



**THE ADJUSTED CORRECTIVE CONSTANT FACTOR
FOR AUDIOMETRIC TEST**

CHARIN YENJAI

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จาก
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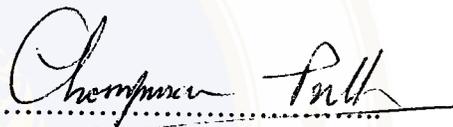
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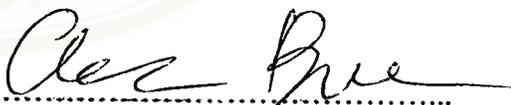
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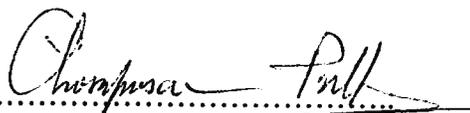
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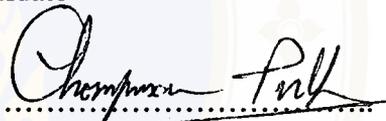
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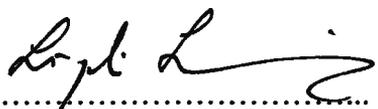
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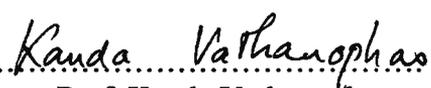
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**KEY WORDS : AUDIOMETRIC TEST/ AMBIENT NOISE LEVELS IN /
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One obstacle in performing field audiometric testing is the unavailability of the mobile laboratory or booth. Thus, most of the time audiometric testing is performed in a room with substandard background noise levels. This study aimed to investigate correction factors to adjust for background noise levels in order to have more accurate audiometric measurements.

This study was a comparative experimental study of normal hearing thresholds and hearing thresholds masked by ambient noise at the frequencies of 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. Sixty one subjects were selected from college students whose ages were 17-23 years old and had audiometric thresholds less than 25 dB at all frequencies. Various maskings of broadband noise at the levels of 40, 50, 60, 70, and 80 dB were generated into the test booth in order to see the impact on the pattern of hearing threshold.

Results of the study revealed that the hearing threshold shift depended upon the level of ambient noise present. At all frequencies, the hearing threshold shift showed significant difference from normal hearing threshold at 60 dB ambient noise level except that at the test of 1000 Hz frequency with 50 dB level. Prediction equations of a change in the hearing threshold shift were as follows: at the frequencies of 500, 1000, 2000 and 3000 Hz, $\hat{Y} = 17.9986 - .9883x + 0.0131x^2$ with .939 coefficient of determination (R^2); at the frequencies of 4000 and 6000 Hz, $\hat{Y} = 22.4775 - 1.0576x - 0.0124x^2$ with $R^2 = .983$; at the frequency of 8000 Hz, $\hat{Y} = 18.5546 - .8285x + 0.0095x^2$ with $R^2 = .980$ (\hat{Y} = hearing threshold shift and X = ambient noise levels [dB(A)]). The adjusted corrective constant factors were demonstrated as both a graphic form and a table form for field practice. Field investigation to determine the actual hearing threshold shift by using the quadratic equation or correction factor in the workplace should also be undertaken.

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ปัญหาในการตรวจวัดสมรรถภาพการได้ยินในโรงงานประการหนึ่งคือ การไม่มีผู้ทดสอบเข้าไปในภาคสนาม เนื่องจากผู้ตั้งกล่าวมีขนาดใหญ่ และน้ำหนักมาก ทำให้การเคลื่อนย้ายทำได้ลำบาก ในทางปฏิบัติจึงมักใช้ห้องที่เงียบที่สุดแทนผู้ทดสอบ ซึ่งห้องดังกล่าวอาจมีระดับเสียงเกินมาตรฐานที่ American National Standard Institute (ANSI) กำหนด ทำให้ผลการตรวจวัดระดับการได้ยินคลาดเคลื่อนได้ ดังนั้นการหาค่าปรับคงที่เมื่อมีระดับเสียงในห้องทดสอบต่าง ๆ กัน จะช่วยให้ค่าการตรวจวัดใกล้เคียงกับความเป็นจริงมากขึ้น

ในการศึกษาครั้งนี้เป็นการศึกษาเชิงทดลองเพื่อเปรียบเทียบระดับการได้ยินปกติ กับระดับการได้ยินที่เปลี่ยนแปลงไปเมื่อมีเสียงรบกวน โดยทำการตรวจวัดระดับการได้ยินของนักศึกษาจำนวน 61 คน อายุระหว่าง 17-23 ปี ซึ่งเป็นผู้ที่มีระดับการได้ยินปกติ (ไม่เกิน 25 dB ในทุกความถี่) ที่ความถี่ 500 Hz 1,000 Hz 2,000 Hz 3,000 Hz 4,000 Hz 6,000 Hz และ 8,000 Hz จากนั้นวัดระดับการได้ยินเมื่อมีเสียงรบกวน (broad band noise) ที่ระดับความดังต่าง ๆ 5 ระดับ คือ 40 dB, 50 dB, 60 dB, 70 dB และ 80 dB แล้วนำระดับการได้ยินที่เปลี่ยนแปลงไปเปรียบเทียบกับระดับการได้ยินปกติเพื่อคำนวณหาค่าปรับคงที่

