an average of the hearing threshold level at four frequencies; 500Hz, 1,000Hz, 2,000Hz and 3,000Hz. Quite a high low fence of 35dB is used. This is considered to be the point at which 4% disability occurs, not the point at which disability starts. If NIHL is associated with tinnitus the low fence is reduced to 25dB and an extra 2% disability is added provided certain criteria are met. A weighting factor of 5:1 is applied for the better ear. The scale is non linear. Allowance for presbyacusis is included by subtracting one half decibel for each year over the age of 60. In the provinces of Alberta, Manitoba, Newfoundland, New Brunswick, Novascotia, Saskatchewan, North West Territories and the Yukon, the same formula as Ontario is used. British Columbia and Quebec use the frequency average of 500Hz, 1,000Hz and 2,000Hz.

British Columbia uses a weighting ratio of 4:1, a low fence of 28dB, and a non linear scale. Quebec uses a weighting ratio of 5:1, a low fence of 25dB and a linear scale. The application of presbyacusis correction varies between provinces, tinnitus is only compensated if there is a co-existing compensatable hearing loss (Alberti 1981).

6.8 The Department of Social Welfare System for Occupational Injury Benefit - Ireland

This system is the only system of assessing hearing disability that is currently on the Statute Books in Ireland.

It is similar to the DHSS system used in the United Kingdom. Namely, an average hearing threshold level of the frequencies 1,000Hz, 2,000Hz and 3,000Hz is taken. The point at which an individual is deemed to qualify for compensation is at an average threshold level of 50dB. Table 3 outlines the percentage disability for ranges of average hearing loss above 50dB. The percentage disability for each ear is calculated as a binaural disability using a 4:1 ratio.

The individual must have worked in a prescribed industry for longer than 10 years and must claim within 5 years of leaving that employment.

TABLE 3. Assessment of the Extent of Occupational Deafness

Average hearing loss (dB) over 1, 2 and 3 kHz	Degree of hearing disablement percent
50-53 dB	20
54-60 dB	30
61-66 dB	40
67-72 dB	50
73-79 dB	60
80-86 dB	70
87-95 dB	80
96-105 dB	90
106 dB or more	100

(Social Welfare (Occupational Injuries) Regulations No. 2 - 1983, S.I. 391 of 1983)

7.0 Irish Hearing Disability Assessment System

7.1 Summary

To Assess Hearing Disability

- Take the Air Conduction hearing threshold levels at 500Hz, 1,000Hz, 2,000Hz and 4,000Hz, add and divide by 4.
- Do this separately for the right and left ears.
- Subtract 20dB from the average obtained for each ear.

This is an average hearing loss.

- Multiply the average hearing loss of each ear by 1.25%.
- Weight the better ear's figure by multiplying by 4, add it to the worse ear's figure and divide the sum by 5.
- Correct for ARHL by table deductions, over the age of 69 years in males and 77 years in females (Table 4).

This figure is the Binaural Percentage Hearing Disability.

An additional disability allowance for moderate or severe tinnitus may be added.

This percentage computed is the proportion of hearing disability that the individual experiences, it is not the proportion of total body disablement.

7.2 Descriptors

Hearing Threshold Level: This is the lowest intensity of sound that is audible to a tested ear. It is a measure of the ear's ability to hear.

Frequencies: Audiological testing should routinely test both ears at 250Hz, 500Hz, 1,000Hz, 2,000Hz, 3,000Hz, 4,000Hz, 6,000Hz and 8,000Hz. One Hz = 1 cycle per second. This is a measure of the vibration of air that constitutes sound.

Low Fence: In a normal population, there is a statistically chosen limit below which the hearing threshold is regarded as normal. Hearing threshold above this level is considered to indicate a disability. The figure chosen is 20dB at the average hearing threshold using the frequencies 500Hz, 1,000Hz, 2,000Hz and 4,000Hz.

High Fence: The High Fence is the average hearing threshold level above which little, if any, unaided meaningful hearing occurs. This is the level at which hearing disability is considered to be 100%. The figure chosen is 100dB.

Multiplier: To calculate the hearing disability between 20dB and 100dB, a multiplier of 1.25 must be applied to obtain the percentage disability.

