THE INFLUENCE OF THE ACOUSTICAL ENVIRONMENT ON AUDIOMETRIC TEST RESULTS

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THE INFLUENCE OF THE ACOUSTICAL ENVIRONMENT ON AUDIOMETRIC TEST RESULTS

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DECLARATION OF INDEPENDENT WORK

I, CARIEN WEYERS, do hereby declare that this research project submitted for the degree MAGISTER TECHNOLOGIAE: ENVIRONMENTAL HEALTH, is my own independent work that has not been submitted before to any institution by me or anyone else as part of any qualification.

.... 30/01/2002

SIGNATURE OF STUDENT DATE

SUMMARY

South African legislation requires that screening audiometry be conducted in an environment that complies with the requirements specified by the South African Bureau of Standards (SABS). The SABS Code of Practice 0182: 1998 specifies the maximum permissible ambient sound pressure levels in an acoustic enclosure used for screening audiometry. Since many industries use audiometry for screening purposes only, audiometric testing tends to be conducted in the absence of an acoustic enclosure. The rationale is that the screening process of hearing-impaired people will not be influenced by environmental sound pressure levels.

A study was conducted with students of the Technikon Free State (men and women) between the ages of 18 to 34 years as test subjects to determine whether the test environment would have a significant influence on screening audiometry results. Audiometric testing was conducted according to OSHA 29 CFR 1910.95, with calibrated Tremetrics RA 400 audiometers in two different audiometric test environments with known sound pressure levels. An approved acoustic environment that complies with the specifications of the SABS Code of Practice 0182: 1998 was used as one environment. A non-approved acoustic environment was simulated by operating a GilAir™ personal air-sampling pump in an approved acoustic environment. Octave band analysis was conducted in both test localities to determine and compare the sound pressure level at the different frequencies of the two test environments.

The results indicate that hearing threshold levels in the approved acoustic environment differed from hearing threshold levels in the simulated non-approved acoustic environment. Statistically significant differences existed between the approved and simulated non-approved acoustic environments at frequencies of 500 Hz and 1000 Hz (Student's *t*-test, $p = 0.05$, $n = 1000$) for all the age groups and both genders.

Subjects tested in the approved acoustic environment revealed a lower hearing threshold than in the simulated non-approved acoustic environment. The difference could possibly be explained by the presence of higher sound pressure levels in the simulated non-approved acoustic environment that interfere at these frequencies during simulation. No statistically significant differences were found between the hearing thresholds in the approved and simulated non-approved acoustic environments at frequencies 2000, 3000, 4000, 6000 and 8000 Hz (Student's *t*-test, $p = 0.05$, $n = 1000$).

The identification of high-frequency noise induced hearing loss would still be possible using tests conducted in the non-approved acoustic environment because the frequencies around 4000 Hz did not show a statistically significantly difference when compared to the results obtained in the approved acoustic environment.

The results coincide with previously conducted research, which indicated that the high ambient sound pressure levels would mask the test signal. The threshold of hearing at 500 and 1000 Hz could not accurately be determined in the simulated non-approved acoustic environment. However, unnecessary referrals result from using a non-approved acoustic environment. This will have a financial impact on industries because they are responsible for the cost of medical examinations.

The results show that the legislated environment is appropriate for the accurate determination of hearing thresholds to categorise a person's hearing status and calculate the percentage binaural hearing loss. Screening audiometric tests should always be done in an approved acoustic environment that complies with the specification of the SABS Code of Practice 0182: 1998.

Further research is necessary to confirm the conclusion with employees working in a noise zone. Additional research using different types of earphones is necessary because this could also have an influence on the accurate determination of the threshold of hearing. The research should also include different test environments including the mobile audiometric test facility placed in different locations on site as well as the use of different types of earphones with each environment and each location.

OPSOMMING

Suid-Afrikaanse wetgewing vereis dat siftingsoudiometrie in 'n omgewing wat aan die vereistes gespesifiseer deur die Suid-Afrikaanse Buro van Standaarde (SABS) voldoen, uitgevoer word. Die SABS Gebruikskode 0182: 1998 spesifiseer die maksimum toelaatbare omringende klankdrukpeile in 'n akoestiese afsluiting wat vir siftingsoudiometrie gebruik word. Aangesien meeste industrieë oudiometrie slegs vir siftingsdoeleindes gebruik, neig hulle om die toetse sonder 'n akoestiese hokkie uit te voer. Die rasionaal is dat die siftingsproses van gehoor-verswakte persone nie deur die omgewingsklankdrukpeile beïnvloed word nie.

'n Studie om vas te stel of 'n toetsomgewing 'n betekenisvolle verskil op siftingsoudiometrie resultate toon, is uitgevoer met studente van die Technikon Vrystaat (mans en dames) tussen die ouderdomme van 18 to 34 jaar. Oudiometriese toetse is volgens OSHA 29 CFR 1910.95, met gekalibreerde Tremetrics RA 400 oudiometers in twee toetsomgewings met bekende klankdrukpeile uitgevoer. 'n Goedgekeurde akoestiese omgewing wat aan die vereistes van die SABS Gebruikskode 0182: 1998 voldoen, is as een omgewing gebruik. 'n Nie-goedgekeurde akoetiese omgewing is deur die werking van 'n GilAir™ persoonlike lugmonsternemingspomp in 'n goedgekeurde akoestiese omgewing, gesimuleer. Oktaafband analise is in albei toetsomgewings uitgevoer om die klankdrukpeile te bepaal en te vergelyk by die verskillende frekwensies in die twee toetsomgewings.

Die resultate dui aan dat die gehoordrempels in die goedgekeurde omgewing verskil van die gehoordrempels in die gesimuleerde nie-goedgekeurde akoestiese omgewing. Statisties betekenisvolle verskille bestaan tussen die goedgekeurde en die gesimuleerde nie-goedgekeurde akoestiese omgewing by frekwensies van 500 en 1000 Hz (Student's *t*-toets, $p = 0.05$, $n = 1000$) vir alle ouderdomsgroepe en albei geslagte.

Persone getoets in die goedgekeurde akoestiese omgewing toon 'n laer gehoordrempel as in die gesimuleerde nie-goedgekeurde akoestiese omgewing. Die verskil kan moontlik deur die aanwesigheid van hoër klankdrukpeile in die gesimuleerde nie-goedgekeurde akoestiese omgewing inmeng verklaar word. Geen statisties betekenisvolle verskille bestaan tussen die goedgekeurde en die gesimuleerde nie-goedgekeurde akoestiese omgewing by frekwensies 2000, 3000, 4000, 6000 en 8000 Hz nie (Student's *t*-toets, $p = 0.05$, $n = 1000$).

Die identifikasie van hoë frekwensie geraas geïnduseerde gehoorverlies sal steeds moontlik wees in die nie-goedgekeurde akoestiese omgewing omdat die frekwensies rondom 4000 Hz geen statisties betekenisvolle verskil getoon het nie toe dit vergelyk is met die resultate verkry in die gesimuleerde goedgekeurde akoestiese omgewing.

Die resultate stem ooreen met vorige navorsing wat aandui dat die hoë omringende klankdrukpeile die toetssein sal maskeer. Die gehoordrempel kan nie in die gesimuleerde nie-goedgekeurde toetsomgewing akkuraat by 500 en 1000 Hz bepaal word nie. Nietemin, onnodige verwysings is die resultaat van die gebruik van 'n nie-goedgekeurde akoestiese omgewing. Dit sal 'n finansiële impak op industrieë hê aangesien hulle verantwoordelik is vir die koste van mediese ondersoeke.

Die resultate dui aan dat die voorgeskrewe toetsomgewing geskik is vir die akkurate bepaling van gehoordrempels om 'n persoon se gehoorstatus te kategoriseer en binorale gehoorverlies te bereken. Siftingsoudiometriese toetse moet altyd in 'n goedgekeurde akoestiese omgewing wat aan die vereistes van die SABS Gebruikskode 0182: 1998 voldoen, uitgevoer word.

Verdere navorsing met werknemers wat in 'n geraassone werk om die gevolgtrekking te bevestig, is nodig. Addisionele navorsing met verskillende tipes oorfone is nodig aangesien dit ook 'n invloed op die akkurate bepaling van die gehoordrempel kan hê. Die navorsing moet ook verskillende toetsomgewings asook die mobile akoestiese omgewing by verskillende liggings insluit asook die gebruik van verskillende oorfone met elke toetsomgewing en ligging.

ALWAYS USE THE ABC OF LIFE: A FOR ATTITUDE, B FOR BELIEF AND C FOR CHOICE

-ALISON-

TO MY PARENTS, BERTIE AND BETTIE WEYERS AND MY DAUGHTER, MARTELIZE

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LIST OF IMPORTANT ABBREVIATIONS

AIA	Approved inspection authority
AIHA	American Industrial Hygiene Association
ANSI	American National Safety Institute
HTL	Hearing threshold level
L_{perm}	Maximum permissible ambient sound pressure level
NIHL	Noise induced hearing loss
NIOSH	National Institute of Occupational Safety and Health
NOSA	National Occupational Safety Association
OSHA	Occupational Safety and Health Association
SABS	South African Bureau of Standards
SPL	Sound pressure level

LIST OF DEFINITIONS

Air conduction	The process by which sound is conducted to the inner ear through air in the outer ear canal
Ambient noise	The all-encompassing noise associated with a given environment; usually a composite of sounds from many sources
Audiogram	A record of hearing loss or hearing level measured at several different frequencies - usually 500 - 6000 Hz. The audiogram may be presented graphically or numerically
Audiometer	A signal generator or instrument that can be operated manually or automatically for measuring objectively the sensitivity of hearing in decibels referred to audiometric zero. Pure tone audiometers are standard instruments for occupational use
Audiometric testing programme	Test records that provide the only data that can be used to determine whether the programme is preventing noise-induced permanent threshold shifts. It is an integral part of the hearing conservation programme
Audiometric zero	The threshold of hearing: 0.0002 microbars of sound pressure
Auditory	Pertaining to, or involving the organs of hearing or the sense of hearing
A-weighted response	The simulation of the sensitivity of the human ear at moderate sound levels
Background noise	Noise coming from sources other than the particular noise source being monitored
Bone conduction	Transmission of sound vibrations to the internal ear via the bones of the skull

Bone conduction test	A special test conducted by placing an oscillator on the mastoid process to determine the nerve-carrying capacity of the cochlea and the eighth cranial (auditory) nerve
Calibrate	To check, adjust or systematically standardise the graduations of a quantitative measuring instrument
Calibration	Establishment of a relationship between various calibration standards and the measurements of them obtained by a measurement system or portions thereof. The levels of the calibration standards should bracket the range of levels for which actual measurements are to be made
Decibel (dB)	A dimensionless unit used to express a logarithmic ration between a measured quantity and a preference quantity. It is commonly used to describe the levels of acoustic intensity, acoustic power, sound pressure levels and hearing threshold when reference quantity is specified
dB(A)	Sound level in decibels on the A scale of a sound-level meter. The A scale discriminates against very low frequencies (as does the human ear) and is therefore better for measuring general sound levels
Ear	The entire hearing apparatus, consisting of three parts: the external ear, the middle ear and the inner ear
Ear wax (cerumen)	The waxy discharge in the outer ear canal
Hearing conservation	The programme for preventing or minimising noise-induced deafness through audiometric testing, measurement of noise, engineering control and ear protection
Hearing level	A measurement of hearing acuity. The deviation in decibels of an individual's threshold from the zero reference of the audiometer

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Hearing level	A measurement of hearing acuity. The deviation in decibels of an individual's threshold from the zero reference of the audiometer

Hearing loss	The deviation of hearing acuity from normal
Hertz (Hz)	Unit of frequency equal to one cycle per second
Masking	The stimulation of a person's ear with controlled noise to prevent that person from hearing with one ear the tone or signal given to the other ear. This procedure is used when there is at least a 15 to 20 dB(A) difference in the hearing level between the ears
Noise	Unwanted sound, unwanted because it can cause annoyance, interfere with speech or communication and / or cause hearing impairment
Noise level	For airborne sound, unless specified to the contrary, noise level is the weighted sound pressure level called sound level; the weighting must be indicated
Noise induced hearing loss	Hearing loss due to excessive exposure to noise
Non-auditory effects of noise	Refers to stress, fatigue, health, work efficiency and performance of loud continuous noise
Octave bands	1. A frequency range in which the ration of upper to lower frequency is 2:1 2. A measurement of the broad range of frequencies humans can hear Frequencies are normally divided into nine octave bands. An octave is defined as a range of frequencies extending from one frequency to exactly double that frequency. Each octave band is named for the center frequency (geometric mean) of the band
Otitis media	An inflammation and infection of the middle ear

Presbycusis	The hearing loss normally occurring due to age because of the degeneration of the nerve cells due to the ordinary wear and tear of the aging process
Pure tone	The sound energy that is characterised by its singleness of frequency
Sound level meter	An instrument used to measure noise and sound levels in a specified manner; the meter may be calibrated in decibels or volume units and includes a microphone, an amplifier, an output meter and frequency-weighting networks
Sound pressure level	The level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ration of the measured pressure of this sound to the reference pressure. The reference pressure is 0.0002 dynes/cm^2
Standard deviation	1. The positive square root of the variance of a distribution, the parameter measuring the spread of values about the mean. 2. The positive square root of the expected value of the square of the difference between a random variable and its mean
Tinnitus	A perception of sound arising in the head. Most often perceived as a ringing or hissing sound in the ears. Can be the result of high frequency hearing loss

(All definitions taken from American Industrial Hygiene Association. 1997. The Occupational environment - its evaluation and control. American Industrial Hygiene Association, Fairfax, Virginia. 1281-1342.)

LIST OF ANNEXES

1. INTRODUCTION

1.1 Background

Audiometry can be defined as the measurement of hearing (Zenz, Dickerson and Horvath, 1994). Before the development of electroacoustic equipment for the generation and measurement of sound, the available hearing tests gave approximate answers at best (Encyclopaedia Britannica, 2000). A person's hearing was specified in terms of the ability to distinguish the ticking of a watch, the clicking of coins or the distance at which conversational speech or whispered voice could be understood (Encyclopaedia Britannica, 2000). In the early 1900's, a tuning fork was used for audiometry. In these tests the examiner noted the length of time the person could hear the gradual diminishing note of a tuning fork and compared that with his own performance (Zenz, Dickerson and Horvath, 1994).

The tuning fork method was further developed to include a qualitative assessment of hearing loss (Encyclopaedia Britannica, 2000). These tests exploited the ability of sound to be conducted through the bones of the skull (bone-conduction). In the Rinne test, for instance, the sounding tuning fork was placed on the mastoid process and the person being tested was asked to report when it could no longer be heard (Encyclopaedia Britannica, 2000). The examiner would then remove the fork immediately and hold the prongs close to the open ear canal (air conduction). The normal ear would continue to hear the sound for about 45 seconds longer and this "positive" result also occurred with incomplete sensorineural impairment of hearing. If the result was "negative" and the fork was heard for a longer period by bone conduction than by air conduction, a conductive type of deafness was identified (Encyclopaedia Britannica, 2000).

The introduction of the electric audiometer in the 1930's made it possible to measure an individual's hearing threshold for a series of pure tones (Encyclopaedia Britannica, 2000).

Electric audiometry can be classified as being either air-conduction or bone-conduction audiometry. Bone-conduction audiometry is used for diagnostic purposes while air-conduction audiometry is used in industry for the identification of noise-induced hearing loss (NIHL) (American Industrial Hygiene Association (AIHA), 1997). In pure-tone air-conduction audiometry the test signal is conducted to the eardrum through air (Zenz, Dickerson and Horvath, 1994). The "zero dB" level represents normal hearing for young adults under favourable, noise-free laboratory conditions. The "zero dB" level was established in 1964 as an international standard (Encyclopaedia Britannica, 2000). The "zero dB" level requires noise-free laboratory conditions, thus it follows that the test environment has an influence on the accurate determination of the threshold of hearing.

Occupational noise exposure (above 85 dB(A)) could cause NIHL in the individual (AIHA, 1997). The hearing capability of employees working in a noise zone should be monitored on a regular basis including a pre- and post-employment audiogram (Environmental Regulations for Workplaces, South Africa, 1987). The first frequency to be affected is usually 4000 Hz. Fox (1953), Sataloff (1957, 1980) and Sataloff, Sataloff and Vassallo (1980) found that if exposure to noise continues for a period of years, damage would spread to both higher and lower frequencies. It is often not noticed until it affects the frequencies involved in speech, namely 500 to 2000 Hz (Lusk and Keleman, 1993).

Screening audiometry is usually conducted in industry to establish baseline hearing threshold levels (HTL's) of employees, identify a referral threshold shift and to identify individuals with possible noise induced hearing loss (NIHL). It is also used to prescribe hearing protection or a medical examination if the results indicate a decrease in hearing acuity. An audiometer, which produces pure tones of various frequencies (500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz) at different known pressure levels, is used in the determination of the threshold of hearing (Smith, Peters and Owen, 1982).

Audiometry should be done in a test room or booth that conforms to the legislative requirements established for the specific country (Plog, 1996). Plog stated that it must be sufficiently quiet in the enclosure to avoid interference of external noise with the test subject's perception of the test sounds.

Background noise limits for audiometry are specified in international standards to limit the effects of masking during a hearing test (AIHA, 1997). The standards provide for audiometric testing to be done over a range of audiometric frequencies extending down to 500 Hz or lower (Regulation CFR1910.95, 1995, American National Safety Institute (ANSI) S3.1-1960, 1995). The lowest frequency of testing is an important factor that determines the admissible background noise (Hirschorn and Singer, 1973).

Legislative requirements for the acoustic environment used during screening audiometry have been available for years in a number of countries. Assessment of hearing disability in the United Kingdom, for instance, is generally based on a consideration of pure-tone HTL's in the frequency range 1000 Hz and upwards (Robinson, 1992). It was also proposed by Robinson (Robinson, 1992) in the United Kingdom, that a modification of the standardised noise limits, which allows some relaxation appropriate to this higher minimum frequency, be implemented in air-conduction audiometry. Robinson showed that these modifications in permissible background noise would, however, affect the frequency range below 1000 Hz (Robinson, 1992).

The American Occupational Safety and Health Administration (OSHA) regulation 29CFR1910.95 requires that audiometric testing be performed in an area that meets the background noise criteria specified in Table D 1 of the Hearing Conservation Amendment, 1995 (Regulation CFR1910.95, 1995, American National Safety Institute (ANSI) S3.1-1960, 1995) (Annex A). These criteria evolved from the 1960 version of the ANSI criteria document S3.1-1960 (Lipscomb, 1988). There is a general agreement among professionals that these criteria are not stringent enough for accurate testing down to 0 dB HTL at all the specified test frequencies (AIHA, 1997).

The American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS, 1983) recommended in 1983 background levels for audiometric testing that were 10 dB more stringent than OSHA (1983) levels at all frequencies in their "Guide for Conservation of Hearing in Noise". The academy further recommended that Practitioners in Hearing Conservation should attempt to comply with these stricter levels concerning admissible background noise when conducting audiometric tests. Another background noise criterion is the criterion proposed by Hirschorn and Singer's (1973). They recommended a maximum background A-weighted noise level of 43 dB. Results from their study at this higher background noise level indicated that accurate threshold testing to 0 dB at all frequencies from 500 to 6000 Hz (Hirschorn and Singer, 1973), using MX-41/AR earphone cushions during the testing, could be achieved. They found that the type of earphone used during the audiometric testing also has an influence on the accurate determination of the threshold of hearing (Hirschorn and Singer, 1973).

Legislation that prescribes the procedure for audiometric testing in South Africa dates back to 1941. It prescribed the procedure, as well as the specifics related to a hearing conservation programme. The first regulation in South Africa that prescribed audiometric tests for employees was Regulation B 17 promulgated in terms of the Factories, Machinery and Building Work Act, Act 22 of 1941. The Regulation required that the hearing acuity of both ears of employees exposed to noise levels equal to or exceeding 85 dB (A) be tested at the frequencies of 500, 1000, 2000, 4000 and 6000 Hz at least once a year, depending on the audiometric test results. These tests were to be conducted in a room or cubicle where the ambient noise level did not exceed 45 dB (A) and the room or cubicle had to be approved by the South African Bureau of Standards (SABS) or another approved inspection authority

(AIA) (South Africa, 1941). However, this legislation has changed over the years to assure better and more accurate hearing tests.

Since 1941, the minimum requirements for the acoustic environment, used in screening audiometry, has changed from an average ambient noise level of 45 dB (A) to maximum permissible ambient sound pressure levels (SPL's) (L_{perm}) in octave bands (SABS, 1998). These maximum permissible ambient SPL's are specified in the SABS Code of Practice 0182: 1998 (SABS, 1998).

The Environmental Regulations for Workplaces (1987) promulgated in terms of the Occupational Health and Safety Act, Act 85 of 1993 currently enforces the audiometric testing of employees exposed to noise levels equal to or exceeding 85 dB (A). The Environmental Regulations for Workplaces (1987) further states that audiometry must be conducted according to the SABS Code of Practice 083: 1996. The Code of Practice describes the practice for the measurement and assessment of occupational noise for hearing conservation purposes (Environmental Regulations for Workplaces, South Africa, 1987).

SABS Code of Practice 083 (SABS, 1996) refers to three supportive documents that must be complied with during audiometric testing. These are the SABS Code of Practice 0154: 1996, that describes the procedure for calibration of pure tone audiometers, the SABS Code of Practice 083: 1996, that provides information for the measurement and assessment of occupational noise for hearing conservation purposes, and the SABS Code of Practice 0182: 1998, that describes the requirements for obtaining an acoustic environment suitable for audiometric testing. Unless the audiometric tests are conducted in compliance with these standards, it is regarded as null and void (SABS, 1996).

1.2 Screening audiometric testing

1.2.1 Calibration of audiometers

Calibration of an audiometer is done initially when the unit is manufactured. Since the instrument is exposed to variable temperatures, humidity and possible mechanical shock, it must also be calibrated annually (SABS, 1996). The audiometer must be calibrated to the earphones with which it will be used since the earphones are probably the weakest link in the calibration chain because of physical handling (Feldman and Grimes, 1985).