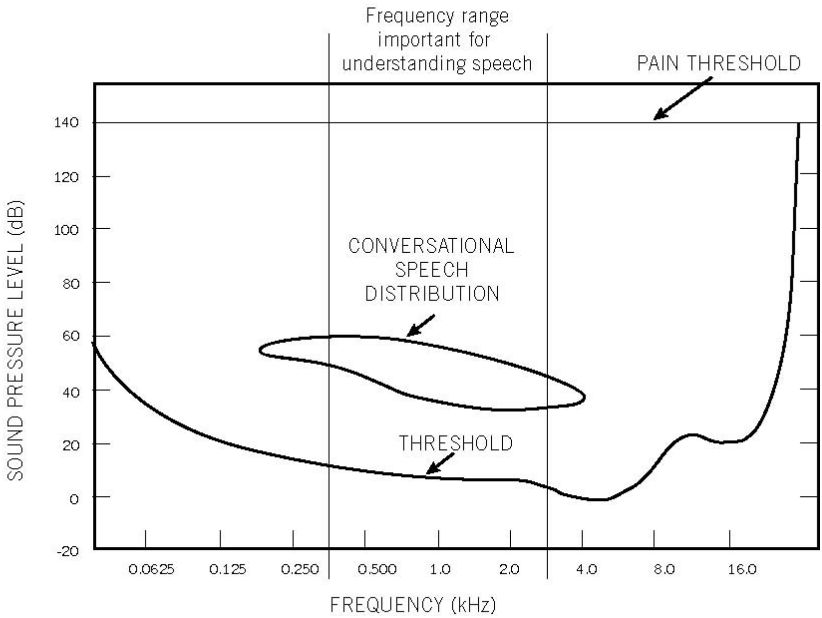
Binaural Evaluation: Since an individual with one normal hearing ear and total hearing loss in the other ear does not have a 50% hearing disability, there is a need to give appropriate weighting to the hearing ability of the better ear. The weighting chosen is 4:1 in favour of the better ear.

Age Related Hearing Loss Correction Factor: All ears develop hearing loss in the upper frequencies with advancing age. This correction subtracts hearing loss of physiological origin from that of pathological origin.

Subjective Tinnitus: This is the subjective sensation of noises in the ears or head, without any external acoustic or mechanical stimulus.

7.3 Frequencies Chosen

The human ear can hear from 50Hz, to 20,000Hz, but with a large degree of individual variation. Most of the information required to convey speech information lies within the range 250Hz – 4,000Hz. Each individual frequency supplies a different quantity of information for understanding speech. All frequencies between 250Hz – 4,000Hz contribute to speech comprehension, but some are more important than others. The most important frequency for understanding speech in a quiet environment is 2,000Hz. The other frequencies, e.g. 250Hz, 500Hz and 4,000Hz are less important as seen in the following illustration: (Figure 13)



Data for human hearing as a function of frequency. An approximate area for conversational speech is shown. Modified from Davis H. Silverman SR: Hearing and Deafness, 3rd ed. New York, Holt, Rhinehart and Winston, 1970.

Figure 13. Data for human hearing as a function of frequency

(Davis & Silverman 1970).

The higher frequencies, particularly 3,000Hz are important in the understanding of speech in a background of noise, but some speech information is carried at 4,000Hz.

Included in the formula are the following frequencies: 500Hz, 1,000Hz, 2,000Hz and 4,000Hz. It is generally acknowledged that the frequencies of 1,000Hz and 2,000Hz are the most important for the recognition of speech (Davis & Silverman 1970; Webster 1964).

Tyler & Smith (1983) demonstrated that frequencies of 500Hz, 1,000Hz, 2,000Hz and 4,000Hz were the best combination of frequencies to predict speech comprehension in continuous noise.

Webster (1964) showed that the inclusion of 500Hz, 1,000Hz and 2,000Hz was the best method of predicting the ability to comprehend speech in the presence of background noise.

It was decided to include 500Hz because:

1. Disability assessment schemes which include 500Hz correlate better with self-rated hearing scores than schemes which exclude 500Hz.
2. The inclusion of 500Hz allows the system to be used for the assessment of hearing disability from causes other than excessive noise.
3. Blast injury may cause damage at low frequencies.
4. Inclusion of the low frequency of 500Hz improves the accuracy of hearing disability assessment (Lutman, Brown and Coles 1987).

Note that there are technical difficulties in performing audiometry at 500Hz and it is important that quality standards for the audiometry are adhered to, as outlined previously.

Harris (1965) found that the four most important frequencies for speech recognition were 1,000Hz, 2,000Hz, 4,000Hz and 500Hz in that order. Harris (1965) found that hearing in the frequency region of 2,000 – 4,000 Hz was the most important for understanding distorted speech (without noise in the background).

Research by the Bell telephone company in the early part of the 20th Century showed that 500Hz, 1,000Hz and 2,000Hz were perfectly sufficient for the comprehension of speech over the telephone (Fletcher 1929). However, in the presence of background noise, higher frequencies become more important (King et al 1982; Suter 1985). Systems for assessment of hearing disability have been developed since the 1930s. One of the first schemes, known as the “point eight” method was devised by Fletcher in the 1920s (Fletcher 1929). In 1953 he produced tables with different degrees of weighting for different frequencies. The frequency 2,000Hz was more weighted, 500Hz and 4,000Hz were less weighted (Fletcher 1953). In 1959 a new system which included the frequencies of 500Hz, 1,000Hz and 2,000Hz was introduced. These frequencies represented the understanding of speech in a quiet environment. To allow for difficulty in hearing in a noisy environment the system was reviewed, and the frequency 3,000Hz was added (Anon 1979).

It was decided not to include the frequency of 250Hz because:

1. The hearing threshold at this frequency is quite difficult to measure accurately.
2. Measuring hearing thresholds at 250Hz may be associated with a significant test/retest repeatability problem. The main reasons for this are audiometer calibration difficulties and the effects of background noise.
3. Bone conduction audiometry using this frequency is extremely unreliable due to tactile stimulation.

The frequencies of 6,000Hz and 8,000Hz carry no information for speech comprehension. Furthermore, it is not possible to accurately measure bone conduction at these frequencies. Therefore these were excluded from the formula.

7.4 Low Fence

There is a continuum of disability which is measurable in most people at a hearing threshold of between 15 and 30 dB. There is no specific threshold at which disability suddenly starts. It is well recognised by vast amounts of experimental data that there is a direct relationship between hearing disability and hearing loss. As hearing threshold increases, hearing disability starts to increase slowly. It then begins to increase more rapidly and then slows again. Expressed mathematically, disability increases in a sigmoidal fashion (Habib and Hinchcliffe 1978; Lutman and Robinson 1992). There is much individual variation. Accordingly, picking a particular point or figure above which disability is deemed to be present or below which it is deemed to be absent has obvious inherent problems. However, such artificial physiological barriers exist commonly in our society, for example, a retirement age of sixty-five years. There are four main methods by which a low fence may be chosen.

1. The low fence may be chosen on the basis of hearing impairment. This is the hearing threshold level at which hearing is considered to be different from normal. For this purpose normal is considered to be the statistical distrib-

ution of hearing threshold levels for young otologically unimpaired individuals, different from normal means, lying beyond a particular percentile of such a population. This may be arbitrarily taken as the 90th, 95th or 98th percentile for example. The cut off point is a matter of judgement (King et al. 1992).

2. The low fence may be calculated by taking a particular percentile of the distribution of scores from a variety of performance based tests (e.g. speech audiometry) given to young otologically unimpaired individuals. This value is then translated back to hearing threshold level (Robinson et al. 1984). This method leads to higher values for the low fence than the last method, depending on what percentile of normal is selected.

3. The low fence may be obtained from self assessment disability questionnaires. Subjects may be asked if hearing is normal or not (Merluzzi & Hinchcliffe 1973). The point of intersection of the distributions of HTLs of those answering “yes” and those answering “no” is taken as the low fence. This method gives a lower value of low fence than either of the methods above.

4. A fourth method of choosing the low fence is to select an arbitrary value on the basis of administrative convenience. Levels of minimum impairment often are selected on the basis of who should qualify for compensation for their disability.

It is important to note that the value of the low fence is dependent on the speech frequencies chosen. In general the lower the frequencies selected, the lower the low fence should be and the higher the frequencies that are included, the higher the low fence should be. A wide range of values for the low fence have been used, ranging from 40dB downwards (Robinson et al. 1984). A number of studies of individuals with NIHL have been performed in an attempt to define the low fence (Acton 1970; Smoorenberg et al. 1982; Suter 1985). Acton showed that individuals with HTLs of 12dB at 1,000Hz, 2,000Hz and 3,000Hz or 15dB at 1,000Hz, 2,000Hz and 4,000Hz performed as well as normal hearing controls even in noisy conditions. Research by Smoorenberg et al. (1981) suggested a value of 15dB for the low fence. Alice Suter in a more recent study suggested a value of

19dB at 1,000Hz, 2,000Hz and 3,000Hz and of 22dB at 1,000Hz, 2,000Hz and 4,000Hz (Suter 1985). On the basis of this research a low fence of 20dB was taken for our selected frequencies of 500Hz, 1,000Hz, 2,000Hz and 4,000Hz. This corresponds to the 90th percentile of hearing threshold level for a 25 year old male from a typical unscreened population (Robinson DW 1988a) or to the 90th percentile of hearing threshold for a 50 year old male from an otologically normal screened population (ISO 7029:1990).