1.2.2 Measurement and assessment of occupational noise for hearing conservation purposes

The SABS Code of Practice 083: 1996 covers the measurement and rating of a working environment for hearing conservation purposes and also the physical demarcation of an area where hearing conservation measures have to be applied. It is also stated in the Code of Practice that the test frequencies should include at least 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz and 8000 Hz.

The frequencies 500, 1000 and 2000 Hz are of special importance since it is generally accepted that hearing loss in these frequencies will result in an inability to understand everyday speech (Schoeman and Schröder, 1994). The percentage binaural hearing impairment is calculated by using 500, 1000, 2000 and 3000 Hz in the South African compensation structures (South Africa, Compensation of Occupational Diseases and Injuries Act, 1993). If the ambient noise levels influence the accurate determination of the hearing threshold in the frequency range below 1000 Hz as stated by Robinson (1992), the percentage binaural hearing loss and thus the categorisation of the employee or referral threshold shift could be influenced by the test environment.

The categorisation method used in South Africa and recommended by the South African Department of Labour (DOL) is based on the method of R.S.F. Shilling (Shilling, 1981)(Annex B). This method of categorisation was originally derived from the recommended method used in Europe. It is directly based on the British Health and Safety Executive discussion document (Shilling, 1981). According to this method, the individual is placed in three different categories according to the percentage hearing loss that the person suffers. The individual is categorised as either having normal hearing, the hearing level exceeds the warning level, or has a referral threshold shift that needs further examination.

The categorisation method is no longer used in practice in South Africa. The SABS Code of Practice 083: 1996 now requires that any threshold shift of more than 15 dB at 500 Hz, 1000 Hz, 3000 Hz, 4000 Hz, 6000 Hz, 8000 Hz over a period of not more than 12 months or 20 dB over a period of not more than 20 months should be referred for medical examination.

1.2.3 Acoustic environment for audiometric testing

Studies conducted by Hirschorn and Singer, 1973 and Frasier, 1965 showed that the ambient noise levels present in the test environment have a definite influence on the accurate determination of the hearing threshold (Hirschorn and Singer, 1973, Frasier, 1965). Hirschorn and Singer, (1973) and Frasier, (1965) further stated that the use of circumaural earphones only as a substitute for a true sound-treated enclosure is not recommended (Hirschorn and Singer, 1973, Frasier, 1965). The relatively poor attenuation prevents it from being an acceptable substitute for a true sound-treated enclosure where low-frequency noise is present (Lipscomb, 1988). In their studies circumaural earphones without a sound-treated enclosure was used.

The intensity level of the background noise in a audiometric test environment must be determined with certainty. The only way to quantify such noise levels is to conduct octave band measurements centred at the test frequencies. It requires the use of a sound level meter with an octave band filter in each location where hearing tests will be administered (Feldman and Grimes, 1985). An octave band analysis is necessary to determine the exact SPL at the different frequencies of the sound in the test environment (Porges, 1977).

It is important that the actual frequency of a sound or the frequencies of all the different sounds should always be taken into account. The most common series of mid-frequencies used is 63, 125, 250, 500, 1000, 2000, 4000, 8000 Hz (Porges, 1977). Frequencies however, can mask one another.

Masking is the effect of one noise on another (Smith, Peters and Owen, 1982). If sounds are similar in character or of nearly the same pitch, it will mask one another and the discrimination process will not function effectively. It is also possible to mask a pure tone by means of a band of random noise, as the pure tone's audibility decreases in the presence of the random noise.

In order to measure hearing loss accurately with audiometric tests, it is important that there is no masking of the test signal or of environmental noise. A criterion must be set at such a level that ensures that the threshold of hearing for people with normal hearing can be measured (i.e. zero hearing loss) (Smith, Peters and Owen, 1982).

The human hearing mechanism can discriminate between sounds of equal intensity and sometimes a sound that is of no interest may even be of a higher intensity than the sound to which reaction is required (Hirschorn and Singer, 1973, Frasier, 1965). This is true for sounds that are dissimilar in character, such as sounds of different frequency where the difference in frequency is large enough, or of sounds of different character such as noise signals against a pure tone sound (National Occupational Safety Association (NOSA), 1974).

Masking noise raises the threshold of audibility of the test signal and therefore will have an effect on the accurate determination of the hearing threshold. The amount of masking is the amount to which the threshold of audibility of the signal is raised in the presence of noise (Smith, Peters and Owen, 1982).

Audiograms that were obtained from people with normal hearing, showed a statistically significant hearing loss at 500 Hz when the tests were performed in an environment where the background noise level was too high (NOSA, 1974). The higher frequencies are normally of greater interest for industrial hearing tests, since NIHL is predominantly found at higher frequencies (NOSA, 1974).

When masking of the test signal occurs a hearing test programme faces serious validity problems from the outset. It is known that if the background noise cannot be maintained at sufficiently low levels, valid hearing tests cannot be performed. Many, but small significant hearing loss may therefore not be identified by the hearing test programme (Feldman and Grimes, 1985).

It may therefore be concluded that although it might be possible to perform audiometry in a locality where some background noise is present, the screening audiometry results may, however, be affected at frequencies where the background noise is predominant.

1.3 Factors influencing the hearing of an individual

If the human ear is subjected to a high level of noise for a prolonged period of time, some loss of hearing will occur (Plog, 1996). There are many factors that affect the degree and extent of hearing loss. These include the characteristics of the person self i.e. age, gender, genetics and health status, individual susceptibility, ear disease and genetic factors of the individual, as well as external factors such as the work environment. The degree of hearing loss that a person suffers thus also depends on the noise exposure in the work environment (specifically for employees) and other factors such as the intensity of the noise, the type of noise, the period of exposure each day, the total work duration, the character of the surroundings in which the noise is produced, the distance form the source and the position of the ear with respect to sound waves (Plog, 1996, AIHA, 1997).

All of the abovementioned factors should be taken into consideration when interpreting audiometric tests.

1.3.1 Personal characteristics

The case history of an individual is important for determining the general health status of the test subject when audiometric testing is conducted. Hearing impairment could be diagnosed by the case history. The age of the individual could also influence the results of the audiometric test. Hearing loss occurs with advanced age (presbycusis) and the range differ between male and females (Peterson, 1991). Even at a very advanced age there is usually little loss of hearing in the range below about 2000 Hz for men, whereas women's hearing may be more seriously affected at the same frequency (Peterson, 1991, Robinson and Stutton, 1979). It may be partially compensated for by the fact that women tend to lose less of their high-frequency hearing ability with increasing age than men do (Peterson, 1991). Presbycusis affects frequencies of 6 000 Hz and upward (Robinson and Sutton, 1979).

The health status of the tympanic membrane influences the accurate determination of the threshold of hearing (American Industrial Hygiene Association (AIHA), 1997). Otoscopic examination before commencing with audiometric testing provides useful information regarding the health status of the tympanic membrane (Carney and Birchall, 1995). Furthermore, any built up of wax (cerumen), dermatitis or any other condition that might be present in the outer ear canal (Schoeman and Schröder, 1994) may be diagnosed. The canal may be filled with wax, debris, blood or a foreign body or even be absent, stenotic or oedematous (Carney and Birchall, 1995).

Tinnitus (i.e. ringing sound in the ears), may have been caused by non-acoustic events such as a blow to the head or prolonged use of aspirin (AIHA, 1997) and can be identified with a thorough case history prior to the test. Tinnitus sufferers often report sleep disturbance. If insomnia and depression are associated with tinnitus there is a decreased tolerance and an increased discomfort with the tinnitus (Alster, Shemesh, Ornan and Attias, 1993). Some diseases (notably measles) and drugs can cause sensorineural hearing loss and thus an increase in the threshold of hearing (Peterson, 1991).

Thomas, Williams and Hoger (1981) and Carter (1980) found that blue-eyed workers are slightly more susceptible to NIHL than brown-eyed workers.

Other non-occupational factors that could possibly influence HTL's include exposure to loud noises of non-occupational origin, such as frequent exposure to firearm blasts (Thiery and Meyer-Bisch, 1988). Chung, Wilson and Gannon (1983) studied 29 953 workers who had been exposed both to industrial noise and gunfire and he concluded that exposure to noise produced by gunfire, as well as industrial noise, may cause a greater hearing loss than occupational noise exposure alone. He concluded however, that as long as compensatable frequencies remained below 3000 Hz and exposure was less than 10 years with some protection, gunfire was not likely to affect compensation (Chung, Wilson and Gannon, 1983). Recreational activities can be potentially damaging to hearing since the noise levels in activities such as hunting or listening to amplified music are often comparable to noise levels in factories (Robert, Bahadori and Bohne, 1993).

Supplementary data must be obtained on personal habits that could possibly influence HTL's. These factors include, for instance, smoking (Thiery and Meyer-Bisch, 1988).

Sieglaub, Friedman, Adour and Seltzer (1974), Barone, Peters, Garabrant, Bernstein and Krebsbach (1987) and Thomas, Williams and Hoger (1981) found that smokers are at a slightly higher risk for NIHL than non-smokers because of the cardiovascular changes resulting from smoking.

1.4 Problem Statement

Early research showed that audiometric tests should ideally be conducted in an environment where the background noise is kept within the specified limits (i.e. an approved acoustic environment) (Frasier, 1965). NOSA also stated that when audiometry is done it must be ensured that the test results would not be distorted by the background noise in the room (NOSA, 1974). An approved acoustic environment is thus used to prevent an increase in the hearing threshold due to masking from high levels of ambient noise (Frank, Greer and Magistro, 1997). In South Africa many industries use audiometry for screening purposes only and audiometric tests tend to be done in the absence of an acoustic enclosure (Ric-Hansen, 1998). In 1992 Robinson, however, stated that the acoustic environment influences accurate determination of the threshold of hearing only in the frequency range of below 1000 Hz. The influence on the lower frequencies affect the percentage binaural hearing loss and therefore the categorisation or referral of the individual. Even with the presence of higher ambient noise levels, the threshold of the higher frequencies will not be influenced and therefore could be determined accurately (Robinson, 1992). If the hearing threshold could be determined accurately in the absence of an acoustic environment, as stated by Robinson, the audiometrist could conduct the audiometric tests in, for example, a normal office. In South Africa especially, this is of importance, since it is highly expensive to create an approved acoustic environment, which in turn results in very costly audiometric tests.

The use of a non-approved environment could save audiometrists and industry the financial layout of sound booths if it could be proved that the results of audiometric test performed in a

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The use of a non-approved environment could save audiometrists and industry the financial layout of sound booths if it could be proved that the results of audiometric test performed in a non-approved acoustic environment do not differ from the results obtained in an approved acoustic environment.

A study was designed to evaluate the influence of both types of test environments (approved and non-approved) on the outcome of screening audiometric tests by performing audiometric tests at different frequencies in these two types of test environments. The aim of the study was thus to determine whether a statistically significant difference exists between the results for screening audiometry obtained in an approved- and a non-approved environment for the following frequencies: 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz for both males and females in different age groups. These frequencies are the frequencies that are used when screening audiometry tests are conducted in the establishment of a hearing conservation programme in industry.

Although screening audiometry is mainly used in industry as part of a hearing conservation programme and to identify possible referral threshold shifts, the setting of new standards could have an influence on the number of referrals (SABS, 1998). Such referrals will certainly have a financial impact on the industry as they are responsible for the costs of medical examinations.

The acoustic environment used for screening audiometry and its influence on the reliability and validity of the test results are of utmost importance to industries, insurance companies, the compensation commissioner, employers and employees.

1.5 Hypothesis

A null hypothesis regarding the influence of the test environment on screening audiometry results is formulated as follows:

H_0: The acoustic test environment has an influence on the accurate determination of the threshold of hearing when conducting screening audiometry.

The alternative hypothesis is:

H_a: The acoustic test environment does not have an influence on the accurate determination of the threshold of hearing when conducting screening audiometry.

2. MATERIALS AND METHODS

Results obtained from audiometric tests performed on test subjects in an approved and simulated non-approved acoustic environment were compared and statistically analysed. In order to do so, octave band analysis was performed in both acoustic environments to have known SPL's for the comparison. Test subjects (males and females) in the age groups 18-34 years were randomly selected from the Technikon Free State student population. Each test subject completed a health questionnaire prior to audiometric testing. Screening audiometry was done in both the approved and simulated non-approved acoustic environment for each test subject.

2.1 Testing procedures

2.1.1 Audiometers

On-site calibrated Tremetrics RA 400 (Tremetrics Inc., Austin, Texas) self-recording micro-processing audiometers were used to determine the threshold of hearing of the test subjects. The audiometers were calibrated by an approved inspection authority (AIA) (NS Clinical Technologies cc., Pretoria) in accordance with the SABS Code of Practice 0154: 1996 (SABS, 1996) (Annex C). The audiometers complied with IEC 645-1 for a type four screening audiometer. Calibration was done before commencement of the study to ensure that instruments would record valid test results. Calibration of the audiometers (sound pressure levels and frequencies) was verified throughout the study by means of the methods described in SABS 083: 1996 (SABS, 1996).

2.1.2 Acoustic test environments

The approved acoustic environment used in the study to conduct the screening audiometry on test subjects was approved by an approved inspection authority (AIA) (NS Clinical

Technologies cc., Pretoria) before commencement of the research. The acoustic environment complied with the specifications of the South African Bureau of Standards (SABS) Code of Practice 0182: 1998 (SABS, 1998) (Annex D).

The non-approved acoustic environment was simulated by operating one GilAir™ personal air-sampling pump (Gilian Instrument Corp., U.S.A.) in the approved acoustic environment. The air-sampling pump was calibrated at 2.0 l/min with a Gilibrator (Gilian Instrument Corp., West Caldwell, New Jersey). Calibration was done in triplicate before and after every day of testing to ensure a uniform flow rate throughout the study. The flow rate was kept constant and verified (weekly) to ensure that the noise emitted by the sampling pump would be of the same magnitude throughout the study.

The SPL's at the different frequencies were determined before audiometric tests were performed and hence were known (see 2.1.3).

2.1.3 Noise measurements in the acoustic test environments

An octave band analysis is necessary to determine the exact SPL at the different frequencies of the sound in the test localities (Porges, 1977). An octave band analysis was conducted to obtain an accurate measurement of the SPL's of each frequency for the test environment in both the approved and the simulated non-approved acoustic environment. Using this method, it was possible to compare the approved- and the simulated non-approved acoustic environments by means of the SPL's at the different frequencies.

To perform the octave band analysis a calibrated type 1 Quest 1800 sound level meter (Amtronix (Pty) Ltd., Bedfordview) was used. The sound level meter was fitted with an OB-300 third octave band filter, that complied with the specifications of IEC 651 (Annex E). The calibration of the sound level meter and the third octave band filter were verified before and after each measurement.

2.1.4 Screening audiometric tests

The audiometric screening tests were done in the approved acoustic and in the simulated non-approved acoustic environment according to the method of the United States OSHA 29CFR1910.95 (Regulation CFR1910.95, 1995, American National Safety Institute (ANSI) S3.1-1960, 1995) (Annex F). This method requires the collection of a case history, an otoscopic examination of the eardrum and then the testing of one ear (normally the best ear first) and then the other ear at the frequencies of 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz. The tests were conducted in the approved acoustic and in the simulated non-approved acoustic environment respectively.

2.1.5 Test subjects

Test subjects (students) were recruited and randomly selected, using advertisements on the Technikon Free State campus. The screening audiometry tests, their uses and advantages were explained and discussed with the students individually.

The test subjects were people that did not work in a noise zone (≥ 85 dB) and of whom the occurrence of work-related NIHL is not expected. Some of the test subjects had a history of intermittent exposure to nonwork-related noise from hobbies associated with exposure to noise. The occurrence of nonwork-related noise exposures were determined by the use of a personal health questionnaire.

Each test subject completed a personal health questionnaire (Annex G) prior to audiometric testing to establish a case history. The case history information included questions regarding tinnitus, deafness in the family (generic deafness), hobbies associated with exposure to noise, head injuries, ear infections, dizzy spells because of a hearing problem, ear surgery and children's diseases such as measles, mumps and scarlet fever. Deviations in the health of the test subjects were used to determine who would be included or excluded from the study population (AIHA, 1997). The study population initially consisted of 1096 Technikon Free State voluntary male and female students, aged between 18 and 34 years.

After completion of the health questionnaire, each test subject was otoscopically examined to determine if the ear canal and tympanic membrane were healthy. Otoscopy was performed to screen for conditions that would exclude a test subject from the study according to the method described by Carney (Carney and Birchall, 1995). Test subjects with only one light reflex or no light reflex were excluded from the study. The results of such subjects were not considered as reliable and valid for the purposes of the study (the actual hearing threshold could be distorted by for example wax in the ear canal or perforations of the tympanic membrane).

Subjects with a hearing threshold of more than 80 dB (i.e. 85 and 90 dB) (in the low frequencies (500 and 1000 Hz)) in the approved acoustic environment were excluded from the study because they did not hear the test signal when tested in the simulated non-approved acoustic environment. Ninety-six test subjects were excluded from the study because of a high threshold of hearing (>80 dB) or because a light reflex (i.e. a healthy eardrum) during the otoscopic examination could not be observed in both ears.

The final total study population consisted of 1000 people between the ages of 18 and 34 years. One thousand test subjects were used to ensure representivity and accuracy of test results. Table 1 shows the distribution in gender and age of the total study population.

TABLE 1: The compilation of the study population

	Age groups			
Gender	18-19	20-24	25-29	30-34
Male	97	314	81	0
Female	112	318	74	4
Total	209	632	155	4

2.1.6 Data analysis

The test results were analysed with a computer program, Everest Audio (Version 1.04), to determine the percentage binaural hearing impairment and the hearing status category of each test subject.

Data analyses were done by using a computer program, Jandel Scientific SigmaPlot (Version 3), for the determination of the mean and standard deviations of the frequencies and of each age group of the different genders. Figures are used to illustrate the differences between hearing thresholds in the approved and simulated non-approved acoustic environment. The figures also illustrate the differences in age and gender groups.

Student *t*-tests were conducted on all the data with the aid of Microsoft Excel (Windows version 4.0) to determine if there were statistically significant differences between the hearing thresholds in the two test localities ($P < 0.05$ indicated a statistically significant difference). The data was grouped according to age, gender and the different frequencies. The paired *t*-test was done for age group, gender and frequency. The same statistical analysis was done on the SPL's in the approved and simulated non-approved acoustic environments to establish whether statistically significant differences between each of the octave band frequencies existed.

3. RESULTS

The results are presented for the differences in SPL's at the different frequencies in the approved and the simulated non-approved acoustic environments. Comparisons between the hearing threshold of the test subjects in the approved and the non-approved acoustic environment are shown for the different age groups as well as for gender at the frequencies of 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz.

3.1 Acoustic test environments

Table 2 (p21) summarises the mean SPL's and the standard deviations in the approved and simulated non-approved acoustic environment. The non-approved acoustic environment showed an increase in the mean SPL at all frequencies. The largest increase recorded in the mean SPL were found at the frequencies of 500, 1000 and 2000 Hz.

In Figure 1 (p22), the differences in the mean SPL at the different frequencies in the approved and simulated non-approved acoustic environment are illustrated. The smallest difference in the mean SPL between the two test environments was observed at a frequency of 63 Hz where the mean SPL of the approved acoustic environment was 0.5 dB louder than that of the non-approved environment. The largest difference in the mean SPL of 33.3 dB between the approved and the simulated non-approved acoustic environment was recorded at a frequency of 500 Hz.

TABLE 2: The mean sound pressure levels (dB) in the approved and simulated non-approved acoustic environment at the different frequencies (Hz)

Frequency (Hz)	Approved acoustic environment (dB)	Non-approved acoustic environment (dB)
31.5	16.7 ± 1.1	18.3 ± 0.02
63	22.9 ± 1.5	23.4 ± 0.7
125	30.1 ± 1.3	32.4 ± 0.6
250	28.3 ± 0.03	44.2 ± 0.7
500	15.8 ± 0.4	49.1 ± 0.6
1000	12.6 ± 0.3	42.9 ± 0.1
2000	12.9 ± 0.1	42.9 ± 1.0
4000	14.0 ± 0.03	35.9 ± 0.2
8000	14.4 ± 0.1	27.4 ± 0.3
16000	6.0 ± 0.06	8.1 ± 0.1

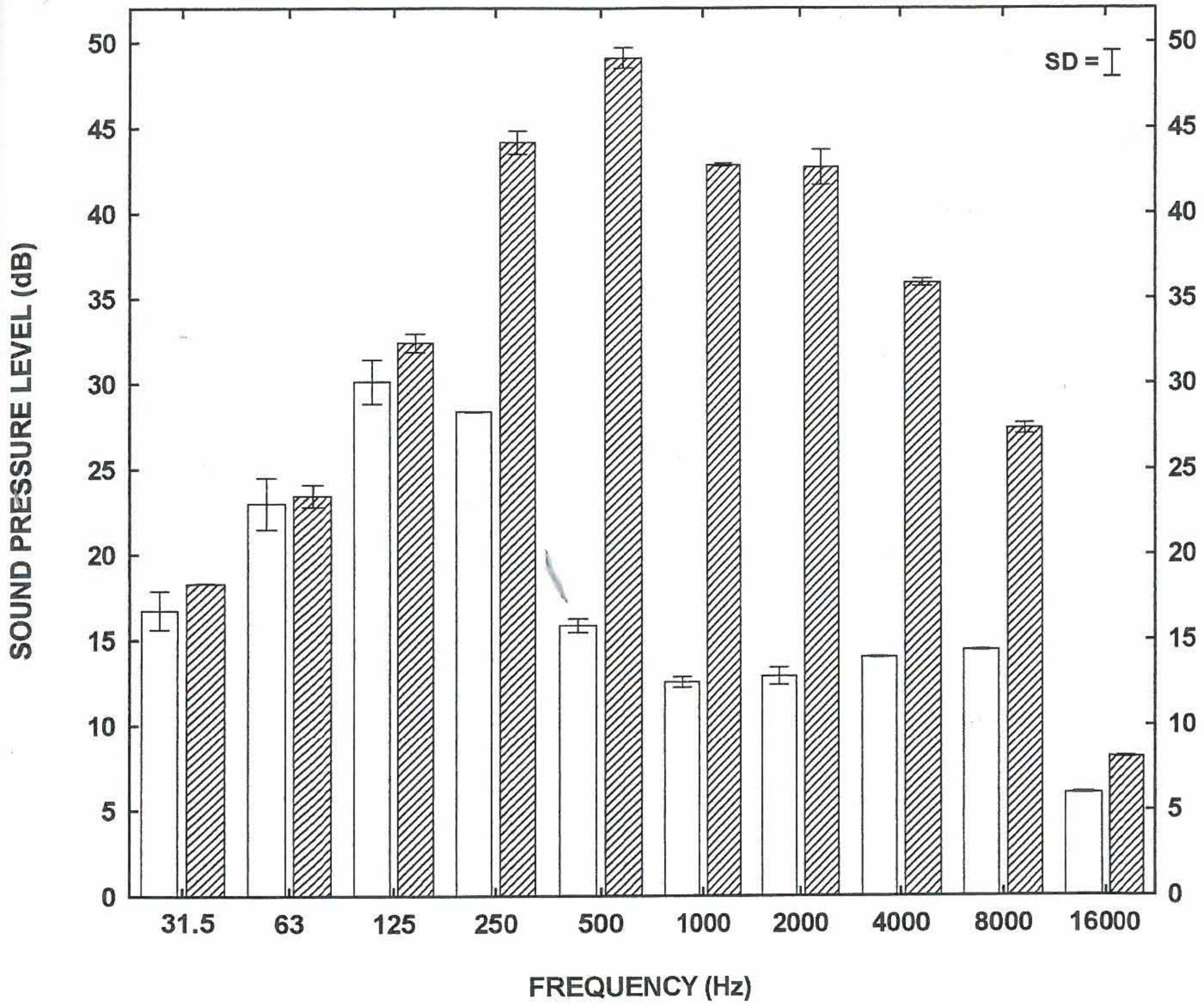

FIGURE 1: The mean sound pressure level (dB) in the approved and simulated non-approved acoustic environment

SD = Standard deviation

☐	Approved acoustic environment
▨	Simulated non-approved acoustic environment

3.2 Hearing threshold levels of men and women in different age groups at the different frequencies

The average HTL's in the approved and simulated non-approved acoustic environment for men and women for the different age groups at the frequencies of 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz are given in Tables 3 to 6.

Statistically significant differences ($P < 0.05$) were observed in the threshold of hearing between the approved and the simulated non-approved acoustic environment for all age groups, both genders and for the left and the right ear for the frequencies 500 and 1000 Hz. At all frequencies the hearing threshold were higher in the simulated non-approved acoustic environment than in the approved acoustic environment, although at the higher frequencies (2000, 3000, 4000, 6000 and 8000 Hz) the difference was not statistically significant.

Figures 2 to 8 illustrate the average HTL's for men and women at frequencies 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz (Figures A illustrate the left ear and Figures B the right ear). The hearing threshold for both men and women seemed to increased as the age increased for both the left and the right ear at all frequencies (ex. from 4.25 dB (18-19 years) to 13,66 dB (20-24years)) in both the environments. However, the raise in the HTL's (i.e. in dB) between the approved and the non-approved acoustic environment were not influenced by age, i.e. the hearing threshold did not seem to increase in the simulated non-approved acoustic environment with advanced age. At frequencies 500 (Figure 2A and 2B, p28), 1000 (Figure 3A and 3B, p29), 2000 (Figure 4A and 4B, p30), 3000 (Figure 5A and 5B, p31) and 4000 Hz (Figure 6A and 6B, 32) differences were observed in the HTL's between men and women of the same age group (18-19years). In the age group 25-29 years the hearing threshold differed between men and women at frequencies 6000 (Figure 7A and 7B, p33) and 8000 Hz (Figure 8A and 8B, p34). In a few instances the HTL of the two ears differed.

TABLE 3: Average left ear hearing threshold levels in the appr on-approved acoustic environment of men in different age groups at the frequencies of 500, 1000, 2000, 3000, 4

	Age group					
	18-19 (N = 97)		20-24 (N = 314)		25-29 (N = 81)	
Frequency	**Approved**	**Non-approved**	**Approved**	**Non-approved**	**Approved**	**Non-approved**
500 Hz						
Average HTL	4.25 ± 6.29	18.88 ± 10.51	13.66 ± 12.02	18.18 ± 12.53	10.96 ± 8.26	21.15 ± 11.70
Maximum	20	40	80	90	35	45
P	*0.0000		*0.0105		*0.0000	
1000 Hz						
Average HTL	2.71 ± 4.08	15.19 ± 6.51	9.35 ± 10.01	12.10 ± 9.87	9.81 ± 10.11	14.23 ± 9.12
Maximum	15	30	80	90	50	45
P	*0.0000		*0.0005		*0.0047	
2000 Hz						
Average HTL	7.24 ± 6.60	7.66 ± 6.27	7.26 ± 8.80	7.75 ± 9.06	8.65 ± 11.81	9.62 ± 11.07
Maximum	20	20	65	50	50	45
P	0.6311		0.4889		0.6006	
3000 Hz						
Average HTL	5.23 ± 6.60	5.79 ± 7.50	5.65 ± 7.51	5.88 ± 7.38	10.38 ± 11.11	11.15 ± 10.53
Maximum	20	20	80	80	40	40
P	0.5621		0.4966		0.6577	
4000 Hz						
Average HTL	3.13 ± 5.15	3.22 ± 4.63	6.80 ± 8.68	8.57 ± 9.82	10.77 ± 11.27	12.12 ± 9.64
Maximum	15	15	80	90	35	35
P	0.8892		0.0539		0.4239	
6000 Hz						
Average HTL	9.91 ± 7.98	10.42 ± 7.46	16.02 ± 14.07	17.36 ± 14.04	21.35 ± 15.51	23.65 ± 14.00
Maximum	20	20	85	90	65	60
P	0.6270		0.2336		0.3309	
8000 Hz						
Average HTL	7.24 ± 6.94	8.88 ± 6.42	11.51 ± 13.54	13.42 ± 12.96	15.58 ± 14.39	15.96 ± 14.77
Maximum	20	20	80	80	65	70
P	0.0750		0.0714		0.8694	

* = Statistically significant difference ($P < 0.05$)

TABLE 4: Average right ear hearing threshold levels in the ap[...] non-approved acoustic environment of men in different age groups at the frequencies of 500, 1000, 2000, 3000, 4[...]

Frequency	Age group: 18-19 (N = 97) Approved	18-19 (N = 97) Non-approved	20-24 (N = 314) Approved	20-24 (N = 314) Non-approved	25-29 (N = 81) Approved	25-29 (N = 81) Non-approved
500 Hz						
Average HTL	4.44 ± 6.34	16.31 ± 6.85	10.86 ± 10.63	14.57 ± 11.22	6.73 ± 5.21	16.15 ± 8.41
Maximum	20	25	60	90	20	30
P	*0.0000		*0.0105		*0.0000	
1000 Hz						
Average HTL	3.50 ± 5.50	14.21 ± 7.68	8.34 ± 9.25	11.83 ± 9.20	6.92 ± 6.70	13.85 ± 7.16
Maximum	10	25	55	65	20	25
P	*0.0000		*0.0000		*0.0000	
2000 Hz						
Average HTL	4.25 ± 6.32	4.67 ± 6.15	5.65 ± 7.51	5.88 ± 7.38	6.35 ± 6.17	6.73 ± 6.83
Maximum	20	20	40	45	20	25
P	0.6225		0.7076		0.7126	
3000 Hz						
Average HTL	3.54 ± 4.58	4.39 ± 4.89	9.19 ± 11.14	9.81 ± 11.73	7.12 ± 6.27	7.12 ± 6.42
Maximum	20	20	80	80	20	20
P	0.0569		0.5094		1.0000	
4000 Hz						
Average HTL	2.15 ± 3.44	2.20 ± 3.45	6.37 ± 8.37	6.82 ± 8.56	6.92 ± 7.53	7.69 ± 7.42
Maximum	10	10	60	90	25	25
P	0.9210		0.0571		0.5215	
6000 Hz						
Average HTL	2.15 ± 3.44	2.20 ± 3.45	6.37 ± 8.37	6.82 ± 8.56	6.92 ± 7.53	7.69 ± 7.42
Maximum	10	10	60	90	25	25
P	0.9210		0.0571		0.5215	
8000 Hz						
Average HTL	12.01 ± 10.68	12.57 ± 11.70	12.87 ± 11.69	14.00 ± 11.69	17.12 ± 11.09	18.27 ± 11.42
Maximum	30	35	75	85	30	55
P	0.7147		0.2385		0.5231	

* = Statistically significant difference ($P < 0.05$)

TABLE 5: Average left ear hearing threshold levels in the appr[...]on-approved acoustic environment of women in different age groups at the frequencies of 500, 1000, 2000, 3000, [...]lz

	Age group							
	18-19 (N = 112)		20-24 (N = 318)		25-29 (N = 74)		30-34 (N = 4)	
Frequency	Approved	Non-approved	Approved	Non-approved	Approved	Non-approved	Approved	Non-approved
500 Hz								
Average HTL	15.18 ± 13.52	22.86 ± 11.58	10.4 ± 10.8	20.8 ± 10.6	9.6 ± 8.0	17.8 ± 9.7	12.5 ± 6.5	27.5 ± 5.0
Maximum	45	50	40	60	25	45	20	35
P	*0.000008		*0.0000		*0.0000		*0.0104	
1000 Hz								
Average HTL	8.6 ± 14.8	21.4 ± 12.6	6.6 ± 7.6	17.2 ± 9.6	9.1 ± 5.6	17.3 ± 8.1	8.8 ± 4.8	17.5 ± 6.5
Maximum	50	50	25	50	20	35	15	25
P	*0.0000		*0.0000		*0.0000		*0.0323	
2000 Hz								
Average HTL	8.2 ± 9.2	10.5 ± 8.7	6.4 ± 6.5	7.7 ± 7.7	7.6 ± 5.3	7.7 ± 6.5	5.0 ± 4.1	7.5 ± 5.0
Maximum	25	25	25	35	20	15	10	10
P	0.0544		0.1970		1.0000		0.4679	
3000 Hz								
Average HTL	6.8 ± 8.3	7.3 ± 8.0	8.4 ± 9.5	7.3 ± 9.6	6.2 ± 5.9	7.6 ± 6.6	7.5 ± 8.7	11.3 ± 10.3
Maximum	20	20	40	45	20	20	15	20
P	0.6232		0.1242		0.2133		0.5976	
4000 Hz								
Average HTL	8.4 ± 7.6	8.4 ± 8.3	7.7 ± 9.2	9.1 ± 10.2	5.1 ± 7.9	5.4 ± 6.5	7.5 ± 6.5	8.8 ± 4.8
Maximum	20	20	40	60	20	25	15	15
P	1.0000		0.0855		0.7990		0.7663	
6000 Hz								
Average HTL	18.4 ± 11.8	20.0 ± 11.8	15.8 ± 11.5	16.8 ± 11.7	14.4 ± 8.2	16.4 ± 7.5	20.0 ± 9.1	21.3 ± 8.5
Maximum	35	40	40	50	30	30	30	30
P	0.3084		0.2752		0.1785		0.8481	
8000 Hz								
Average HTL	19.1 ± 12.2	19.6 ± 11.9	13.2 ± 11.4	14.8 ± 13.4	11.7 ± 9.7	12.0 ± 7.8	15.0 ± 7.1	22.5 ± 15.0
Maximum	50	50	50	50	25	30	35	40
P	0.7403		0.0973		0.8756		0.4006	

* = Statistically significant difference ($P < 0.05$)

TABLE 6: Average right ear hearing threshold levels in the app[illegible] non-approved acoustic environment of women in different age groups at the frequencies of 500, 1000, 2000, 3[illegible] 00 Hz

	Age group							
	18-19 (N = 112)		20-24 (N = 318)		25-29 (N = 74)		30-34 (N = 4)	
Frequency	**Approved**	**Non-approved**	**Approved**	**Non-approved**	**Approved**	**Non-approved**	**Approved**	**Non-approved**
500 Hz								
Average HTL	6.79 ± 6.47	18.93 ± 10.25	7.64 ± 8.44	20.25 ± 11.60	10.17 ± 6.63	18.98 ± 10.82	16.25 ± 7.50	28.75 ± 7.50
Maximum	20	25	35	50	20	40	20	35
P	*0.0000		*0.0000		*0.0000		*0.0365	
1000 Hz								
Average HTL	8.57 ± 14.76	21.43 ± 12.58	5.09 ± 6.96	16.01 ± 8.86	7.46 ± 5.28	17.71 ± 8.11	11.25 ± 2.50	23.75 ± 4.79
Maximum	20	40	35	35	20	35	10	20
P	*0.0000		*0.0000		*0.0000		*0.0036	
2000 Hz								
Average HTL	7.32 ± 8.00	9.64 ± 9.67	5.35 ± 7.87	6.60 ± 7.79	6.10 ± 4.83	8.05 ± 6.50	10.00 ± 0.00	11.25 ± 6.29
Maximum	20	30	40	45	15	20	10	20
P	0.0515		0.0531		0.0671		0.7049	
3000 Hz								
Average HTL	6.61 ± 6.85	8.39 ± 6.98	7.26 ± 9.45	8.45 ± 9.61	7.03 ± 6.70	7.54 ± 7.45	7.50 ± 6.46	8.75 ± 4.79
Maximum	20	20	40	40	20	20	15	15
P	0.0546		0.1774		0.6974		1.0000	
4000 Hz								
Average HTL	5.18 ± 7.29	6.79 ± 8.30	6.70 ± 8.31	7.58 ± 8.14	5.76 ± 6.68	6.69 ± 8.28	20.00 ± 9.13	21.25 ± 8.54
Maximum	20	20	35	50	20	20	15	20
P			0.8576		0.5025		0.5945	
6000 Hz								
Average HTL	12.01 ± 10.68	12.57 ± 11.70	12.87 ± 11.69	14.00 ± 11.69	12.97 ± 10.26	14.92 ± 9.98	15.00 ± 7.07	17.50 ± 15.00
Maximum	30	35	60	60	30	50	30	30
P	0.0521		0.0813		0.2977		0.8394	
8000 Hz								
Average HTL	9.29 ± 7.95	10.89 ± 6.67	13.14 ± 11.27	13.24 ± 11.35	8.76 ± 9.46	12.20 ± 10.39	10.00 ± 5.77	10.00 ± 5.77
Maximum	20	25	20	25	30	35	25	25
P	0.1026				0.4326		0.5891	

* = Statistically significant difference ($P < 0.05$)

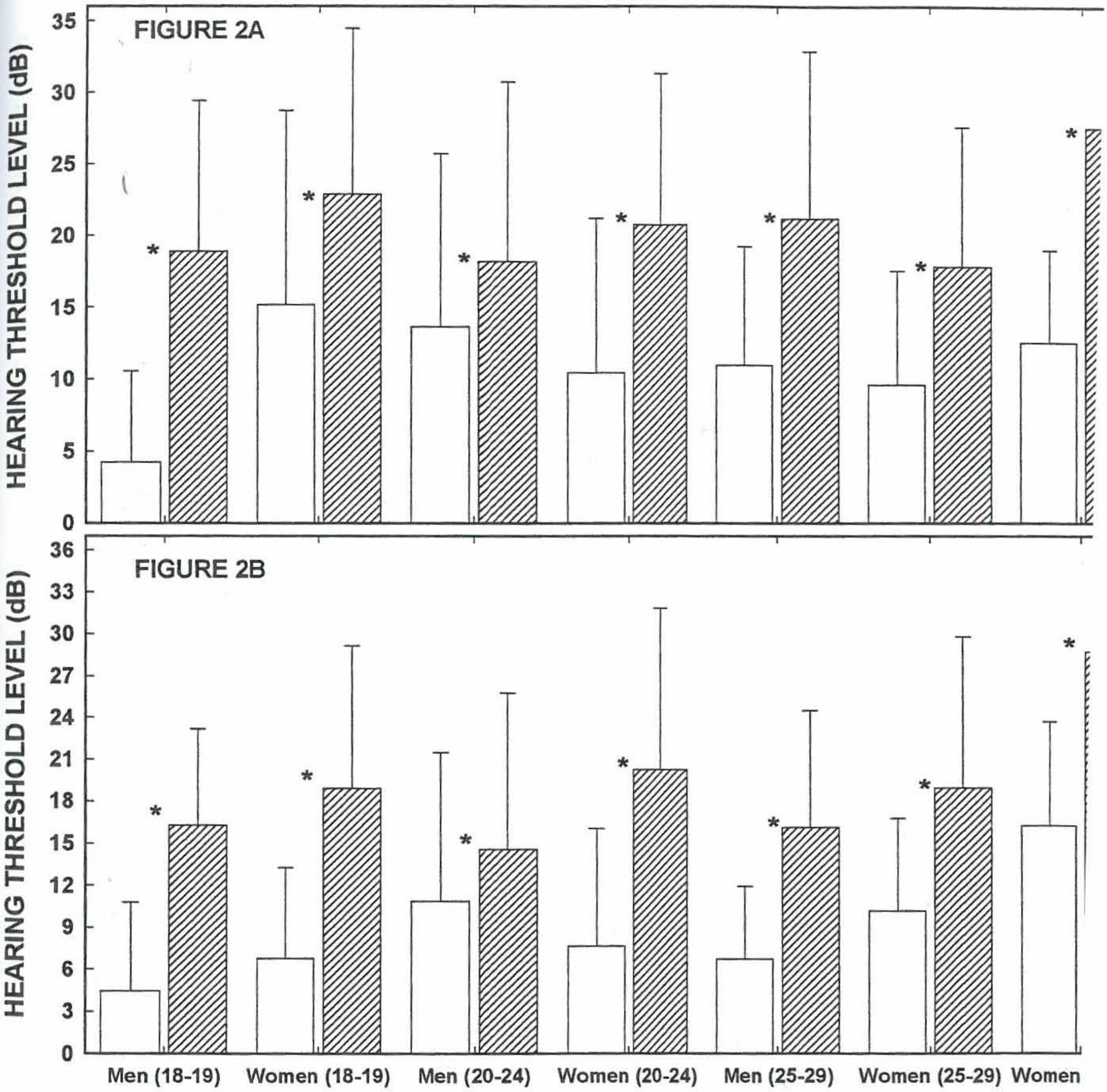

FIGURE 2A: Average left ear hearing threshold level (dB) of men and women in the ap| and simulated non-approved acoustic environment at the frequency of 50

* Statistically significant different

FIGURE 2B: Average right ear hearing threshold level (dB) of men and women in the a and simulated non-approved acoustic environment at the frequency of 50

* Statistically significantly different

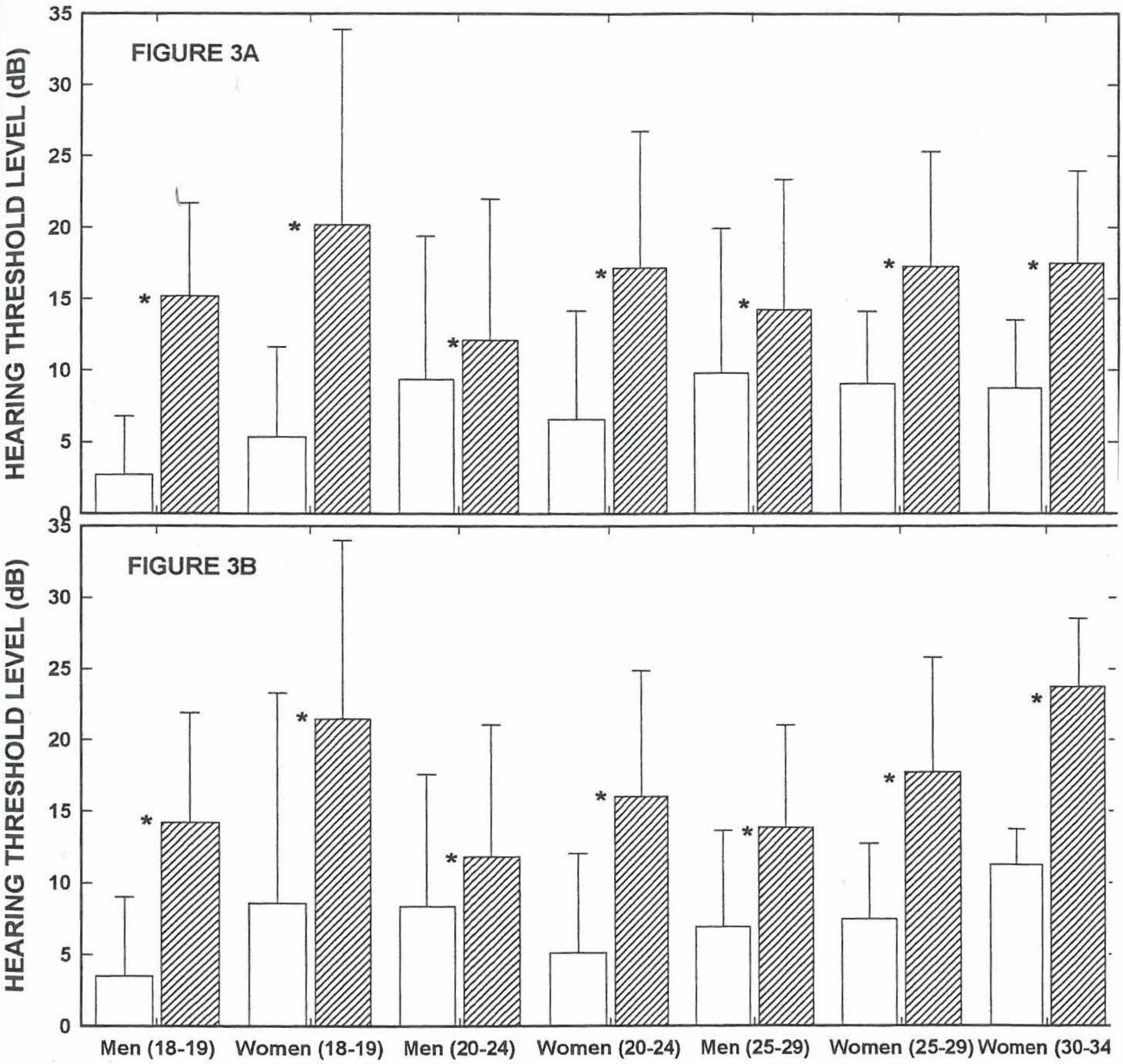

FIGURE 3A: Average left ear hearing threshold level (dB) of men and women in the approve and simulated non-approved acoustic environment at the frequency of 1000 Hz