7.5 Multiplier

At the frequencies chosen, disability is considered to begin at an average hearing threshold level of greater than 20dB.

The group considered that a hearing threshold level greater than 100dB constituted 100% disability.

The relationship between these levels of disability is expressed as an S-Shaped curve on a graph which approximates closely with a straight line with a slope of 1.25 between the high and low fence. Therefore an average hearing loss of greater than 20dB is multiplied by 1.25 to calculate the “monaural hearing disability percentage”.

7.6 Weighting For The Better Ear

It is well recognised that an individual who totally loses hearing in one ear does not suffer from a 50% disability. Accordingly, for individuals who have different levels of hearing in either ear, a weighting factor is applied to allow calculation of binaural hearing disability. A wide variety of weightings have been used by different systems in the past. These have varied from 2:1 to 10:1. From a practical point of view, whichever weighting is chosen makes little difference. A weighting of 4:1 was chosen as there is some scientific evidence to favour this (Davis & Haggard 1982).

7.7 Age Related Hearing Loss Correction

Hearing loss caused by noise and by ageing is additive, but is less than the sum of the two causes (Williams 1996). In constructing a hearing disability formula, it is common to assess how much of the hearing loss is due to ARHL and how much to NIHL. In a formula using the HTLs at 500Hz, 1,000Hz, 2,000Hz and 4,000Hz it is possible to predict the median (or average) ARHL for an average individual at any age or either sex.

ISO 7029:1990 reveals that an average male will suffer a hearing loss of 20.6 dB at the age of 70 years. An average female will suffer a hearing loss of 20.25 dB at the age of 78 years.

The Group therefore recommends that in males over the age of 69 years and in females over the age of 77 years that a percentage be subtracted from the overall hearing disability to allow for ARHL. These percentages have been calculated from ISO 7029:1990 and are shown below (Table 4) and in Appendix 1.

Table 4. Disability Percentage Age Correction Factor

Age(years)	Males	Females
70	1%	
71	2%	
72	3%	
73	4%	
74	5%	
75	6%	
76	7%	
77	8%	
78	9%	1%
79	11%	1%
80	12%	2%

7.8 Age Related and Noise Induced Hearing Loss

Excessive noise may damage the same hair cells in the cochlea that degenerate with advancing age causing hearing loss and possibly tinnitus. The effects on hearing of ARHL and NIHL are additive, though less than the sum of the two causes (Williams 1996). Obviously, if hair cells have been damaged by one of these causes, they cannot be re-damaged by the other. The effect of the noise component of the true hearing threshold progressively diminishes with time. Thus, at the age of 80 years it makes virtually no difference to an individual’s hearing ability what his/her noise exposure has been (Robinson 1988b).

NIHL may ‘bring forward’ the age at which an individual will suffer hearing difficulty due to the additional effects of ARHL. A younger individual, who would not currently suffer from ARHL, may sustain NIHL but not to the extent which causes a disability. In this case the Expert Group recommends that such an individual should be reassessed at an appropriate time interval, when or if, a disability has become apparent.

7.9 Tinnitus

Noise induced hearing loss is the most common identifiable pathological cause of tinnitus (Axelsson and Barrenas 1992). Noise Induced Tinnitus (NIT) may result following an episode of severe acoustic trauma or may be the result of continuous noise exposure. NIT may be temporary or permanent.

Noise Induced Permanent Tinnitus (NIPT) may occur immediately following a single episode of acoustic trauma (Alberti 1987b). However, in the majority of cases the onset is usually insidious and many individuals are unable to determine when it first started.

It is important to note that the prevalence of tinnitus in the normal population is high. Coles (1982) found tinnitus in 11% of people 40 years old or younger, in 13% of people aged between 40 and 60 years and in 18% of people older than 60 years of age. Other authors have also found an increase of tinnitus with increased age (Chung et al 1984; Weiss and Weiss 1984) but a further analysis of this data indicated that in the majority of cases it was an individual’s hearing threshold and not age that mattered.