* Statistically significantly different

FIGURE 3B: Average right ear hearing threshol level (dB) of men and women in the approve and simulated non-approved acoustic environment at the frequency of 1000 Hz

* Statistically significantly different

☐	Approved acoustic environment
▨	Simulated non-approved acoustic environment

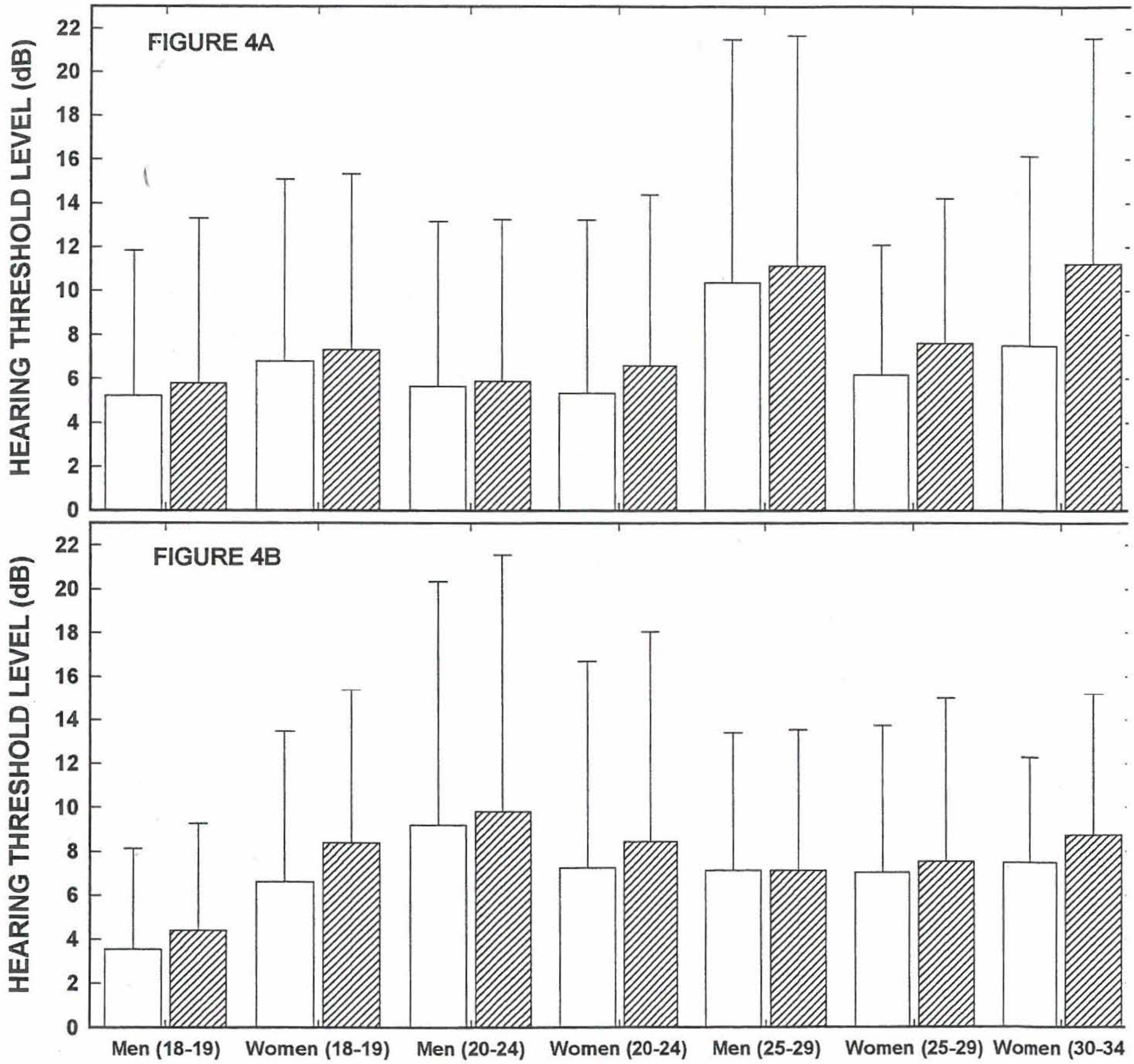

FIGURE 4A: Average left ear hearing threshold level (dB) of men and women in the approvec and simulated non-approved acoustic environment at the frequency of 2000 Hz

FIGURE 4B: Average right ear hearing threshold level (dB) of men and women in the approve and simulated non-approved acoustic environment at the frequency of 2000 Hz

Approved acoustic environment
Simulated non-approved acoustic environment

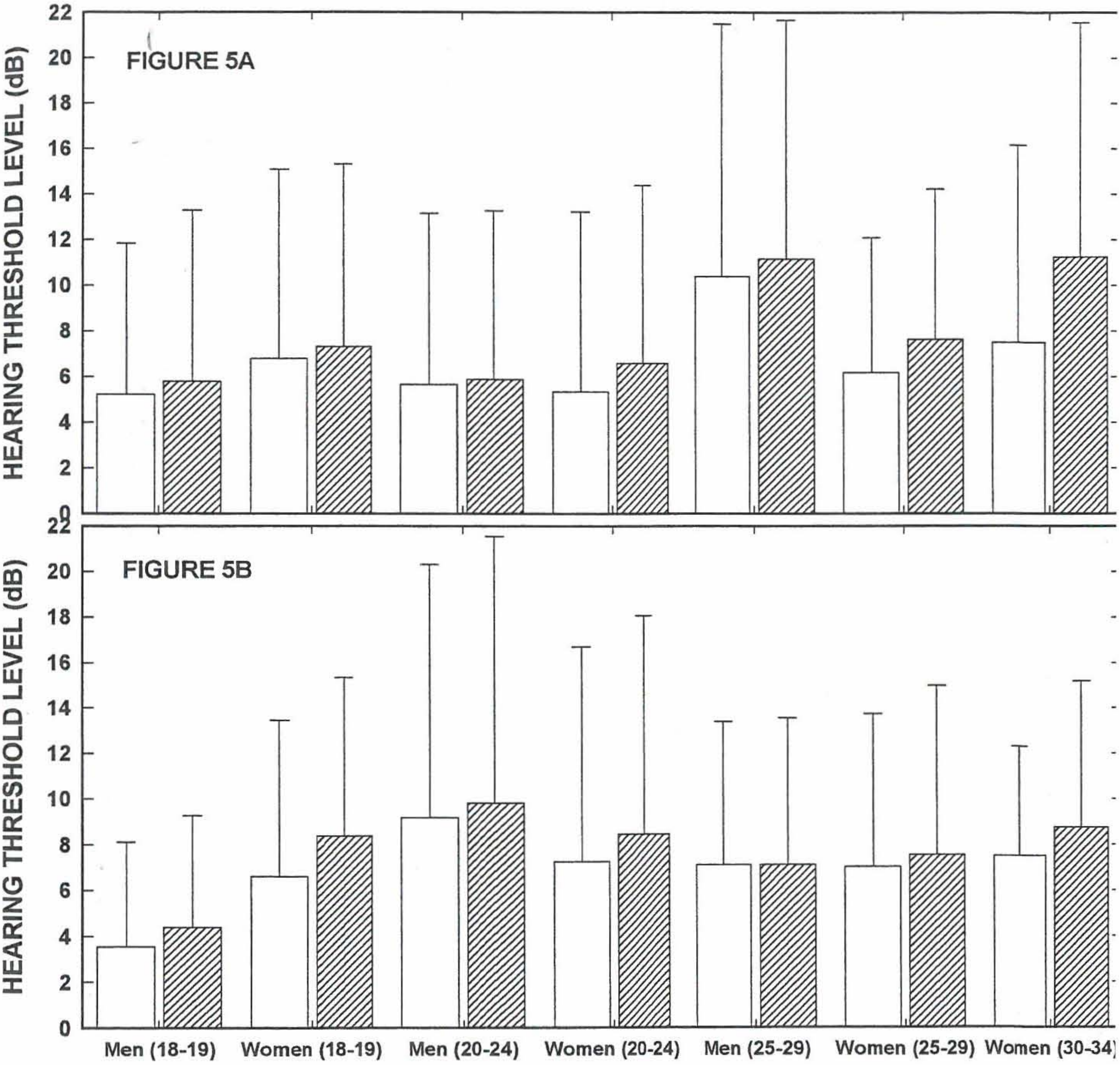

FIGURE 5A: Average left ear hearing threshold level (dB) of men and women in the approved and simulated non-approved acoustic environment at the frequency of 3000 Hz

FIGURE 5B: Aveage right ear hearing threshold level (dB) of men and women in the approve and simulated non-approved acoustic environment at the frequency of 3000 Hz

Approved acoustic environment
Simulated non-approved acoustic environment

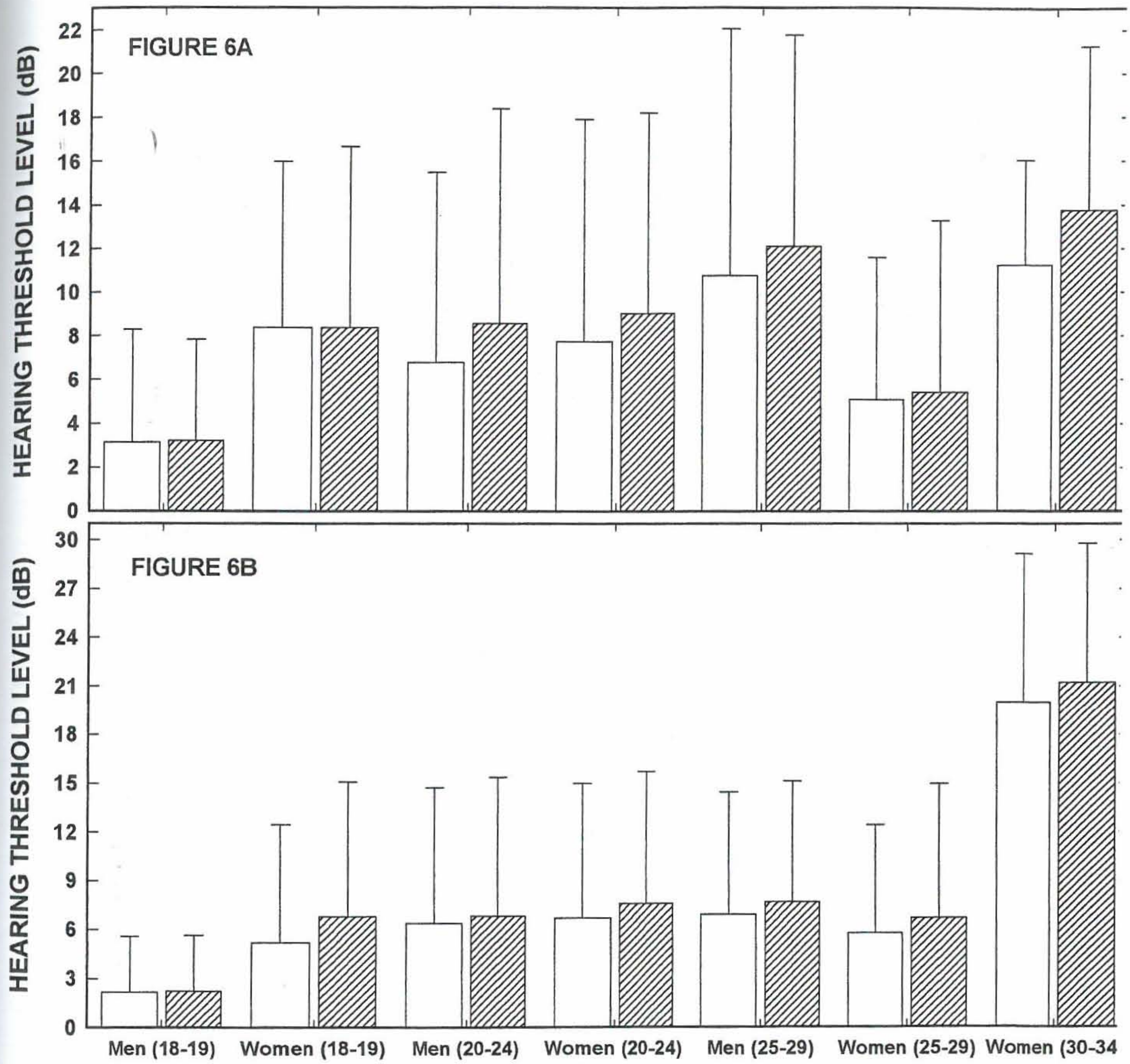

FIGURE 6A: Average left ear hearing threshold level (dB) of men and women in the approve and simulated non-approved acoustic environment at the frequency of 4000 Hz

FIGURE 6B: Average right ear hearing threshold level (dB) of men and women in the approv and simulated non-approved acoustic environment at the frequency of 4000 Hz

☐	Approved acoustic environment
▨	Simulated non-approved acoustic environment

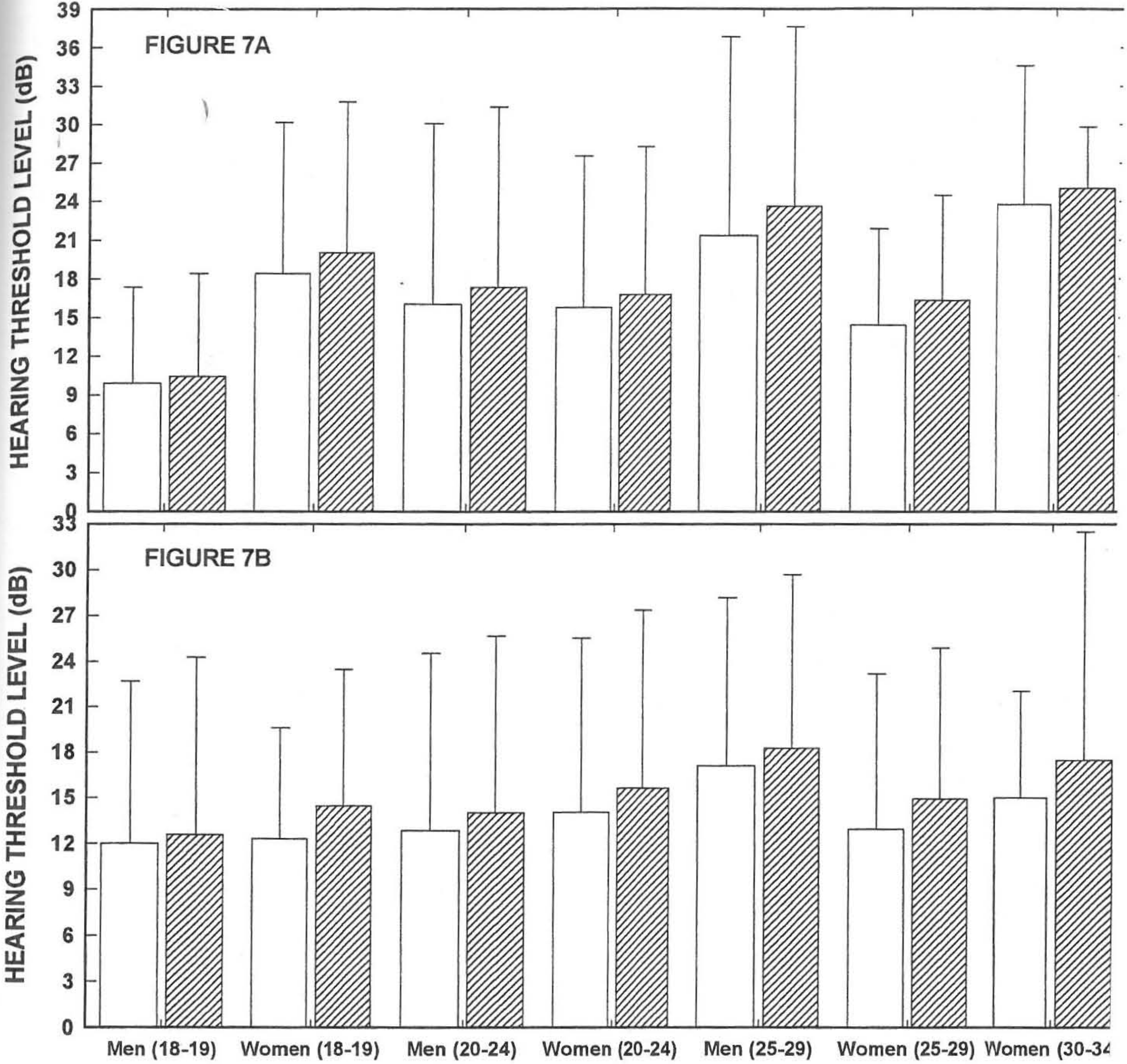

FIGURE 7A: Average left ear hearing threshold level (dB) of men and women in the approve and simulated non-approved acoustic environment at the frequency of 6000 Hz

FIGURE 7B: Average right ear hearing threshold level (dB) of men and women in the appro and simulated non-approved acoustic environment at the frequency of 6000 Hz

Approved acoustic environment
Simulated non-approved acoustic environment

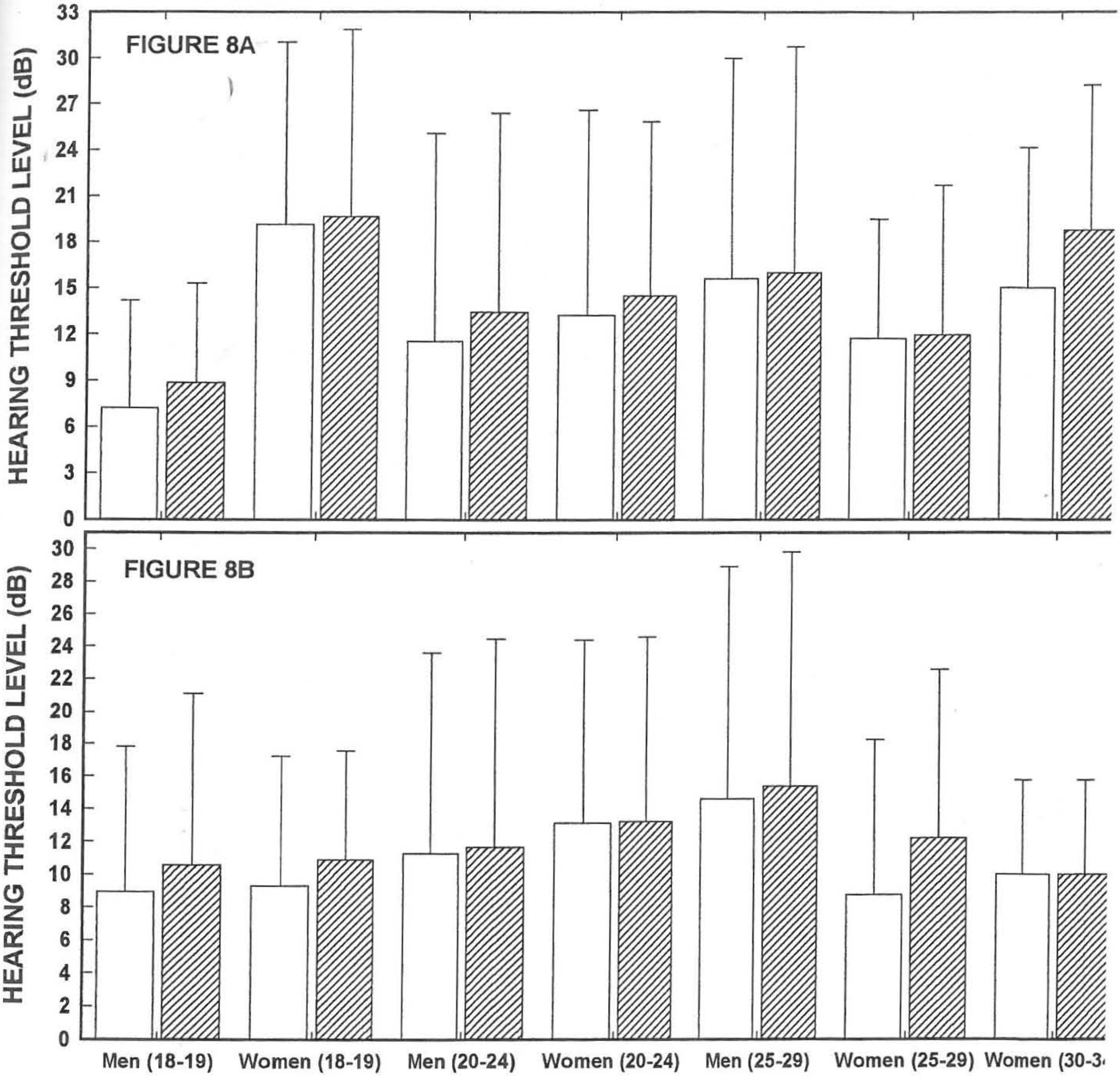

FIGURE 8A: Average left ear hearing threshold level (dB) of men and women in the approv and simulated non-approved acoustic environment at the frequency of 8000 H

FIGURE 8B: Average right ear hearing threshold level (dB) of men and women in the appro and simulated non-approved acoustic environment at the frequency of 8000 Hz

☐	Approved acoustic environment
▨	Simulated non-approved acoustic environment

3.3 Hearing threshold levels of men and women at the different frequencies

The average left ear HTL of men in the approved and non-approved acoustic environment at the different frequencies is represented in Table 7 (p36) and in Figure 9 (p37). The average left ear HTL at a frequency of 500 Hz in the approved acoustic environment was 11.2 ± 11.1 dB and in the non-approved acoustic environment 17.5 ± 12.1 dB which proved to be a statistically significant difference. At a frequency of 1000 Hz, the average left ear HTL changed statistically significantly ($P < 0.05$) from 8.2 ± 9.5 dB in the approved acoustic environment to 12.9 ± 9.4 dB in the non-approved acoustic environment. The average left ear HTL at a frequency of 2000 Hz changed from 7.5 ± 8.9 dB in the approved to 8.0 ± 8.9 dB in the non-approved acoustic environment and it proved to be not statistically significant. The approved acoustic environment showed an average left ear HTL of 8.7 ± 10.5 dB as opposed to an average of 9.0 ± 10.9 dB in the non-approved acoustic environment at a frequency of 3000 Hz. The calculated average left ear HTL at a frequency of 4000 Hz was 8.1 ± 10.2 dB in the approved acoustic environment and 8.9 ± 10.2 dB in the non-approved acoustic environment. The average left ear HTL in the approved acoustic environment was 15.5 ± 13.8 dB and in the non-approved acoustic environment was 16.9 ± 13.4 dB at a frequency of 6000 Hz. At a frequency of 8000 Hz the approved acoustic environment showed an average left ear HTL of 11.6 ± 12.9 dB compared to the 12.4 ± 12.4 dB in the non-approved acoustic environment. No statistically significant differences ($P < 0.05$) were observed in HTL at frequencies 2000 to 8000 Hz between the approved and the simulated non-approved acoustic environment.

TABLE 7: Average left ear hearing threshold levels in the approved and simulated non-approved acoustic environment of men at the frequencies of 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz

	Left ear	
Frequency	Approved	Non-approved
500 Hz Average HTL Maximum	 11.22 ± 11.14 80	 17.54 ± 12.12 90
P	*0.0000	
1000 Hz Average HTL Maximum	 8.17 ± 9.55 80	 12.89 ± 9.36 90
P	*0.0000	
2000 Hz Average HTL Maximum	 7.47 ± 8.93 50	 8.03 ± 8.91 65
P	0.3294	
3000 Hz Average HTL Maximum	 8.65 ± 10.51 90	 9.04 ± 10.86 90
P	0.5638	
4000 Hz Average HTL Maximum	 8.12 ± 10.17 65	 8.93 ± 10.15 65
P	0.2074	
6000 Hz Average HTL Maximum	 15.54 ± 13.78 85	 16.85 ± 13.42 90
P	0.1276	
8000 Hz Average HTL Maximum	 11.64 ± 12.86 80	 12.43 ± 12.36 80
P	0.3218	

* = Statistically significant difference ($P < 0.05$)

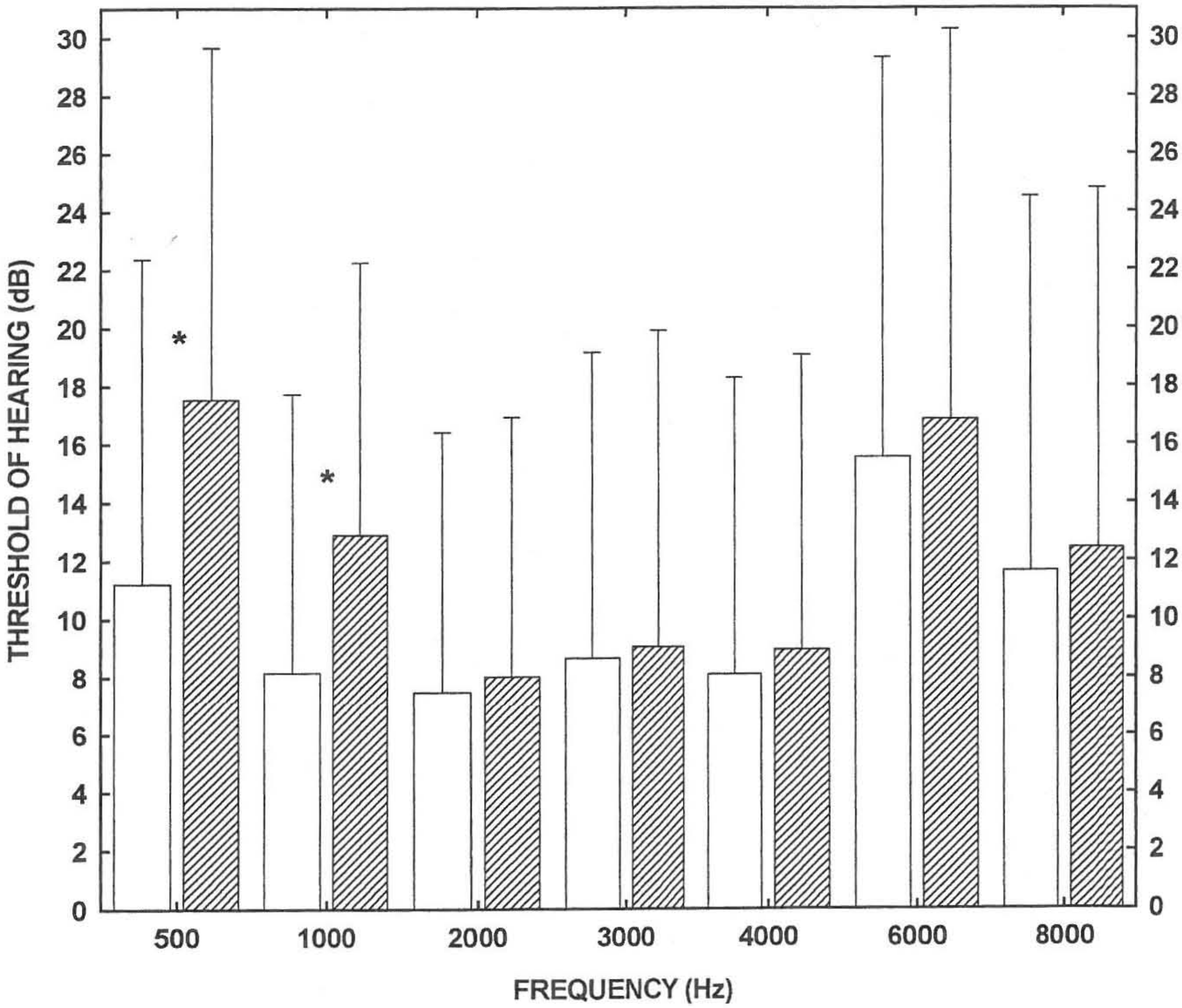

FIGURE 9: Average left ear hearing threshold levels (dB) of men in the approved and simulated non-approved acoustic environment

* Statistically significantly different

Approved acoustic enivironment
Simulated non-approved acoustic environment

The average right ear HTL of men in the approved and in the non-approved acoustic environment at the different frequencies is shown in Table 8 (p39) and Figure 10 (p40); the difference proved to be statistically significant at frequencies of 500 and 1000 Hz. The average right ear HTL of 8.8 ± 9.6 dB at a frequency of 500 Hz in the approved acoustic environment was lower than the 15.2 ± 10.0 dB measured in the non-approved acoustic environment. At a frequency of 1000 Hz, the average right ear HTL changed significantly ($P < 0.05$) from 6.2 ± 8.3 dB in the approved acoustic environment to 12.9 ± 8.5 dB in the non-approved acoustic environment. The average HTL at a frequency of 2000 Hz was 5.5 ± 7.0 dB in the approved and 5.7 ± 7.1 dB in the non-approved acoustic environment. In the approved acoustic environment the average right ear HTL was 5.7 ± 7.7 dB and 6.1 ± 7.6 dB in the non-approved acoustic environment at a frequency of 3000 Hz. At a frequency of 4000 Hz, the average right ear HTL was 5.8 ± 7.9 dB in the approved acoustic environment and 7.1 ± 8.8 dB in the non-approved acoustic environment. The average right ear HTL at a frequency of 6000 Hz did not change significantly between the two test localities. It changed from 13.6 ± 11.5 dB in the approved acoustic environment to 14.1 ± 12.2 dB in the non-approved acoustic environment. In the approved acoustic environment the average right ear HTL was 11.3 ± 12.1 dB and 12.0 ± 12.7 dB in the non-approved acoustic environment at a frequency of 8000 Hz.

TABLE 8: Average right ear hearing threshold levels in the approved and simulated non-approved acoustic environment of men at the frequencies of 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz

	Right ear	
Frequency	**Approved**	**Non-approved**
500 Hz		
Average HTL	8.84 ± 9.55	15.19 ± 10.04
Maximum	60	90
P	*0.0000	
1000 Hz		
Average HTL	6.19 ± 8.33	12.87 ± 8.49
Maximum	55	65
P	*0.0000	
2000 Hz		
Average HTL	5.52 ± 7.05	5.69 ± 8.49
Maximum	45	50
P	0.7039	
3000 Hz		
Average HTL	5.73 ± 7.70	6.06 ± 7.64
Maximum	60	60
P	0.4961	
4000 Hz		
Average HTL	5.82 ± 7.89	7.06 ± 8.84
Maximum	50	50
P	0.1094	
6000 Hz		
Average HTL	13.65 ± 11.47	14.06 ± 12.19
Maximum	75	85
P	0.5836	
8000 Hz		
Average HTL	11.29 ± 12.12	12.01 ± 12.69
Maximum	80	85
P	0.3586	

* = Statistically significant difference ($P < 0.05$)

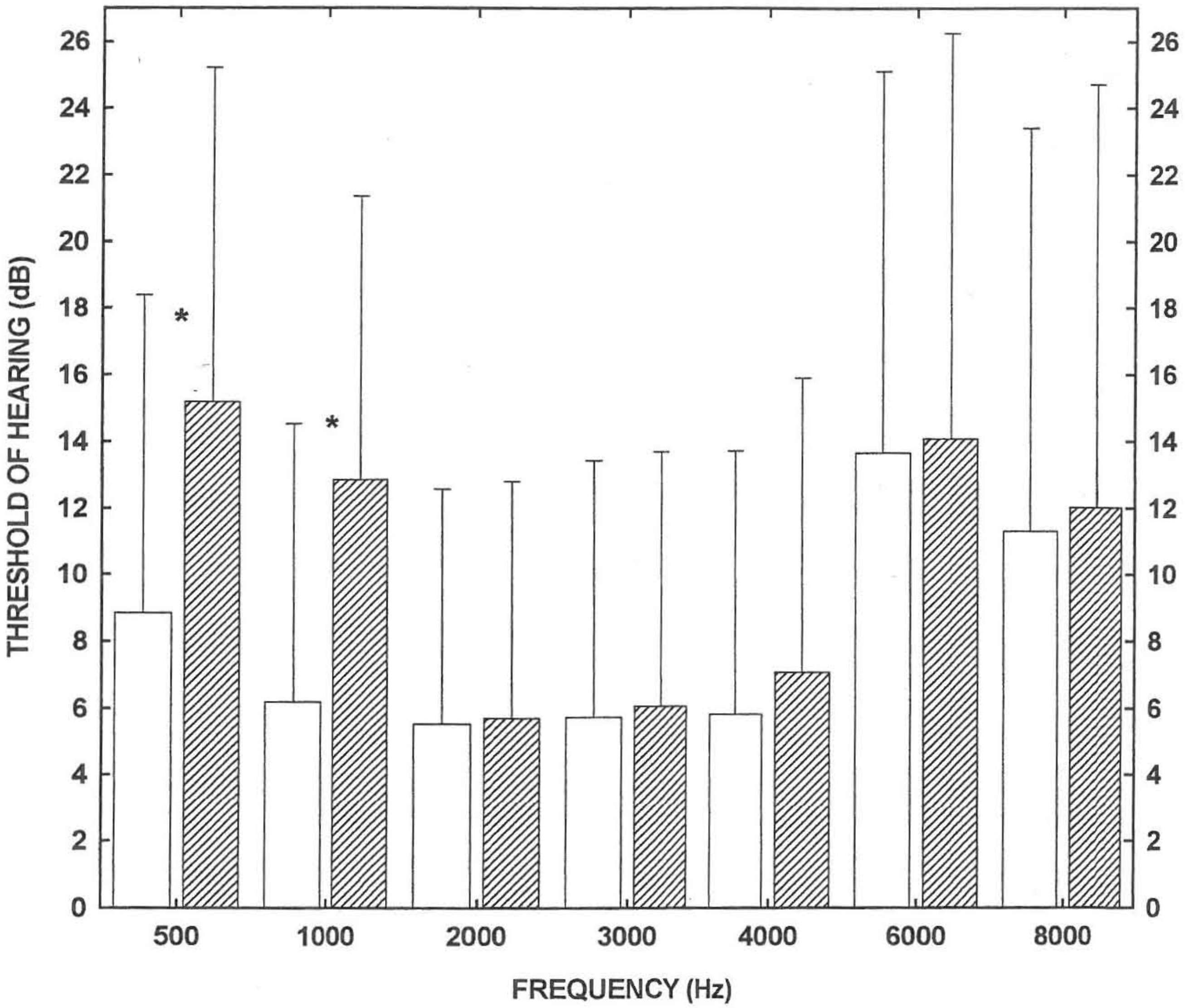

FIGURE 10: Average right ear hearing threshold levels (dB) of men in the approved and simulated non-approved acoustic environment

* Statistically significantly different

Approved acoustic environment
Simulated non-approved acoustic environment

Left ear HTL's of women in the approved and in the simulated non-approved acoustic environment at different frequencies are illustrated in Table 9 (p42) and in Figure 11 (p43). The average left ear HTL at a frequency of 500 Hz was 11.3 ± 11.3 dB in the approved acoustic environment and the average HTL increased to 20.8 ± 10.8 dB in the non-approved acoustic environment (i.e. statistically significantly different). At a frequency of 1000 Hz, the average left ear HTL was 7.3 ± 9.5 dB in the approved acoustic environment and 18.0 ± 10.3 dB in the non-approved acoustic environment ($P < 0.05$). The average left ear HTL at a frequency of 2000 Hz was 7.0 ± 7.2 dB in the approved acoustic environment and 8.4 ± 7.8 dB in the non-approved acoustic environment. The average left ear HTL was measured as 7.1 ± 8.9 dB measured in the approved acoustic environment and 7.9 ± 8.8 dB in the non-approved acoustic environment, at a frequency of 3000 Hz. At a frequency of 4000 Hz, the average left ear HTL was 7.5 ± 9.3 dB in the approved acoustic environment and 8.4 ± 8.8 dB in the non-approved acoustic environment. The average left ear HTL at the frequency of 6000 Hz in the approved acoustic environment was measured as 16.3 ± 11.4 dB. The average left ear HTL in the non-approved acoustic environment on the other hand was 17.5 ± 11.3 dB at the same frequency. The average left ear HTL in the approved acoustic environment was 14.4 ± 12.6 dB and in the non-approved acoustic environment 15.6 ± 16.7 dB at a frequency of 8000 Hz.

TABLE 9: Average left ear hearing threshold levels in the approved and simulated non-approved acoustic environment of women at the frequencies of 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz

	Left ear	
Frequency	**Approved**	**Non-approved**
500 Hz Average HTL Maximum	11.33 ± 11.26 50	20.80 ± 10.76 60
P	*0.0000	
1000 Hz Average HTL Maximum	7.27 ± 9.50 50	18.04 ± 10.26 50
P	*0.0000	
2000 Hz Average HTL Maximum	6.97 ± 7.21 25	8.38 ± 7.79 35
P	0.1029	
3000 Hz Average HTL Maximum	7.11 ± 8.86 40	7.86 ± 8.84 45
P	0.1751	
4000 Hz Average HTL Maximum	7.54 ± 9.26 40	8.43 ± 8.82 45
P	0.1204	
6000 Hz Average HTL Maximum	16.30 ± 11.40 40	17.53 ± 11.25 50
P	0.0840	
8000 Hz Average HTL Maximum	14.41 ± 12.62 50	15.56 ± 16.65 60
P	0.1351	

* = Statistically significant difference (P < 0.05)

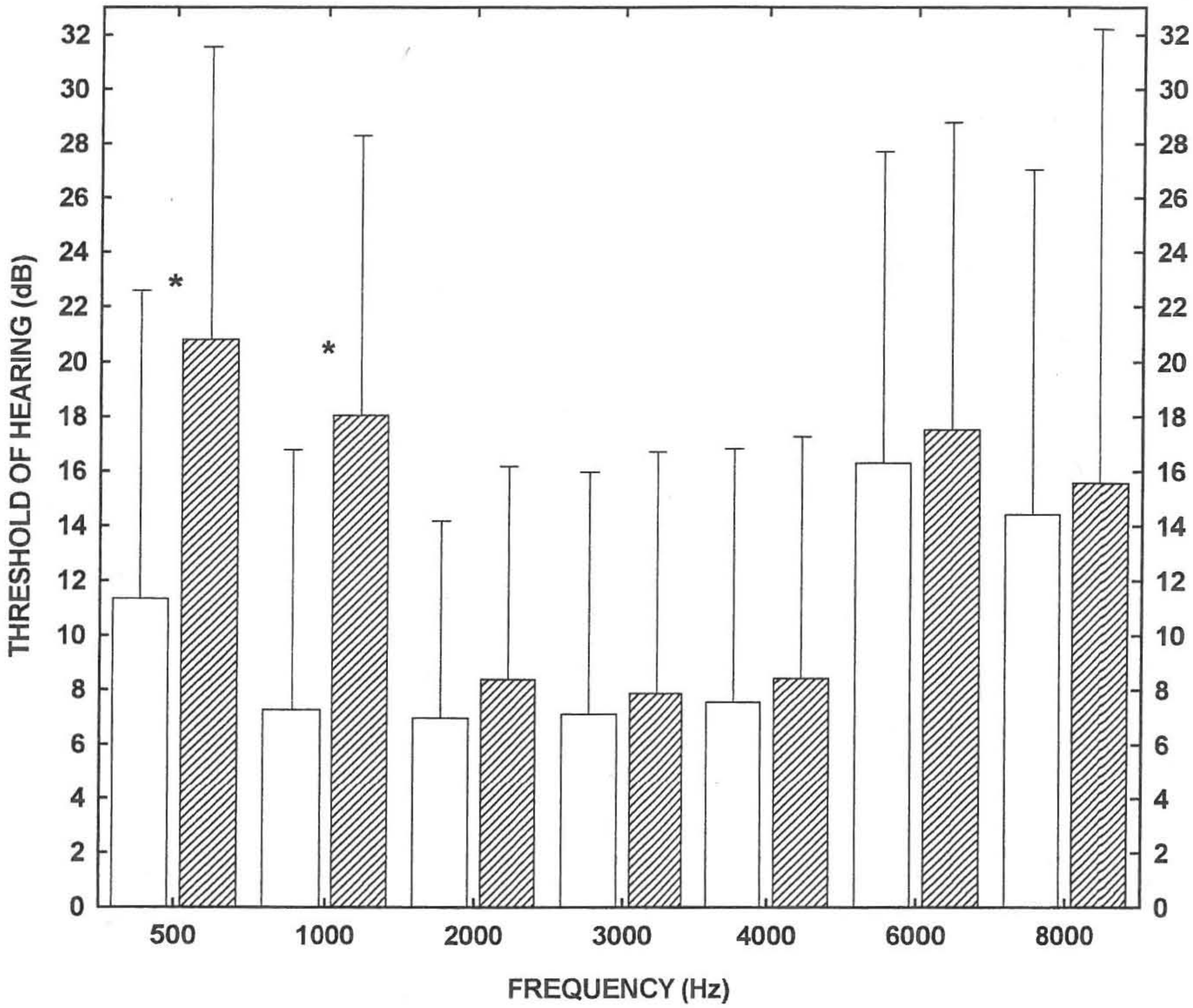

FIGURE 11: Average left ear hearing threshold levels (dB) of women in the approved and simulated non-approved acoustic environment

* Statistically significantly different

Approved acoustic environment
Simulated non-approved acoustic environment

Table 10 (p45) and Figure 12 (p46) show the average right ear HTL of women in the approved and non-approved acoustic environment at different frequencies. The average HTL at a frequency of 500 Hz in the approved acoustic environment was 7.8 ± 7.9 dB and in the non-approved acoustic environment 19.8 ± 11.2 dB, when tested this difference proved to be statistically significant. At a frequency of 1000 Hz, the average HTL was 5.5 ± 6.6 dB in the approved acoustic environment and 17.2 ± 10.3 dB in the non-approved acoustic environment ($P < 0.05$). The average right ear HTL at a frequency of 2000 Hz was 5.9 ± 7.6 dB in the approved and 7.5 ± 8.1 dB in the non-approved acoustic environment. The average HTL in the approved acoustic environment was 6.7 ± 7.8 dB and in the non-approved acoustic environment 7.8 ± 7.8 dB at a frequency of 3000 Hz. At a frequency of 4000 Hz, the average HTL was 6.3 ± 8.4 dB in the approved and 6.9 ± 8.5 dB in the non-approved acoustic environment. The average HTL at a frequency of 6000 Hz in the approved acoustic environment was 14.4 ± 10.6 dB and in the non-approved acoustic environment was 14.7 ± 10.9 dB. The average right ear HTL in the approved acoustic environment was 12.2 ± 10.4 dB and in the non-approved acoustic environment was 12.2 ± 10.4 dB at a frequency of 8000 Hz.