Estimates of tinnitus prevalence in a normal population in industrialised countries based on the National Study of Hearing and other studies are as follows (Coles 1997):

1. Approximately 35% of the population studied, remember an experience of tinnitus.
2. Approximately 10% have experienced spontaneous tinnitus lasting over 5 minutes.
3. At least 5% experience tinnitus causing interference with getting to sleep and/or causing moderate or severe annoyance.
4. Only 0.5% experience tinnitus that has a severe effect on their ability to lead a normal life.

Probably the most useful single statistic is that 7% of the adult population of the UK have at some time been to see their family doctor about tinnitus. It is of interest also that, of adults with auditory complaints, over one-third were complaining of tinnitus.

Work by Coles (1982), indicates that a history of noise exposure almost doubles an individual's risk of tinnitus. Work by McShane et al (1988) found that the incidence of tinnitus in a noise exposed claimant population was 34% among those who had been exposed for up to 10 years. This increased to 54% for those who had worked with noise between 11 and 30 years and 50% for those who had worked with noise for greater than 30 years. Axelsson and Barrenas (1992) showed that NIHL normally occurred long before noise induced permanent tinnitus appeared. The interval between an individual's first exposure to noise and development of tinnitus ranged from as short as 11 years for military workers to as long as 35 years for workshop mechanics who had continued to work in noise. It was noted however, that amongst military workers several developed immediate onset of tinnitus following severe acoustic trauma. It is noted that tinnitus following impulsive noise occurs more frequently than following exposure to continuous noise (Man & Naggan 1981). Comparing individuals with approximately similar hearing thresholds, tinnitus occurred in 63% to 70% of people exposed to impulsive noise, compared to 47% to 57% of people exposed to continuous noise (Alberti 1987b). Hamberger and Liden (1951) investigated military personnel exposed to acoustic trauma, and found that tinnitus was clearly related to the degree of hearing loss.

It is important to note that NIPT is a subjective symptom, and currently there exists no objective test that can prove its existence. Alberti found a variety of descriptions of the tinnitus associated with NIHL. The quality of tinnitus was described as ringing, in 34%, buzzing, in 26%, whistling, in 12% and pulsatile in 9% (Alberti 1987b). When individuals with tinnitus are asked to compare the sound/character of the tinnitus with a pure tone, a good correlation is usually noted between the individual's hearing loss frequencies and the pitch of the tinnitus (Axelsson and Sandh 1985). However, this is not invariably the case (Man and Naggan 1981). Techniques such as pitch matching may be helpful in assessing tinnitus. This is particularly so if the pitch of his/her tinnitus correlates with the frequency of maximum hearing loss.

Pitch matching of tinnitus provides extra information and may help in the clinical assessment of tinnitus. The prevalence of tinnitus tends to increase pro rata with hearing loss. However, several authors have found no correlation between the severity of noise induced tinnitus and the amount of hearing loss (Weiss and Weiss 1984; McShane et al 1988).

There are a number of significant causes of tinnitus reported, including older age and exposure to noise. However, the main determinant predicting the likelihood of tinnitus appears to be the hearing threshold level. The greater the reduction in hearing threshold level, the more likely the presence of tinnitus. Coles (1997) described this more pathophysiologically in stating that what matters is the degree of cochlear disorder, not its cause. The Expert Group consider that NIT should be closely associated with the period of noise exposure. However, tinnitus may occur years following exposure to noise due simply to age related hearing loss (Mills et al 1996).

Epidemiological studies show that the majority of people with tinnitus do not complain of it. Tinnitus causes fewer problems over time due to the effects of habituation (Coles 1997; Tyler and Baker 1983).

The Group recommends that two different categories of individuals complaining of tinnitus with a history of noise exposure should be considered.

Category 1: Those who complain of slight, mild, moderate or severe tinnitus and have a compensatable hearing loss on pure tone audiometry.

Category 2: Those who complain of moderate or severe tinnitus but do not have a compensatable hearing loss.

Category 2 may be subdivided into two further sub-categories;

(a) Those who develop tinnitus following exposure to acute episodes of impulsive noise such as may occur following a blast, with a normal audiogram

(b) Individuals with tinnitus and a history of noise exposure who have an audiogram consistent with noise induced hearing loss.

The Group recommends that tinnitus be categorised as slight, mild, moderate or severe on the basis of history and if possible specific pitch matching. In the presence of a compensatable hearing loss, tinnitus is likely to be due to NIHL. Disability from persistent slight and mild tinnitus due to NIHL is included as ‘part and parcel’ of our recommended system. For those who have moderate or severe tinnitus, certain criteria should be met before additional disability is apportioned.

1. Noise induced permanent tinnitus should start at or about the time of exposure to noise (i.e. within 1 year of the cessation of exposure).