TABLE 10: Average right ear hearing threshold levels in the approved and simulated non-approved acoustic environment of men at the frequencies of 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz

	Right ear	
Frequency	**Approved**	**Non-approved**
500 Hz Average HTL Maximum	 7.77 ± 7.88 35	 19.79 ± 11.20 50
P	*0.0000	
1000 Hz Average HTL Maximum	 5.48 ± 6.62 35	 17.23 ± 10.25 40
P	*0.0000	
2000 Hz Average HTL Maximum	 5.93 ± 7.63 40	 7.53 ± 8.15 45
P	0.0601	
3000 Hz Average HTL Maximum	 6.74 ± 7.77 40	 7.79 ± 7.75 40
P	0.0812	
4000 Hz Average HTL Maximum	 6.28 ± 8.44 35	 6.85 ± 8.47 35
P	0.2871	
6000 Hz Average HTL Maximum	 14.42 ± 10.59 60	 14.70 ± 10.93 60
P	0.6811	
8000 Hz Average HTL Maximum	 12.21 ± 10.38 60	 12.23 ± 10.41 60
P	0.9033	

*= Statistically significant difference ($P < 0.05$)

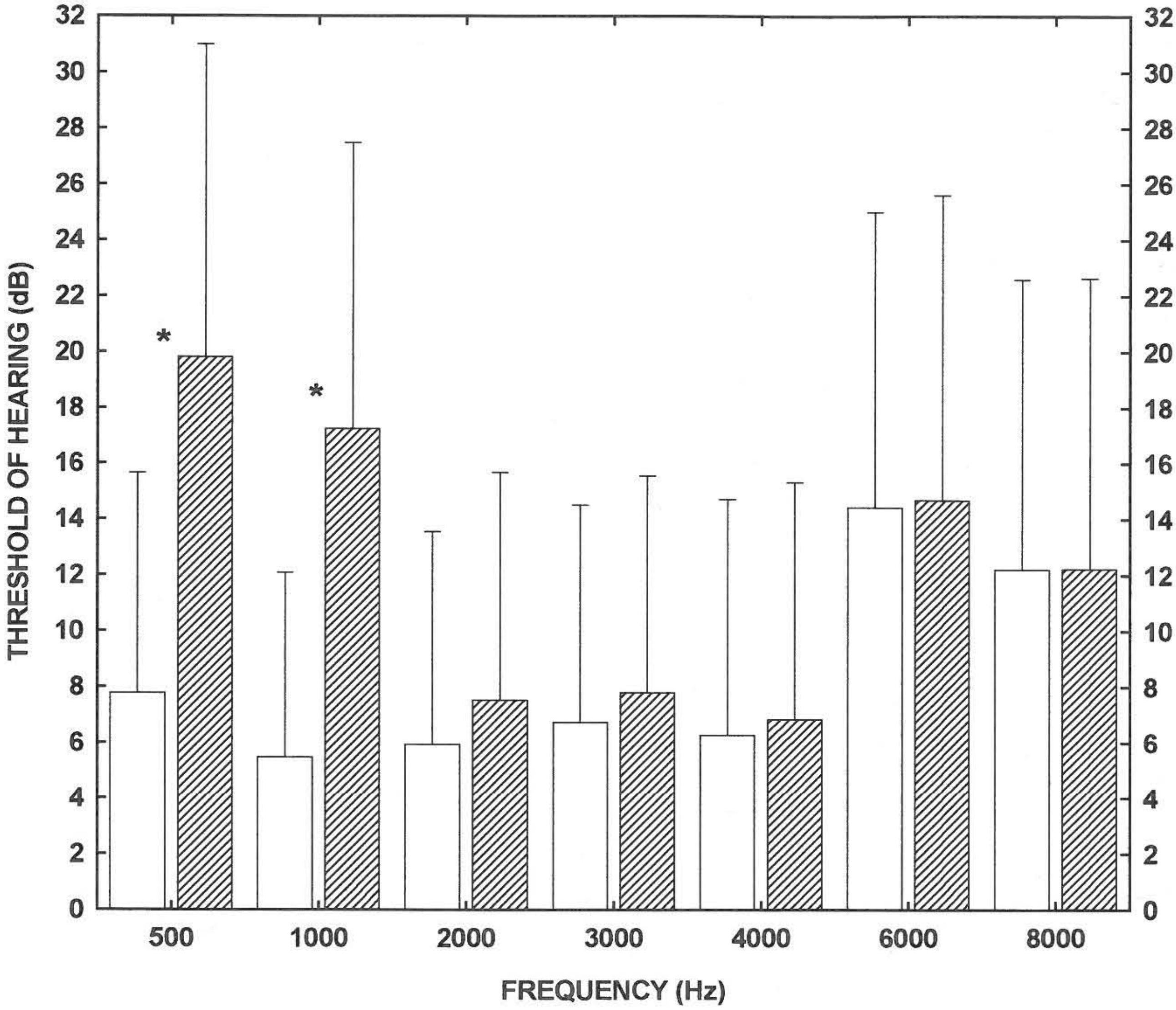

FIGURE 12: Average right ear hearing threshold levels (dB) of women in the approved ai simulated non-approved acoustic environment

* Statistically significantly different

Approved acoustic environment
Simulated non-approved acoustic environment

3.4 Case history

Figures 13A, 13B, 13C and 13D (p49) illustrate differences in reported previous exposure to certain conditions by the test subjects. The figures illustrate the occurrence of these exposure conditions in the different age groups of both men and women.

Eighty-one percent of men aged 18-19 years, 39% for the age groups 20-24 and 53% (25-29 years) reported that they thought that they experienced tinnitus. Sixty-three percent (18-19 years), 70% (20-24 years) and 78% (25-29 years) reported that they have hobbies that create noise. Thirty-six percent (18-19 years), 23% (24-24 years) and 17% (25-29 years) reported that they contracted measles at a younger age and 36% (18-19 years), 9% (20-24 years) and 10% (25-29 years) mumps.

Women in the age group between 18-19 years reported the following: 51% thought that they experienced tinnitus, 100% have hobbies associated with excessive noise, 30% had measles and 20% mumps at a younger age.

In the next age group (20-24 years) for women a lower percentage than men thought they experienced tinnitus (31%), while a lower percentage than men had hobbies associated with noise (60%). Thirty-two percent reported that they had measles and 17% mumps at a younger age.

In the age group 25-29 years 42% of women reported that they thought they had experienced tinnitus, they had hobbies associated with excessive noise and had measles at a younger age. Only 15% of the women had mumps when they were younger.

There were only four women in the age group 30-34 included in the study population; three of them (75%) thought that they experienced tinnitus and they had measles earlier in life, only one reported (25%) that she had hobbies associated with excessive noise and that she had mumps at a younger age.

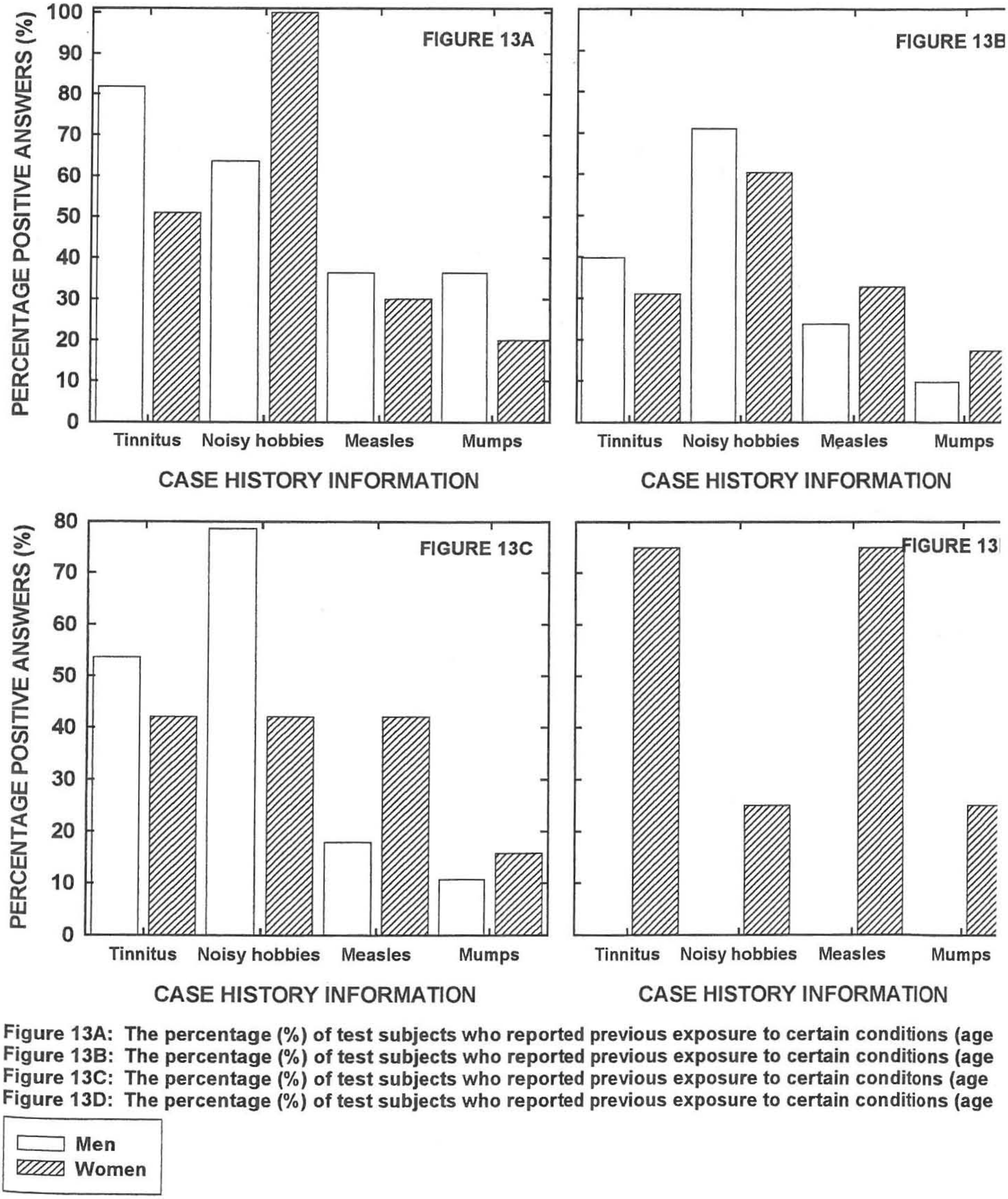

Figure 13A: The percentage (%) of test subjects who reported previous exposure to certain conditions (age
Figure 13B: The percentage (%) of test subjects who reported previous exposure to certain conditions (age
Figure 13C: The percentage (%) of test subjects who reported previous exposure to certain conditons (age
Figure 13D: The percentage (%) of test subjects who reported previous exposure to certain conditions (age

3.5 Categorisation

In the categorisation method, category one means the HTL's fall within the normal limits for the age and gender of the test subject. Category two indicates that the HTL for the individual's age and gender has reached warning levels, the test subject should therefore be warned to protect his/her hearing. Category three is when a referral threshold shift occurs, that is the test subject should be referred for further examination and the industry should pay for this examination. Tables 11 (p51) and 12 (p51) illustrate the difference in the categorisation of men and women respectively between the approved and the simulated non-approved acoustic environment. The number of referral cases (category 3) increased dramatically from the approved to the simulated non-approved acoustic environment for both men and women. In the approved environment only 9 men and 6 women fall in the referral category, whereas in the simulated non-approved acoustic environment 104 men and 107 women seem to be referral cases.

TABLE 11: The difference in the categorisation of men in the approved and simulated non-approved acoustic environment

	Men					
	Approved acoustic environment			Non-approved acoustic environment		
Age group	Category number 1	Category number 2	Category number 3 (a, b, c)	Category number 1	Category number 2	Category number 3 (a, b, c)
18-19	89	6	2	43	26	28
20-24	299	9	6	152	96	66
25-29	76	4	1	57	14	10
30-34	0	0	0	0	0	0
Total	464	19	9	252	136	104

TABLE 12: The difference in the categorisation of women in the approved and simulated non-approved acoustic environment

	Women					
	Approved acoustic environment			Non-approved acoustic environment		
Age group	Category number 1	Category number 2	Category number 3 (a, b, c)	Category number 1	Category number 2	Category number 3 (a, b, c)
18-19	104	7	1	51	29	32
20-24	306	8	4	156	97	65
25-29	70	3	1	54	11	9
30-34	4	0	0	0	3	1
Total	484	18	6	261	140	107

4. DISCUSSION

Screening audiometric tests should, according to legislation in South Africa, be done in an approved acoustic environment. However, a number of audiometrists in South Africa are convinced that the absence of audiometric enclosures would not have any effect on the screening audiometric test results (Ric-Hansen, 1998). The main reason for their standpoint is that they believe that the test person could still hear the test signals sufficiently during testing and that the deviation of the threshold of hearing would be below the levels needed for the determination of the percentage of binaural hearing impairment to be submitted for a diagnostic audiometric test.

The present study attempted to further investigate the abovementioned assumption by evaluating the influence of background noise in an acoustic test environment on the outcome of screening audiometric tests. Screening audiometric tests were conducted in an approved acoustic test environment as well as in a simulated non-approved acoustic environment.

4.1 Acoustic test environments

The non-approved test environment was simulated by operating a GilAir™ personal air-sampling pump in an approved acoustic test environment. The differences in the mean SPL's between the two test localities were due to the operation of the GilAir™ personal air-sampling pump. In the simulated non-approved acoustic environment all the SPL's, at all frequencies tested, were higher than in the approved acoustic environment. The environmental circumstances in the two test localities were similar, except for the additional noise source in the non-approved acoustic environment. The octave band analysis was conducted successively in the same room. Thus, the only difference between the non-approved and the approved acoustic environment was the operating GilAir™ personal air-sampling pump. Therefore the rise in SPL's were due to the noise emitted from tl sampling pump.

At the frequencies between 250 and 8000 Hz the differences were more pronounced non-approved acoustic environment. The frequencies used during screening audiome in this range. If the higher SPL's generated by the air-sampling pump have a statis significant influence on the accurate determination of the hearing threshold, the approved acoustic environment will indicate a different threshold of hearing.

There was no statistically significant difference in the mean SPL's in the approved an approved acoustic environment at the frequencies of 31.5, 63 and 125 Hz (P > 0.05). non-approved acoustic environment, the greatest difference of 33.3 dB was at the freq of 500 Hz. There was a difference of 30.3 dB at the frequency of 1000 Hz and 30 dB frequency of 2000 Hz.

It was noted that the frequencies specific to speech (500, 1000 and 2000 Hz) showed SPL's in the simulated non-approved acoustic environment. Therefore, it is deducte the GilAir™ personal air-sampling pump emits more low frequency than high freq noise. The higher frequencies are also affected by the ambient sound level, but not same degree (e.g. at 6000 Hz the difference between the acoustic test environments 21.9 dB). In this study, thus, with the non-approved acoustic environment simulated by emitted from a personal air-sampling pump, it is expected that if the acousti environment influences the outcome of the screening audiometric tests these would be pronounced in the speech frequency range.

Different test environments could render different results because of differences in the emitted by different noise sources. This study only applies to this specific simulate approved acoustic environment used.

4.2 Hearing threshold levels of men and women in different age groups at the different frequencies

The SABS Code of Practice 083: 1996 states that test frequencies should include at least 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz (SABS, 1996) and the percentage binaural hearing impairment is calculated by using 500, 1000, 2000 and 3000 Hz in the South African compensation structures (South Africa, 1993). In the present study the threshold of hearing of the study population was thus determined for each of the abovementioned frequencies in both the approved and the simulated non-approved acoustic environment, since there exits some controversy in the literature regarding the precise influence of a non-approved acoustic test environment at all these frequencies (Robinson, 1992, Hirschorn and Singer, 1973, Frasier, 1965)

There was a statistically significant difference ($P < 0.05$) in the threshold of hearing of both the left and right ear between the two test localities of both genders and of all age groups at the frequency of 500 Hz. The threshold of hearing in the simulated non-approved acoustic environment was statistically significantly higher than in the approved acoustic environment. Thus, the SPL present in the simulated non-approved acoustic environment had a statistically significant influence on the accurate determination of the hearing threshold. The test signal was seemingly masked by the presence of higher ambient SPL's present in the simulated non-approved acoustic environment.

It appears that the higher SPL present in the simulated non-approved acoustic environment caused the threshold of hearing to increase. Therefore at this frequency (500 Hz), the threshold of hearing could not be determined accurately in the simulated non-approved acoustic environment. These findings are in conjunction with previous research results that stated that the threshold of hearing would be influenced by the ambient SPL present in the test environment at the 500 Hz frequency (Hirschorn and Singer, 1973). Robinson (1992) also stated that the hearing threshold would be influenced by the higher ambient SPL's at frequencies below 1000 Hz. Hirschorn and Singer (1973) found that the hearing threshold would increase uniformly by 10 to 15 dB at the frequency of 500 Hz in the presence of high ambient noise levels. The threshold of hearing increased by between 4 to 14 dB in the simulated non-approved acoustic environment compared to the approved acoustic environment. In this study, the test locality therefore had a statistically significant influence on the accurate determination of the threshold of hearing at a frequency of 500 Hz.

Frasier (1965) stated that the standards developed for the acoustic environment would govern the amount of compensation claims. He said that because the 500 Hz frequency is used in the calculation of the percentage binaural hearing loss, unnecessary referrals would result from testing people in a non-approved acoustic environment (Frasier, 1965). Frank, Greer and Magistro (1997) stated that the SPL's present in the non-approved acoustic environment would have a masking effect on the test signal (Frank, Greer and Magistro, 1997). The results of this research on the influence of a non-approved acoustic environment on the HTL agree with the findings of Frasier and Frank, Greer and Magistro signal (Frank, Greer and Magistro, 1997). The test signal seems to be masked by the presence of ambient noise levels present in the simulated non-approved acoustic test environment as stated by Frank, Greer and Magistro. Using these test results in calculating the percentage binuaral hearing loss it would result in unnecessary referral cases as Frasier and Hirschorn and Singer (1973) indicated (Frasier, 1965, Frank, Greer and Magistro, 1997, Hirschorn and Singer 1973).

Gender or age did not seem to influence the differences in the HTL between the approved and simulated non-approved acoustic environment. For all age groups and for both genders a statistically significant difference ($P < 0.05$) in the hearing threshold was observed between the two test localities at the frequency of 500 Hz.

The difference in the threshold of hearing of men and women (age 18-19, 20-24, 25-29, 30-34) between the approved and non-approved environment at a frequency of 1000 Hz proved to be statistically significant ($P < 0.05$). The hearing threshold of both ears of men and women was higher in the non-approved than in the approved acoustic environment. This indicates that the difference in the mean SPL in the non-approved acoustic environment negatively influenced the accurate determination of the hearing threshold. The test signal was probably masked by the presence of high ambient SPL's present in the non-approved acoustic environment at the frequency of 1000 HZ. Previous research indicated that the ambient SPL present in the test environment would not have an influence on the hearing threshold at the frequency of 1000 Hz (Robinson, 1992, Frank, Greer and Magistro, 1997, Hirschorn and Singer, 1973). However, other studies (Franks, Engel and Theman, 1992, Franks, 1992, Franks, Merry and Engel, 1989, Frank, Greer and Magistro, 1997) showed that the type of earphone used during the test could generally have a significant influence on the accurate determination of the hearing threshold. In this study, the ambient SPL at the frequency of 1000 Hz influenced the hearing threshold. The difference between this and previous research probably indicates that different non-approved acoustic test environment could render different results. In this study the SPL present in the test environment could have been higher than the environment used in Robinson's (1992) research (the exact SPL's in this study were not indicated). This could explain differences in research results. It is possible that the use of different types of earphones than the types used by Robinson, Franks and Hirschorn and Singer could have caused the difference in the results obtained by them and in the present study. Further research is needed to determine the most effective type of earphone to minimise the influence of SPL's in the acoustic test environment (Robinson's, 1992, Franks, 1992, Hirschorn and Singer, 1997).

NOSA (1974) stated the hearing threshold will be distorted by the background noise level (NOSA, 1974). This statement is corroborated by this study's results of the hearing threshold in the simulated non-approved acoustic test environment at the frequency of 1000 Hz. It is obvious that the test signal was masked by the higher ambient SPL present in the non-approved acoustic environment.

If the acoustic test environment does not meet the requirements specified in the SABS Code of Practice 0182: 1998, the hearing threshold would differ because of the presence of different SPL's present in different non-approved acoustic test environments. Non-approved acoustic test environments would be individualised by different noise sources thus presenting different hearing thresholds that are unreliable and invalid. In the present study, the hearing threshold was notably raised in the non-approved acoustic environment (created by the GilAir™ personal air-sampling pump) at 500 and 1000 Hz and therefore small but statistically significant hearing losses might not have been identifiable at the frequencies of 500 and 1000 Hz. The audiometric test results obtained from non-approved test environments could thus induce unnecessary referrals that in turn would have financial implications for industries; they will have to carry the cost of these referral cases, unless proofed as NIHL, the Compensation Commissioner would pay the costs.

The hearing threshold of men and women of all age groups (18-19, 20-24, 25-29, 30-34) in the approved and simulated non-approved acoustic environment at the frequencies of 2000 and 3000 Hz, showed no statistically significant difference for neither the left nor the right ear ($P > 0.05$). It appears that although there was a high SPL present at this frequency the accurate determination of the hearing threshold was not influenced.

As predicted by previous studies (Robinson, 1992, Frank, Greer and Magistro, 1997, Hirschorn and Singer, 1973) the frequency of 2000 and 3000 Hz was not influenced by the environmental SPL. The screening audiometric test results performed in a non-approved acoustic environment in this study coincided with the conclusion of these previous studies.

The specific test environment used during the audiometric tests did not influence the accurate determination of the threshold of hearing but, as the SPL between environments differ, other environments might render different results.

No statistically significant difference ($P > 0.05$) between the threshold of hearing in the approved and simulated non-approved environment for the frequency of 4000 Hz was observed.