   Tinnitus that starts more than 1 year after the removal from a noisy environment is unlikely to be related to noise. In view of the high prevalence of tinnitus in normal populations, tinnitus due to age related hearing loss and tinnitus of unknown origins should be considered as possible causes of the tinnitus. Coles et al (1988) introduced the term “audiologically honest”. Essentially, if an individual gives reliable and consistent information about his health, his degree of noise exposure and if consistent in repeated audiometric testing, it is reasonable to believe that s/he is also “honest” concerning his complaint of tinnitus.

2. The tinnitus should be present for more than 2 years, when awake, lying or sitting quietly and be clearly audible to the individual for at least 50% of that time.

3. The complaint of tinnitus should be medically documented prior to any compensation claim. If no previous complaint has been made, adequate reason for this should be given.

A complete history using open ended, non-leading questions is essential in deciding the severity of an individual's tinnitus. For an individual to be assigned to a severity category, s/he must meet all the criteria in the said category.

7.9.1 Classification of Tinnitus

Slight Tinnitus

- Noise heard in the head or either ear occurring occasionally (e.g. once or twice per month).
- Does not cause any interference with sleep or concentration and does not interfere with lifestyle.

Mild Tinnitus

- Noise in the head or either ear, not heard in the presence of background noise.
- Noise may occasionally interfere with sleep or concentration.
- Does not interfere with normal lifestyle activities.

Moderate Tinnitus

- This is defined as intermittent or continuous sounds heard in the head or either ear occurring for a period of at least two years.
- The noise is heard during waking hours in the presence of background noise and frequently interferes with the ability to get to sleep, (e.g. on a monthly basis).
- The onset of the tinnitus should be closely approximate to the time of noise exposure.
- The individual should have documented evidence of attending a primary care physician for advice and management regarding the tinnitus, prior to any claim being lodged.

Severe Tinnitus

- This is defined as noise localised to the head or ears present during waking hours and interfering with the ability to get asleep.
- It causes disturbance of sleep pattern and interferes with

the ability to carry out normal occupational and social activities.

- The tinnitus should have been constantly present in such a manner for two years and the date of the onset should have been at or closely approximate to the time of noise exposure.
- There should be documented evidence of the individual seeking primary physician care and evidence of referral for specialist opinion. This should have occurred prior to any claim.
- There must be documented evidence of the individual requiring treatment with tinnitus maskers and/or medication to control sleep and improve concentration.

7.9.2 Percentage Disability Due to Tinnitus

- Severe tinnitus represents 6% disability
- Moderate tinnitus represents 2% disability
- Slight/Mild tinnitus represents 0% disability

Table 5 - Disability associated with Tinnitus

Hearing Loss	*Category*	*Severity of Tinnitus*	*Disability*
Compensatable Hearing Loss	Category 1	Slight/Mild Moderate Severe	0% 2% 6%
Non-Compensatable Hearing Loss	Category (2a) (Acoustic Trauma)	Slight/Mild Moderate Severe	0% 2% 6%
	Category (2b) (Audio typical of NIHL)	Slight/Mild Moderate Severe	0% 2% 6%

Appendix 1

Median Hearing Loss (dB) due to age for each sex at the frequencies 500 Hz, 1,000Hz, 2,000Hz and 4,000Hz for each year of age, and percentage disability due to ARHL for a low fence of 20 dB.

Male

Age	500Hz	1000Hz	2000Hz	4000Hz	Disability % Fence 20dB
18	0.0	0.0	0.0	0.0	
19	0.0035	0.004	0.007	0.016	
20	0.014	0.016	0.028	0.064	
21	0.0315	0.036	0.063	0.144	
22	0.056	0.064	0.112	0.256	
23	0.0875	0.1	0.175	0.4	
24	0.126	0.144	0.252	0.576	
25	0.1715	0.196	0.343	0.784	
26	0.224	0.256	0.448	1.024	
27	0.2835	0.324	0.567	1.296	
28	0.35	0.4	0.7	1.6	
29	0.4235	0.484	0.847	1.936	
30	0.504	0.576	1.008	2.304	
31	0.5915	0.676	1.183	2.704	
32	0.686	0.784	1.372	3.136	
33	0.7875	0.9	1.575	3.6	
34	0.896	1.024	1.792	4.096	
35	1.0115	1.156	2.023	4.624	
36	1.134	1.296	2.268	5.184	
37	1.2635	1.444	2.527	5.776	
38	1.4	1.6	2.8	6.4	
39	1.5435	1.764	3.087	7.056	
40	1.694	1.936	3.388	7.744	
41	1.8515	2.116	3.703	8.464	
42	2.016	2.304	4.032	9.216	
43	2.1875	2.5	4.375	10.0	
44	2.366	2.704	4.732	10.82	
45	2.5515	2.916	5.103	11.66	
46	2.744	3.136	5.488	12.54	
47	2.9435	3.364	5.887	13.46	
48	3.15	3.6	6.3	14.4	
49	3.3635	3.844	6.727	15.38	
50	3.584	4.096	7.168	16.38	
51	3.8115	4.156	7.623	17.42	
52	4.046	4.624	8.092	18.5	
53	4.2875	4.9	8.575	19.6	
54	4.536	5.184	9.072	20.74	
55	4.7915	5.476	9.583	21.9	
56	5.054	5.776	10.11	23.1	
57	5.3235	6.084	10.65	24.34	
58	5.6	6.4	11.2	25.6	
59	5.8835	6.724	11.77	26.9	
60	6.174	7.056	12.35	28.22	
61	6.4715	7.396	12.94	29.58	
62	6.776	7.744	13.55	30.98	
63	7.087	8.1	14.18	32.4	
64	7.406	8.464	14.81	33.86	
65	7.7315	8.836	15.46	35.34	
66	8.064	9.216	16.13	36.86	
67	8.4035	9.604	16.81	38.42	
68	8.75	10.0	17.5	40.0	
69	9.1035	10.4	18.21	41.62	
70	9.46	10.82	18.93	43.26	1%
71	9.8315	11.24	19.66	44.94	2%
72	10.206	11.66	20.41	46.66	3%
73	10.588	12.1	21.18	48.4	4%
74	10.976	12.54	21.95	50.18	5%
75	11.372	13.0	22.74	51.98	6%
76	11.774	13.46	23.55	53.82	7%
77	12.184	13.92	24.37	55.7	8%
78	12.6	14.4	25.2	57.6	9%
79	13.024	14.88	26.05	59.54	11%
80	13.454	15.38	26.91	61.5	12%

Female

Age	500Hz	1000Hz	2000Hz	4000Hz	Disability % Fence 20dB
18	0.0	0.0	0.0	0.0	
19	0.0035	0.004	0.006	0.009	
20	0.014	0.016	0.024	0.036	
21	0.0315	0.036	0.054	0.081	
22	0.056	0.064	0.096	0.144	
23	0.0875	0.1	0.15	0.225	
24	0.126	0.144	0.216	0.324	
25	0.1715	0.196	0.294	0.441	
26	0.224	0.256	0.384	0.576	
27	0.2835	0.324	0.486	0.729	
28	0.35	0.4	0.6	0.9	
29	0.4235	0.484	0.726	1.089	
30	0.504	0.576	0.864	1.296	
31	0.5915	0.676	1.014	1.521	
32	0.686	0.784	1.176	1.764	
33	0.7875	0.9	1.35	2.025	
34	0.896	1.024	1.536	2.304	
35	1.0115	1.156	1.734	2.601	
36	1.134	1.296	1.944	2.916	
37	1.2635	1.444	2.166	3.249	
38	1.4	1.6	2.4	3.6	
39	1.5435	1.764	2.646	3.969	
40	1.694	1.936	2.904	4.356	
41	1.8515	2.116	3.176	4.761	
42	2.016	2.304	3.456	5.184	
43	2.1875	2.5	3.75	5.625	
44	2.36	2.704	4.056	6.086	
45	2.5515	2.916	4.374	6.561	
46	2.744	3.136	4.704	7.056	
47	2.9435	3.364	5.046	7.569	
48	3.15	3.6	5.4	8.1	
49	3.3635	3.844	5.766	8.649	
50	3.584	4.096	6.144	9.216	
51	3.8115	4.356	6.534	9.801	
52	4.046	4.624	6.936	10.4	
53	4.2875	4.9	7.35	11.03	
54	4.536	5.184	7.776	11.66	
55	4.7915	5.476	8.214	12.32	
56	5.054	5.776	8.664	13.0	
57	5.3235	6.084	9.126	13.69	
58	5.6	6.4	9.6	14.4	
59	5.8835	6.724	10.09	15.13	
60	6.174	7.056	10.58	15.88	
61	6.4715	7.396	11.09	16.64	
62	6.776	7.744	11.62	17.42	
63	7.0875	8.1	12.15	18.23	
64	7.406	8.464	12.7	19.04	
65	7.7315	8.836	13.25	19.88	
66	8.064	9.216	13.82	20.74	
67	8.4035	9.604	14.41	21.61	
68	8.75	10.0	15.0	22.5	
69	9.1035	10.4	15.61	23.41	
70	9.464	10.82	16.22	24.34	
71	9.8315	11.24	16.85	25.28	
72	10.206	11.66	17.5	26.24	
73	10.588	12.1	18.15	27.23	
74	10.976	12.54	18.82	28.22	
75	11.372	13.0	19.49	29.24	
76	11.774	13.46	20.18	30.28	
77	12.184	13.92	20.89	31.33	
78	12.6	14.4	21.6	32.4	1%
79	13.024	14.88	22.33	33.49	1%
80	13.454	15.38	23.06	34.6	2%