According to these results, the acoustic test environment does not play a role in the identification of NIHL, as there is no statistically significant difference in the threshold of hearing between the approved and the simulated non-approved acoustic environment at the frequency of 4000 Hz. Therefore, the characteristic dip at the frequency of 4000 Hz, which indicates NIHL would still be recognisable. If a person is tested audiometrically solely for the purpose of identifying NIHL, characterised by the characteristic dip at 4000 Hz, the tests could be done in a non-approved acoustic test environment. Since no statistically significant difference was found between the approved and the simulated non-approved acoustic test environment the threshold could be determined in a non-approved acoustic environment. However, since the lower frequencies (i.e. 500 and 1000 Hz) were statistically significant different in the two acoustic test environments the identification of NIHL may be more difficult in the non-approved acoustic environment, since it is necessary to compare to the other frequencies in order to "see" the characteristic dip.

The hearing threshold of men and women in the two acoustic test environments at the frequencies of 6000 and 8000 Hz showed no statistically significant difference for neither the left nor the right ear ($P > 0.05$). It appears that the SPL present in the simulated non-approved acoustic environment did not influence the accurate determination of the hearing threshold. The hearing threshold could still be determined accurately in the simulated non-approved acoustic environment, even with the presence of higher ambient SPL's.

The environment in which the screening audiometry tests are conducted seems mainly to influence the accurate determination of the threshold of hearing at the frequencies of 500 and 1000 Hz. The statistically significant difference in the hearing threshold between the two acoustic test environments at the frequency of 500 Hz coincide with previous research (Robinson, 1992, Frasier, 1965). The difference in the HTL's was probably as a result of the higher ambient SPL's present in the simulated non-approved acoustic environment. The results could differ if different types of earphones are used during the evaluation of different acoustic test environments (Franks, Engel and Theman, 1992, Franks, 1992, Franks, Merry and Engel, 1989, Frank, Greer and Magistro, 1997).

This trend is in accordance with what Robinson and Hirschorn and Singer predicted, namely that frequencies below 1000 Hz would be affected by the ambient SPL present in the test environment. Hirschorn and Singer stated that the threshold of hearing would increase uniformly with about 10 to 15 dB at the 500 Hz frequency if the ambient SPL were higher than 43 dB.

It seems therefore that the environment in which the screening audiometric tests are conducted has a statistically significant influence on the accurate determination of the threshold of hearing of all age groups and for both genders. The frequencies of 500 and 1000 Hz showed a statistically significant increase in the hearing threshold in the presence of high ambient SPL's in the test environment. These frequencies are used in the calculation of binuaral hearing impairment and to categorise the individual's hearing loss. The categorisation of the individual will therefore be negatively influenced. The categorisation shifts from normal hearing to a referral threshold shift in the presence of high ambient SPL's and therefore, as Frasier stated, compensation claims would be governed by the standards developed (Frasier, 1965).

Audiometric test results however, should not be viewed in isolation. Many factors have an influence on hearing. Interpreting audiometric tests should always include conducting otoscopic examinations, investigating the case history of the test subject and all information regarding the noise exposure of the individual. Factors that may influence the hearing of individual include personal characteristics of the individual, noise exposure in the work environment and exposure to other noise sources (e.g. noise emitted form hobbies) and other stresses. Information gained from a case history should be used in conjunction with the test results before a conclusion is reached.

Supplementary data have been obtained on occupational and non-occupational factors that could possibly influence HTL's. In the manufacturing industry the noise level is above 85 dB(A), which could cause hearing loss. The first frequency to be affected is usually 4000 Hz. Fox (1953), Sataloff (1957, 1980) and Sataloff et al. (1980) found that if exposure to noise continues for a period of years, damage would spread to both higher and lower frequencies. It is often not noticed until it affects the frequencies involved in speech, 500 to 2000 Hz (Lusk and Keleman, 1993). There are different types of work or work activities that could generate noise sources above the allowable legislated level (85 dB(A)). These include truck drivers where hearing loss is experienced in one or both ears at the frequencies of 4000 to 6000 Hz (Van den Heever and Roets, 1996).

Another work environment which exposes the employee to noise in excess of 85 dB(A) is the gold mining industry. An example would be a survey that revealed that 27 of the 28 underground occupations and 20 of the 22 surface occupations on several South African gold mines had noise levels in excess of 85 dB(A) (Hessel and Sluis-Cremer, 1987). This is the maximum allowable noise level for non-mining industrial factories in South Africa. This noise level would also influence the hearing level negatively and could cause hearing damage after continuous exposure.

Other factors or exposures in the work environment could also have a negative effect on the hearing of the employee. Exposure to lead in the work environment increases the hearing threshold significantly at 500, 1000, 2000 and 4000 Hz (possibly because of nerve damage) as the blood-lead level increases (Wu, 2000). The exposure to solvents has only recently been considered as a contributor to the development of hearing impairment (Morata, Dunn, Kretschmer, Lemasters and Keith, 1993, Morioka, 1999). These include solvents like toluene, xylene and styrene.

In other work and non-work environments impulse noise may occur. These include mandatory military services as well as shooting impulses from hunting rifles (Pekkarinen, Iki, Starck and Pyykkö, 1993). These shooting impulses from large calibre weapons are known to produce peak levels of above 185 dB (Pääkkönen, 1988, Pekkarinen Strack and Ylikoski, 1992). Whether this noise is experienced as part of the work environment or of the non-work environment it would be dangerous to the hearing of the individual.

Previous research (Clark, 1991, Babisch and Ising, 1994, Ising, 1994, Schimdt, Verschuure and Brocaar, 1994, Yassi, Pollock, Tran and Cheang, 1993, Drake-Lee, 1992, Tsumura and Dicus, 1992, Fearn and Hanson, 1989, Plath, 1994) indicates that listening to loud music could have a significant influence on the hearing threshold.

Individuals go to rock concerts without knowing the effect the noise could have on their hearing. On the other hand rockers like Metallica and Aerosmith wear earplugs on stage to keep noise levels under control (Nugel, 1998), while the public seems unaware of the danger. A concert generating noise at 120 dB may not produce excessive stress in the willing listener but to the unwilling could cause stress reactions (Niemtzow, 1993). This reaction affects every system in the body and are charaterised by increases in pulse, respiration, blood pressure, gastrointestinal activity, pupillary size of the eyes and adrenal hormone secretions (Niemtzow, 1993).

In the age group 18-19 years men showed a lower HTL than women in the same age group for both the left and the right ear (at all frequencies tested). This difference can be explained when taking into account the case history of the test subjects. One-hundred percent of women reported having hobbies associated with noise exposure that include listening to loud music where only about 60% of men reported this activity. Therefore it is expected that the HTL of women would be higher than that of men. It seems as if listening to loud music does influence the hearing of the individual negatively although the study design did not specifically set out to prove this.

The recorded hearing threshold of men compared to that of women in the age group 25-29 did not show a distinct difference. It could be explained that their hobbies associated with exposure to noise might not only be listening to loud music. The specific type of hobbies associated with increased noise exposure was not determined by the case history.

Personal charateristics could influence the sensitivity of hearing and therefore result in damage to the hearing mechanism. Chronic tinnitus could cause sleep disturbance (Alster, Shemesh, Ornan and Attias, 1993). Tinnitus is characterised by a frequency of 3000 Hz or above and is closely related to the frequency range of maximal hearing loss (Negri and Schorm, 1991). Individuals with blue eyes are more prone to hearing loss than individuals with brown eyes (Barrenas and Lindgren, 1991). Smoking may influence the susceptibility of the individual for hearing loss as well as Parkinson's disease (Hedin, 1991). Smoking, ethnic background, exposure to loud noises of non-occupational origin, such as frequent exposure to firearm blasts (Thiery and Meyer-Bisch, 1988) may have an influence on hearing ability. Presbycusis affects frequencies of 6000 Hz and upward (Robinson and Sutton, 1979). The abovementioned aspects were not covered in this particular research project. Attention should also be given to the actual audiometric testing, instrumentation used during audiometry and procedures used during audiometric testing as well as the above-mentioned aspects.

Another aspect that should be investigated in South Africa, is the procedure of the screening audiometric tests, which include the calibration of audiometers and approval of the acoustic test environment. Ric-Hansen (1998) found that the frequency of audiometric tests was not related to the actual noise exposure levels. It was also noted that only larger industries used their own occupational nurse and audiometer. Seventy-nine percent of audiometers used were calibrated within the last year while 71% of audiometric booths (i.e. acoustic test environment) were calibrated within the last year. Industries need to be aware of the advantages of regular audiometric testing by qualified people and with calibrated equipment. This could lead to better hearing conservation programmes. Other information also needs be obtained in order for the programme to work effectively.

4.3 Hearing threshold levels of all the men and women at the different frequencies

There are statistically significant differences ($P < 0.05$) for men and women's left and right ear at frequencies of 500 and 1000 Hz. None of the other frequencies showed a statistically significant different hearing threshold in the simulated non-approved acoustic environment from the approved acoustic environment. However, since the 500 and 1000 Hz frequencies were influenced by the environmental SPL's present in the simulated non-approved acoustic environment the categorisation and the percentage binaural hearing loss would be influenced as well. The difference in the threshold of hearing between the approved and the simulated non-approved acoustic environment was not dependent on either gender or age since the same results were evident even when pooling the results of men and women of all ages in one group. The results coincide with the research done by Robinson and Frasier (i.e. lower frequencies will be affected by the presence of high ambient SPL) (Robinson, 1992, Frasier, 1965).

Since this research only included individuals up to 34 years, conclusions could not be made with regard to the effect of ambient noise present in a non-approved acoustic environment on the hearing threshold of people older than 34 years. More research needs to be done including people older than 34 years. Older people may render different results when tested in an approved and non-approved acoustic test environment.

4.4 Categorisation

In the categorisation method the test subject is categorised as a category 1, 2, 3a, 3b or 3c. This is done according to the gender and age of the individual. Category 1 refers to an individual with normal hearing, 2 refers to hearing levels that is within warning levels and 3 is the referral threshold shift. Category 3 individuals will be referred for medical examination and the industry will have to pay for these examination (Shilling, 1981).

For this specific study the SABS method was not used; the experimental design was specifically employed to show differences in categories according to Shilling's method (Shilling, 1981).

In the present study the categorisation of individuals changed between the two test environments. The number of individuals that were in category one (normal hearing) when audiometrically tested in the approved acoustic test environment was dramatically reduced when the tests were performed in the simulated non-approved acoustic environment. The screening audiometry results in the simulated non-approved acoustic environment showed more referral cases than the same people tested in the approved acoustic environment. The referral cases will have a financial impact on industries as they will have to pay for these unnecessary referrals that result from tests done in a non-approved acoustic environment.

Results from this study thus indicate that the HTL could not be accurately determined at the frequencies of 500 and 1000 Hz. Since these frequencies are used in the calculation of binaural hearing loss results from a non-approved acoustic test environment would be invalid and unreliable. There proved to be no statistically significant difference in the HTL tested at the other frequencies (i.e. 2000, 3000, 4000, 6000 and 8000 Hz) between the approved and simulated non-approved acoustic environment. The 4000 Hz frequency is used in the identification of NIHL. Considering that the acoustic test environment did not seem to statistically significantly influence the accurate determination of the HTL, audiometric test results obtained in a non-approved acoustic environment could probably be used to identify NIHL. However, the use of a non-approved acoustic environment is not recommended since identifying NIHL will be more difficult because the hearing threshold at the frequency of 4000 Hz is compared to the other frequencies to "see" the characteristic dip. The frequencies (500 and 1000 Hz) that were statistically significantly influenced by the presence of high SPL's could hamper the identification of NIHL.

The H_0 hypothesis is accepted since the acoustic test environment has a significant influence on the accurate determination of the threshold of hearing when conducting screening audiometry. Therefore the H_a hypothesis is rejected.

5. CONCLUSIONS AND RECOMMENDATIONS

The question arises whether the requirements for the acoustic test environment for screening audiometry are too stringent. If the SPL's present in the acoustic environment could be lowered, it could influence the determination of the threshold of hearing in a positive way. In other words, it could be that the person tested in the approved acoustic environment actually has better hearing than that shown by the test results.

The research showed that this specific simulated non-approved acoustic environment did not accomplish accurate determination of the hearing threshold. The test environment therefore has a statistically significant influence on the accurate determination of the threshold of hearing and the H_o hypothesis is accepted. The screening audiometry results obtained from a simulated non-approved acoustic environment appear to be unreliable and invalid and should not be used in the calculation of the percentage binaural hearing loss or the categorisation of an individual.

The HTL at the frequencies of 500 and 1000 Hz could not be accurately determined in the simulated non-approved acoustic environment. However, none of the other frequencies (i.e. 2000, 3000, 4000, 6000 and 8000 Hz) showed a statistically significant difference between the approved and the simulated non-approved acoustic environment. This influence of the acoustic test environment at the 500 and 1000 Hz frequencies will have an impact on the number of referral cases for medical examination and therefore a financial impact on industry: they will have to pay for these unnecessary referrals.

There were no differences between age groups or genders. The results did not seem to be influenced by either the age or the gender of the test subjects.

According to these results, the identification of NIHL would not be influenced by the acoustic test environment. If the only reason for the screening audiometry is to identify NIHL cases, it seems that the tests could be done in a non-approved acoustic environment. This was the case because the 4000 Hz frequency did not seem to be influenced by the ambient noise level in this specific simulated non-approved acoustic environment. The characteristic dip at this frequency would still be identifiable.

However, different test environments with different component SPL's could influence the test results differently. The test subjects used during the audiometric screening test could also influence the results. Further research using employees that are exposed to noise higher than 85 dB (A) should be used. These people would possibly suffer from NIHL and therefore could render different results.

Different non-approved acoustic environments should be tested against one another to get a more comprehensive picture of the influence of a test environment on the accurate determination of the hearing threshold. As different test environments would have different SPL's at the mid-frequencies because of location; the results could be different for each test locality.

Different non-approved acoustic environments would have different constituent sounds and two acoustic test environments might render different results because of masking effects on the test signal at the different frequencies. In addition, the type of earphone used during these tests also influences the determination of the threshold of hearing. Therefore different non-approved acoustic environments should be simulated with the use of different types of earphones.

Research should also be conducted using test environments with lower SPL's than the approved acoustic environment to establish the difference between these two environments.

It could be possible that the person tested in the approved acoustic environment actually has a lower hearing threshold in an environment with lower SPL's.

The fact that a person could actually listen more carefully when he knows that he will hear a specific sound is also a factor to keep in mind. After the initial screening audiometric test, the test subjects would have "identified" the sound, therefore the test person actually knows what to listen for. The differences in the SPL are not as great in the high frequencies than in the low frequencies and therefore test environments with higher SPL's at the higher frequencies should also be tested. This could significantly influence the higher frequencies statistically significantly.

It is recommended that screening audiometry must always be done in the specified acoustic environment. The environment must comply with the requirements of the SABS Code of Practice 0182: 1998. Test results obtained from a non-approved acoustic environment should not be used in the calculation of binaural hearing loss or to categorise the individual.

6. REFERENCES

Alster, J., Shemesh, Z., Oman, M., Attias, J. 1993. Sleep disturbance associated with chronic tinnitus. *Biological Psychiatry*. 34: 84-90.

American Academy of Otolaryngology – Head and Neck Surgery (AAO-HNS). 1983. Otologic referral criteria for occupational hearing conservation programs. Washington, DC.

American Industrial Hygiene Association. 1997. The Occupational environment - its evaluation and control. American Industrial Hygiene Association, Fairfax, Virginia. 433-438.

American National Safety Institute. 1995. American Standard Criteria for Background Noise in Audiometry Rooms (ANSI S3.1-1960). New York, Inc.

Babisch, W., Ising, H. 1994. Music listening habits of adolescents. With special reference to dischothek exposure. *Hals-Nasen-Ohren*. 42(8): 466-469.

Barrenas, M.L., Lindgren, F. 1991. The influence of eye colour on susceptibility to TTS in humans. *British Journal of Audiology*. 25(5): 303-307.

Barone, J.A., Peters, J.M., Garabrant, D.H., Bernstein, L., Krebsbach, R. 1987. Smoking as a risk factor in noise induced hearing loss. *Journal of Occupational Medicine*. 29: 741-745.

Carter, N.L. 1980. Eye colour and susceptibility to noise-induced permanent threshold shift. *Audiology*. 19: 86-93.

Carney, A.S., Birchall, J.P. 1995. How to use an otoscope. Student BMJ. Second edition. Volume 2. Fourth term. 20-24.

Chung, D.Y., Wilson, G.N., Gannon, R.P. 1983. Lateral differences in susceptibility to noise damage. *Audiology*. 22: 199-205.

Clark, W.W. 1991. Noise exposure from leisure activities: a review. *Journal of Acoustic Society of America.* 90(1): 175-181.

Drake-Lee, A.B. 1992. Beyond music: auditory temporary threshold shift in rock musicians after a heavy metal concert. *Journal of Social Medicine.* 82(10): 617-619.

Encyclopaedia Britannica. 2000. http://www.britannica.com.

Fearn, R.W., Hanson, D.R. 1989. Hearing levels of student and professional musicians. *Journal of sound and vibration.* 133(1): 173-176.

Feldman, A.S., Grimes, C.T. 1985. Hearing conservation in industry. Williams & Wilkins. London. 164-166, 180-187,196-197.

Frank, T., Greer, A.C., Magistro, D.M. 1997. Hearing thresholds, threshold repeatability and attenuation values for passive noise-reducing earphone enclosures. *American Industrial Hygiene Association Journal.* 58(11): 772-778.

Franks, J.R., Engel, D.P., Theman, C.L. 1992. Real ear attenuation at threshold for three audiometric headphone devices: implications for maximum permissible ambient noise level standards. *Ear and hearing.* 13(1): 2-10.

Franks, J.R. 1992. The effects of noise reducing earphone enclosures on audiometric threshold and maximum permissible background noise level. *Proceedings, 1992 Hearing*

Conservation Conference, April 1-4, 1992, Lexington, Kentucky, Office of Engineering Services, University of Kentucky and NIOSH. 125-129.

Fox, M.S. 1953. Industrial noise and hearing conservation programs. *Industrial Medical Surgery*. 22. 161-164.

Franks, J.R., Merry, C.J., Engel, D.P. 1989. Noise reducing muffs for audiometry. *Hearing Instruments.* 40(11): 29-36.

Frasier, F.E. 1965. Compensation claims for loss of hearing - Impact of Standards. *Archives of Environmental Health.* 10. 572-575.

Hedin, C.A. 1991. Smoker's melanosis may explain the lower hearing loss and lower frequency of Parkinson's disease found among tobacco smokers - a new hypothesis. *Medical hypothesis.* 35(3): 247-249.

Hessel, P.A., Sluis-Cremer, G.K. 1987. Hearing loss in white South African goldminers. *South African Medical Journal.* 71: 364-367.

Hirschorn, M., Singer, E. 1973. The effect of ambient noise on audiometric room selection. *Sound Vibration*. 7: 18-22.

Ising, H. 1994. Potential hearing loss caused by loud music. Current status of knowledge and need for management. *Hals-Nasen-Ohren.* 42(8): 465-466.

Lipscomb, D.M. 1988. Hearing concervation in industry, schools, and the military. Taylor & Francis. London. 212-214.

Lusk, S.L., Keleman, M.J. 1993. Predicting use of hearing protection: A preliminary study. *Public Health Nursing*. 10(3): 189-196.

Morata, T.C., Dunn, D.E., Kretschmer, L.W., Lemasters, G.K., Keith, R.W. 1993. Effects of occupational exposure to organic solvents and noise on hearing. *Work environmental health*. 19: 245-254.

Morioka, I. 1999. Evaluation of organic solvents ototoxicity by the upper limit of hearing. *Archives of Environmental Health.* http//www.findarticles.com.

National Occupational Safety Association. 1974. Safety Management Techniques. National Occupational Safety Association, South Africa. 14.1-14.6

Negri, B., Schorn, K. 1991. Noise induced hearing loss and tinnitus. *Hals-Nasen-Ohren.* 39(5): 192-194.

Niemtzow, R.C. 1993. Loud noise and Pregnancy. *Military medicine*. 158(1): 10.

Nugel, B. 1998. Listen up! Rockers and their fans face the music with hearing damage (loud music can damage hearing mechanisms in the ear). *Science world.* http//www.findarticles.com

Occupational Safety and Health Administration. 1983. Occupational noise exposure; hearing conservation amendment; final rule. Federal Register 46. 9738-9785.

Pääkkönen, R. 1988. Low-frequency high level noise impulses near weapons and explosions. *Journal of Low Frequency Noise Vibration.* 7: 42-49.

Pekkarinen, J., Strack, J., Ylikoski, J. 1992. Hearing protection against high level shooting impulses in relation to hearing damage. *Journal of Acoustic Society of America.* 91: 196-202.

Pekkarinen, J., Iki, M., Starck, J., Pyykkö, I. 1993. Hearing loss risk from expsure to shooting impulses in workers exposed to occupational noise. *British Journal of Audiology.* 27: 175-182.

Peterson, J.E. 1991. Industrial Health. American Conference of Governmental Industrial Hygienists, Inc. Cincinnati. 204-205.

Plath, P. 1994. Hearing loss caused by leisure activity-induced noise. *Hals-Nasen-Ohren.* 42(8): 483-487.

Plog, B.A. 1996. Fundamentals of Industrial Hygiene. Fourth edition. National Safety Council. United Sates of America. 163, 178, 183-188.

Porges, G. 1977. Applied acoustics. Edward Arnold (Publishers) Limited. 11, 48, 49

Ric-Hansen, J.E. 1998. An evaluation of compliance with noise and hearing conservation regulations in industry. *Occupational Health SA.* 4(3): 28-31.

Robert, S., Bahadori, M.D., Bohne, B.A. 1993. Adverse effects of noise on hearing. *American family physician.* April 1219-1226.

Robinson, D.W. 1992. Background noise in rooms used for pure-tone audiometry in disability assessment. *Audiology.* 5: 132-141.