Appendix 2

Worked Examples

1. Find the hearing disability of a 35 year old male without tinnitus and with the following hearing threshold levels.

	Right Ear	Left Ear
500Hz	10dB	10dB
1,000Hz	10dB	10dB
2,000Hz	10dB	10dB
4,000Hz	30dB	30dB

Average hearing threshold level right ear = 15 dB

Average hearing threshold level left ear = 15 dB

Hearing threshold level in both ears fails to reach the low fence - no disability

2. Find the hearing disability of a 55 year old male without tinnitus and with the following hearing threshold levels.

	Right Ear	Left Ear
500Hz	10dB	10dB
1,000Hz	20dB	20dB
2,000Hz	30dB	35dB
4,000Hz	45dB	45dB

Average hearing threshold level right ear = 26.25 dB

Average hearing threshold level left ear = 27.5 dB

Subtract low fence (20 dB): right ear = 6.25 dB
left ear = 7.5 dB

Multiplier effect: right ear: 6.25 dB x 1.25% = 7.8%
left ear: 7.5 dB x 1.25% = 9.4%

Binaural disability: $\frac{(7.8\% \times 4) + (9.4\% \times 1)}{5}$ = 8.12% Hearing Disability

3. Find the hearing disability of a 57 year old male with "moderate" tinnitus and the following hearing threshold levels:

	Right Ear	Left Ear
500Hz	10dB	15dB
1,000Hz	20dB	25dB
2,000Hz	35dB	40dB
4,000Hz	45dB	50dB

Average hearing threshold level right ear = 27.5 dB

Average hearing threshold level left ear = 32.5 dB

Subtract low fence (20 dB): right ear = 7.5 dB
left ear = 12.5 dB

Multiplier effect: right ear: 7.5 dB x 1.25% = 9.4%
left ear: 12.5 dB x 1.25% = 15.6%

Binaural disability: $\frac{(9.4\% \times 4) + (15.6\% \times 1)}{5}$ = 10.6% Hearing Disability

Add 2% disability for "moderate" tinnitus.

Overall disability = 12.6%

4. Find the hearing disability of a 53 year old male with “severe” tinnitus and the following hearing threshold levels:

	Right Ear	Left Ear
500Hz	10dB	10dB
1,000Hz	10dB	15dB
2,000Hz	20dB	25dB
4,000Hz	40dB	45dB

Average hearing threshold level right ear = 20 dB

Average hearing threshold level left ear = 23.75 dB

Subtract low fence (20 dB): right ear = 0 dB
left ear = 3.75 dB

Multiplier effect: right ear: 0 dB x1.25% = 0%
left ear: 3.75 dB x 1.25% = 4.7%

Binaural disability: $\frac{(4.7\% \times 4) + (0\% \times 1)}{5}$ = 3.76% Hearing Disability

Add 6% disability for “severe” tinnitus.

Overall disability = 9.76%

5. Find the noise induced hearing disability of a 72 year old male with "mild" tinnitus and the following hearing threshold levels:

	Right Ear	Left Ear
500Hz	20dB	20dB
1,000Hz	25dB	25dB
2,000Hz	40dB	45dB
4,000Hz	55dB	60dB

Average hearing threshold level right ear = 35 dB

Average hearing threshold level left ear = 37.5 dB

Subtract low fence (20 dB): right ear = 15 dB
left ear = 17.5 dB

Multiplier effect: right ear: 15 dB x1.25% = 18.75%
left ear: 17.5 dB x 1.25% = 21.9%

Binaural disability: $\frac{(18.75\% \times 4) + (21.9\% \times 1)}{5}$ = 19.4% Hearing Disability

Subtract 3% disability for ARHL.

Overall disability = 16.4%

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