Robinson, D.W., Sutton, G.J. 1979. Age effects in hearing. A comparative analysis of published threshold data. *Audiology*. 18: 320-334.

Sataloff, J. 1957. Hearing testing and noise measurement. Industrial Deafness. McGraw-Hill, New York. 41-42.

Sataloff, J. 1980. Noise induced hearing loss. Hearing conservation. Charles Thomas, Springfield, Illinois. 70-84.

Sataloff, J., Sataloff, R.T., Vassallo, L.A. 1980. Occupational deafness: legislation, compensation, conservation. Hearing loss. J.B. Lippincott, Philadelphia. 383-412.

Schmidt, J.M., Verschuure, J., Brocaar, M.P. 1994. Hearing loss in students at a conservatory. *Audiology*. 33(4): 185-194.

Schröder, H.H.E., Schoeman, J.J. 1994. Occupational hygiene. Juta & Co, Ltd. 226-227, 232-233.

Shilling, R.S.F. 1981. Occupational Health Practice. Second edition. Butterworths. London. 63-89.

Sieglaub, A.B., Friedman, G.D., Adour, K., Seltzer, C.C. 1974. Hearing loss in adults: relation to age, sex, exposure to loud noise and cigarette smoking. *Archives of Environmental Health*. 29: 107-109.

Smith, B.J., Peters, R.J., Owen, S. 1982. Acoustics and noise control. Longman. London & New York. 18, 86-87.

South Africa. 1993. Compensation of Occupational Diseases and Injuries Act, Act 130 of 1993. State press, Pretoria.

South Africa. 1987. Environmental Regulations for Workplaces, 1987. State press, Pretoria.

South Africa. 1941. Factories, Machinery and Building Work Act, Act 22 of 1941. Lex-Patria Publishers, Johannesburg.

South Africa. 1983. Machinery and Occupational Safety Act, Act 6 of 1983. Lex-Patria Publishers, Johannesburg.

South Africa. 1993. Occupational Health and Safety Act, Act 85 of 1993. Lex-Patria Publishers, Johannesburg.

South African Bureau of Standards (SABS). 1996. Code of Practice for calibration of pure-tone audiometers. SABS 0154 Part 1: air conduction, Pretoria.

South African Bureau of Standards (SABS). 1996. Code of Practice for the measurement and assessment of occupational noise for hearing conservation purposes. SABS 083, Pretoria.

South African Bureau of Standards (SABS). 1998. Code of Practice for obtaining as acoustic environment suitable for audiometric testing. SABS 0182, Pretoria.

Thiery, L., Meyer-Bisch, C. 1988. Hearing loss due to partly impulsive industrial noise exposure at levels between 87 and 90 dB(A). *Journal of Acoustical Society of America*. 84 (2). 651-659.

Thomas, G.B., Williams, C.E., Hoger, N.G. 1981. Some non-auditory correlates of the hearing threshold of an aviation noise-exposed population. *Aviation, Space, Environmental Medicine*. 52: 531-536.

Tsumara, T. K., Dicus, G. 1992. Degree of hearing loss due to personal stereo use. *Journal of Health.* 62(4): 119.

Van den Heever, D.J., Roets, F.J. 1996. Noise exposure of truck drivers: a comparitive study. *American Industrial Hygiene Association Journal.* 57: 564-566.

Wu, T.N. 2000. Effects of lead and noise exposure on hearing ability. *Archives of Environmental Health.* http//www.findarticles.com

Yassi, A., Pollock, N., Tran, N., Cheang, M. 1993. Risks to hearing from a rock concert. *Canadian Family Physician.* 39: 1045-1050.

Zenz, C., Dickerson, O.B., Horvath, E.P. 1994. Occupational Medicine. Mosby Year Book Inc. 267.

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ANNEX A

TABLE D-1 - MAXIMUM ALLOWABLE OCTAVE-BAND SOUND PRESSURE LEVELS FOR AUDIOMETRIC TEST ROOMS

Octave-band center					
Frequency (Hz)	500	1000	2000	4000	8000
Sound pressure level (dB)	40	40	47	57	62

ANNEX B

In summary; according to RSF Shilling each category of hearing impairment is bound by a strict definition. The definitions are as follows:

Category 1: Describes a person who is within acceptable limits of noise exposure (hearing loss covers the average healthy person and will be regarded by the Compensation Commissioner as a "zero disablement"

Category 2: When the sum of the hearing levels in either the low- or high frequency groups exceeds the warning levels, but is below the referral level while involving a slight hearing deficiency, it is not considered an impediment and qualifies as a "zero disablement"

Category 3: Sees a serious hearing loss and requires the audiometrist to refer the patient for diagnostic testing. It is divided into three sections and applies to each ear:

A: The sum of hearing levels in either the low- or the high frequency groups, or both, exceeds the referral level

B: The difference between the sums of hearing between the two ears on the low-frequency groups is greater than 45dB, and on the high group is greater than 60dB

C: The sum of the low-frequency group or the sum of the high-frequency group shows an increase of 30dB or more compared to a recent preceding examination, or 45dB over the past three years

The following table gives the warning and referral levels of the different age groups in the low and high frequency groups.

LOW GROUP (500/1K/2K)			HIGH GROUP (3K/4K/6K)	
AGE (YRS)	WARNING	REFERRAL	WARNING	REFERRAL
20-24	45	60	45	75
25-29	45	66	45	87
30-34	45	72	45	99
35-39	48	78	54	111
40-44	51	84	66	123
45-49	54	90	75	135
50-54	57	90	75	144
55-59	60	90	87	144
60-64	63	90	99	144
65+	66	90	115	144

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AUDIOMETER CALIBRATION CERTIFICATE

Calibration Officer: **Neil Schalkwyk**	Cert. No: 394/NS/99

SITE OF CALIBRATION

Company	TECHNIKON FREE STATE
Address	PRIVATE BAG X20539
	BLOEMFONTEIN
	9300

UNIT UNDER CALIBRATION

SUBJECT	MAKE	MODEL	SERIAL NO.
Audiometer	TREMETRICS	RA 300	991244
Earphone Left	TELEPHONICS	TDH-39P	C 79797
Earphone Right	TELEPHONICS	TDH-39P	C 79791
Bone Vibrator	RADIO EAR	B -----	------

CALBRATION EQUIPMENT

ITEM	MODEL	SERIAL NO.
Sound Level Meter	Quest 1800	HP 5120015
Sound Level Calibrator	Quest QC-20	QE 8020016
1/3 Octave Filter	Quest OB-300	HV 6010011
Frequency Counter	Goldstar DM 332	332019443
Artificial Ear	Bruël & Kjaer 4153	1877747
Calibration date : APRIL 1999	Calibration Cert. No:AV\AS 1969/70/71 CSIR	

TEST ENVIRONMENT CONDITIONS

Wide Band Background Noise Level: 61.1 dB.	Background Noise Level @ 4000Hz: 20.7 Db.
Calibration Signal: Before: 114.0dB.	Calibration Signal: After: 114.0Db.

COMPLIANCE OF EQUIPMENT

1. This audiometer is hereby certified as calibrated in accordance with SABS 0154-1&2:1996 for Pure-tone Audiometers.	YES
2. This audiometer is hereby certified as calibrated in accordance with ISO 389-4 for Narrow Band and Masking Noise.	NO
3. This audiometer is hereby certified as calibrated in accordance with ISO 389-7 for Sound Field System.	NO
4. This audiometer is hereby certified as calibrated in accordance with IEC 645-2 for Speech Audiometry.	NO
5. **Remarks : ---------**	
Certificate expires on:	24-05-2000

NOTES

1. This certificate is valid for a period of 12 months(subject to exceptions given in SABS 0154-1996,section 6)
2. This certificate relates only to the specific item(s) listed above and does not imply compliance in respect of a similar item that has not been examined.
3. While every endeavour is made to ensure that this certificate is accurate, NS Clinical Technologies cc or its representatives shall in no way be liable for any errors, whether in fact or opinion.

SIGNATURE

24-05-1999

DATE

Members: Neil Schalkwyk, William de Klerk

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Calibration Officer: **Neil Schalkwyk**	Cert. No: 395/NS/99

SITE OF CALIBRATION

Company	TECHNIKON FREE STATE
Address	PRIVATE BAG X20539
	BLOEMFONTEIN
	9300

UNIT UNDER CALIBRATION

SUBJECT	MAKE	MODEL	SERIAL NO.
Audiometer	TREMETRICS	RA 400	935318
Earphone Left	TELEPHONICS	TDH-39P	B 06240
Earphone Right	TELEPHONICS	TDH-39P	
Bone Vibrator	RADIO EAR	B -----	------

CALBRATION EQUIPMENT

ITEM	MODEL	SERIAL NO.
Sound Level Meter	Quest 1800	HP 5120015
Sound Level Calibrator	Quest QC-20	QE 8020016
1/3 Octave Filter	Quest OB-300	HV 6010011
Frequency Counter	Goldstar DM 332	332019443
Artificial Ear	Bruël & Kjaer 4153	1877747
Calibration date : APRIL 1999	Calibration Cert. No:AV\AS 1969/70/71 CSIR	

TEST ENVIRONMENT CONDITIONS

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Calibration Signal: Before: 114.0dB.	Calibration Signal: After: 114.0Db.

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5. **Remarks :** ---------	
Certificate expires on:	24-05-2000

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SITE OF CALIBRATION

Company	TECHNIKON FREE STATE
Address	PRIVATE BAG X20539
	BLOEMFONTEIN
	9300

UNIT UNDER CALIBRATION

SUBJECT	MAKE	MODEL	SERIAL NO.
Audiometer	TREMETRICS	RA 400	945427
Earphone Left	TELEPHONICS	TDH-39P	B 34178
Earphone Right	TELEPHONICS	TDH-39P	B 34165
Bone Vibrator	RADIO EAR	B -----	------

CALBRATION EQUIPMENT

ITEM	MODEL	SERIAL NO.
Sound Level Meter	Quest 1800	HP 5120015
Sound Level Calibrator	Quest QC-20	QE 8020016
1/3 Octave Filter	Quest OB-300	HV 6010011
Frequency Counter	Goldstar DM 332	332019443
Artificial Ear	Bruël & Kjaer 4153	1877747
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5. **Remarks :** ---------	
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24 May 1999

Attention : Mr D van den Heever

TECHNIKON FREE STATE
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EVALUATION OF AUDIOMETRIC TEST SITE

1. Purpose of Test

To determine if the proposed site would meet the requirements of *SABS Code of Practice 0182-1998* "Obtaining an Acoustic Environment suitable for Audiometric Testing".

2. Test Site

The sound level measurements were performed by Mr N Schalkwyk on 24 May 1999 in the laboratory of the Environmental Science Department of the Technikon Free State in Bloemfontein. The sound level measurements were performed inside the Audiometric Test Enclosure which is situated in the laboratory.

3. Test Equipment

1.	Sound Level Meter:	Quest 1800	#HP 5120015
2.	Sound Level Calibrator:	Quest QC-20	#QE 8020016
3.	Octave Band Filter:	Quest OB300	#HV 60100115
4.	Microphone:	Quest 4146	#17893

The equipment was certified as accurate by the CSIR in April 1999. The calibration certificate number for the above mentioned equipment is AV\AS-1969

Calibration Signal: Before: 114,0dB After: 114,0dB.

4. Test Procedure

The test procedure outlined in SABS 0182-1998 paragraph 5.5 was followed to obtain the readings noted in table 1.

Central University of Technology, Free State

5. Test Results

Octave Band Frequencies (Hz)	Maximum Sound Pressure Level Allowed in dB (SABS – 0182)	Sound Pressure Levels Obtained at Test Site (dB)
125	52.0	41.2
250	38.5	33.1
500	22.0	19.8
1000	24.0	18.4
2000	31.0	16.5
4000	37.0	15.2
8000	35.5	17.1

TABLE .1.

6. Conclusion

As can be seen from the above results the measured sound pressure levels are all below the recommended sound pressure levels for industrial screening audiometry according to SABS 0182-1998. The audiometric booth is therefore suitable for industrial screening audiometry.

Best Regards

NEIL SCHALKWYK

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CSIR

Custodian of the
national measuring standards

National Metrology Laboratory

CERTIFICATE OF CONFORMANCE

No: AV\AS-1962

Calibration of	: IMPULSE INTEGRATING SOUND LEVEL METER ½" MICROPHONE SOUND LEVEL CALIBRATOR ⅓ OCTAVE BAND FILTER OCTAVE BAND FILTER
Manufacturer	: QUEST
Model Nos	: 1800, 4150, CA-22 & OB-300
Serial Nos	: HP2050009, 13648, J2050045 & HV2060001
Calibrated for	: FREE STATE TECHNIKON
Calibration procedures	: NML-AV\AS-0007 Rev 1A NML-AV\AS-0008 Rev 1A NML-AV\AS-0009 Rev 1A NML-AV\AS-0010 Rev 1A
Date of calibration	: April 1999
Date of issue	: 15 April 1999
Calibrated by	: E Struthers (012) 841-3698
Checked by (Project Leader)	: C S Veldman
No of pages	: 4

(for Director)

ANNEX F

- **Standard Number:** 1910.95 App C
- **Standard Title:** Audiometric measuring instruments
- **SubPart Number:** G
- **SubPart Title:** Occupational Health and Environmental Control

This Appendix is Mandatory

1. In the event, that pulsed-tone audiometers are used, they shall have a tone on-time of at least 200 milliseconds.

2. Self-recording audiometers shall comply with the following requirements:

(A) The chart upon which the audiogram is traced shall have lines at positions corresponding to all multiples of 10 dB hearing level within the intensity range spanned by the audiometer. The lines shall be equally spaced and shall be separated by at least 1/4 inch. Additional increments are optional. The audiogram pen tracings shall not exceed 2 dB in width.

(B) It shall be possible to set the stylus manually at the 10-dB increment lines for calibration purposes.

(C) The slewing rate for the audiometer attenuator shall not be more than 6 dB/sec except that an initial slewing rate greater than 6 dB/sec is permitted at the beginning of each new test frequency, but only until the second subject response.

(D) The audiometer shall remain at each required test frequency for 30 seconds (+ or - 3 seconds). The audiogram shall be clearly marked at each change of frequency and the actual frequency change of the audiometer shall not deviate from the frequency boundaries marked on the audiogram by more than + or - 3 seconds.

(E) It must be possible at each test frequency to place a horizontal line segment parallel to the time axis on the audiogram, such that the audiometric tracing crosses the line segment at least six times at that test frequency. At each test frequency the threshold shall be the average of the midpoints of the tracing excursions.

- **Standard Number:** 1910.95 App D
- **Standard Title:** Audiometric test rooms
- **SubPart Number:** G
- **SubPart Title:** Occupational Health and Environmental Control

This Appendix is Mandatory

Rooms used for audiometric testing shall not have background sound pressure levels exceeding those in Table D-1 when measured by equipment conforming at least to the Type 2 requirements of American National Standard Specification for Sound Level Meters, S1.4-1971 (R1976), and to the Class II requirements of American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, S1.11-1971 (R1976).

TABLE D-1 - MAXIMUM ALLOWABLE OCTAVE-BAND SOUND PRESSURE LEVELS FOR AUDIOMETRIC TEST ROOMS

Octave-band center Frequency (Hz)	500	1000	2000	4000	8000
Sound pressure level (dB)	40	40	47	57	62

- **Standard Number:** 1910.95 App E
- **Standard Title:** Acoustic calibration of audiometers
- **SubPart Number:** G
- **SubPart Title:** Occupational Health and Environmental Control

This Appendix is Mandatory

Audiometer calibration shall be checked acoustically, at least annually, according to the procedures described in this appendix. The equipment necessary to perform these measurements is a sound level meter, octave-band filter set, and a National Bureau of Standards 9A coupler. In making these measurements, the accuracy of the calibrating equipment shall be sufficient to determine that the audiometer is within the tolerances permitted by American Standard Specification for Audiometers, S3.6-1969.

(1) "Sound Pressure Output Check"

A. Place the earphone coupler over the microphone of the sound level meter and place the earphone on the coupler.

B. Set the audiometer's hearing threshold level (HTL) dial to 70 dB.

C. Measure the sound pressure level of the tones at each test frequency from 500 Hz through 6000 Hz for each earphone.

D. At each frequency the readout on the sound level meter should correspond to the levels in Table E-1 or Table E-2, as appropriate, for the type of earphone, in the column entitled "sound level meter reading."

(2) "Linearity Check"

A. With the earphone in place, set the frequency to 1000 Hz and the HTL dial on the audiometer to 70 dB.

B. Measure the sound levels in the coupler at each 10-dB decrement from 70 dB to 10 dB, noting the sound level meter reading at each setting.

C. For each 10-dB decrement on the audiometer the sound level meter should indicate a corresponding 10 dB decrease.

D. This measurement may be made electrically with a voltmeter connected to the earphone terminals.

(3) "Tolerances"

When any of the measured sound levels deviate from the levels in Table E-1 or Table E-2 by + or - 3 dB at any test frequency between 500 and 3000 Hz, 4 dB at 4000 Hz, or 5 dB at

6000 Hz, an exhaustive calibration is advised. An exhaustive calibration is required if the deviations are greater than 15 dB or greater at any test frequency.

- **Standard Number:** 1910.95 App G
- **Standard Title:** Monitoring noise levels non-mandatory informational appendix
- **SubPart Number:** G
- **SubPart Title:** Occupational Health and Environmental Control

This appendix provides information to help employers comply with the noise monitoring obligations that are part of the hearing conservation amendment.

WHAT IS THE PURPOSE OF NOISE MONITORING?

This revised amendment requires that employees be placed in a hearing conservation program if they are exposed to average noise levels of 85 dB or greater during an 8 hour workday. In order to determine if exposures are at or above this level, it may be necessary to measure or monitor the actual noise levels in the workplace and to estimate the noise exposure or "dose" received by employees during the workday.

WHEN IS IT NECESSARY TO IMPLEMENT A NOISE MONITORING PROGRAM?

It is not necessary for every employer to measure workplace noise. Noise monitoring or measuring must be conducted only when exposures are at or above 85 dB. Factors which suggest that noise exposures in the workplace may be at this level include employee complaints about the loudness of noise, indications that employees are losing their hearing, or noisy conditions which make normal conversation difficult. The employer should also consider any information available regarding noise emitted from specific machines. In addition, actual workplace noise measurements can suggest whether or not a monitoring program should be initiated.

HOW IS NOISE MEASURED?

Basically, there are two different instruments to measure noise exposures: the sound level meter and the dosimeter. A sound level meter is a device that measures the intensity of sound at a given moment. Since sound level meters provide a measure of sound intensity at only one point in time, it is generally necessary to take a number of measurements at different times during the day to estimate noise exposure over a workday. If noise levels fluctuate, the amount of time noise remains at each of the various measured levels must be determined.

To estimate employee noise exposures with a sound level meter it is also generally necessary to take several measurements at different locations within the workplace. After appropriate sound level meter readings are obtained, people sometimes draw "maps" of the sound levels within different areas of the workplace. By using a sound level "map" and information on employee locations throughout the day, estimates of individual exposure levels can be developed. This measurement method is generally referred to as "area" noise monitoring.

A dosimeter is like a sound level meter except that it stores sound level measurements and integrates these measurements over time, providing an average noise exposure reading for a given period of time, such as an 8-hour workday. With a dosimeter, a microphone is attached to the employee's clothing and the exposure measurement is simply read at the end of the desired time period. A reader may be used to read-out the dosimeter's measurements. Since the dosimeter is worn by the employee, it measures noise levels in those locations in which the employee travels. A sound level meter can also be positioned within the immediate vicinity of the exposed worker to obtain an individual exposure estimate. Such procedures are generally referred to as "personal" noise monitoring.

Area monitoring can be used to estimate noise exposure when the noise levels are relatively constant and employees are not mobile. In workplaces where employees move about in different areas or where the noise intensity tends to fluctuate over time, noise exposure is generally more accurately estimated by the personal monitoring approach.

In situations where personal monitoring is appropriate, proper positioning of the microphone is necessary to obtain accurate measurements. With a dosimeter, the microphone is generally located on the shoulder and remains in that position for the entire workday. With a sound level meter, the microphone is stationed near the employee's head, and the instrument is usually held by an individual who follows the employee as he or she moves about.

Manufacturer's instructions, contained in dosimeter and sound level meter operating manuals, should be followed for calibration and maintenance. To ensure accurate results, it is considered good professional practice to calibrate instruments before and after each use.

HOW OFTEN IS IT NECESSARY TO MONITOR NOISE LEVELS?

The amendment requires that when there are statistically significantly changes in machinery or production processes that may result in increased noise levels, remonitoring must be conducted to determine whether additional employees need to be included in the hearing conservation program. Many companies choose to remonitor periodically (once every year or two) to ensure that all exposed employees are included in their hearing conservation programs.

Central University of Technology, Free State

ANNEX G

PERSONAL DETAILS:
SURNAME:______________________________
NAME:______________________________
DATE OF BIRTH:____/____/19___
IN SERVICE:____/____/19___
EMPLOYEE NR.:______________________________
FACULTY:______________________________
DEPARTMENT:______________________________
POSITION:______________________________
STATE OF HEARING:
1. Evaluation of hearing: Good (G) Fair (F) Poor (P):______________
2. Which one is the best? Left (L) Right (R):______________

	YES	NO
3. Noise in ear?		
4. Deafness in family?		
5. Second job?		
6. Noisy hobbies?		
7. Head injuries?		
8. Ear infection?		
9. Dizzy spell?		
10. Ear surgery?		
11. Measles?		
12. Mumps?		
13. Scarlet fever?		
14. Previous hearing test?		
15. Physician's care for ear problem?		
16. Reason?		
17. Noise at previous job?		
18. When?		
19. Years?		
20. Previous employer?		
21. Hearing conservation program?		
22. Ear protection?		
23. Type of noise?		
24. Hearing test?		
25. Date of last test?		
26. Noise at present job?		
27. Type of noise?		

28. Otoscopic examination:______________________________
29. Any other information:______________________________