ผลการทดลองพบว่า ระดับการได้ยินจะเปลี่ยนแปลงไปในทิศทางเดียวกับระดับความดังของเสียงรบกวน ระดับการได้ยินที่ทุกความถี่จะเริ่มเปลี่ยนแปลงไปที่ระดับเสียงรบกวน 60 dB ยกเว้นที่ความถี่ 1,000 Hz จะเริ่มเปลี่ยนแปลงที่ 50 dB สมการทำนายค่าระดับการได้ยินที่เปลี่ยนแปลงไปที่ความถี่ 500 Hz, 1,000 Hz 2,000 Hz และ 3,000 Hz คือ $\hat{Y} = 17.9986 - .9983x + 0.0131x^2$ มีค่าสัมประสิทธิ์การตัดสินใจ (R^2) เท่ากับ .939, ที่ความถี่ 4,000 Hz และ 6,000 Hz คือ $\hat{Y} = 22.4775 - 1.0576x + 0.0124x^2$ มีค่าสัมประสิทธิ์การตัดสินใจ (R^2) เท่ากับ .983, ที่ความถี่ 8,000 Hz คือ $\hat{Y} = 18.5546 - .8285x + 0.0095x^2$ มีค่า สัมประสิทธิ์การตัดสินใจ (R^2) เท่ากับ .980. โดยที่ \hat{Y} คือ ระดับการได้ยินที่เปลี่ยนแปลงไปเมื่อมีเสียงรบกวน และ X คือระดับความดังของเสียงรบกวน dB(A) ค่าปรับคงที่จากการคำนวณได้ถูกนำมาสร้างเป็นตาราง และกราฟ เพื่อประโยชน์ต่อการปฏิบัติงานในภาคสนาม

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CHAPTER I

INTRODUCTION

In Thailand, noise is one of the greatest hazards in the workplace. Noise affects people in many ways. The most serious consequence of exposure to excessive noise levels is hearing damage. Noise also has physiological effects; different studies indicated that respiratory, cardiovascular, digestive, glandular and neurological disorders were related to noise exposure, but these disorders were not direct effects of noise exposure.

The prevention of noise induced hearing loss is a major concern in many industries. The methods for achieving this prevention is to controlling at the source by reducing noise level and using Hearing Protective Devices (HPDs). This is not always possible, due to engineering or economic constrains and workers cooperation. For this reason, Hearing Conservative Program (HCP) is designed for protection of hearing loss due to the assessive noise exposure. One of the most important protocol for HCP programe is to provide hearing measurement using a pure tone audiometer. Pure tone audiometric protocol should be conducted in an environment that will insure the validity of test measurements. This means that the background noise level in the test booth must be lower than that which will mask or interfere with the pure tone thresholds of every tested frequencies.

However, this is unpractical to carry test booth to the field, due to heavy weight and big size. Thus before conducting the test, ambient noise in the test room must be evaluated. If the ambient sound level in the test room is too high, the test signal may be masked by it.

The recommendation from The Division of Occupational Health, Ministry of Public Health for audiometric test indicated that ambient noise level must be less than 40 dB at all frequencies. (8)

The purpose of this study is to describe the correlation between ambient noise generated in test booth and hearing threshold shift to establish the correction factor for audiometric test.

1.1 General objective

The general objective of this study is to investigate the hearing threshold shift pattern when masked by ambient noise in audiometric test.

1.2 Specific objectives

1.2.1 To study the correlation between ambient noise in test room and hearing threshold shift.

1.2.2 To establish the adjusted correction factors for audiometric test.

1.3 Variables

1.3.1 Independent variables

- 1.3.1.1 Broadband noise levels of 40,50,60,70 and 80 dB(A)

1.3.2 Dependent variables

- 1.3.2.1 Hearing threshold shift.

1.3.3 Control variables

- 1.3.3.1 Subject age (17-23 years old)

- 1.3.3.2 Subject hearing threshold less than 25 dB HL at 0.5,1,2,3,4,6 and 8 KHz

- 1.3.3.3 Health status

During audiometric measurement, the subjects have to be in decent health condition, not inflicting any diseases or abnormalities.

1.3.3.4 Ear diseases

Subjects must not have a history of any ear problems such as pain, drainage, ear diseases or excessive wax build-up, otitis, fullness sensation, tinnitus.

1.3.3.5 Medication affecting hearing threshold

During the measurement, subjects must not take medications which may affect hearing, this includes diuretics drug, antiseptic drug (streptomycin, kanamycin, neomycin), anti-inflammatory, antimalarials, and antineoplastic agents.

1.3.3.6 Temperature (20-28 °C)

1.3.3.7 Pressure (Atmospheric pressure)

1.4 Definitions

Ambient noise

Noise level in audiometric test room. In this study the ambient noise is broadband noise.

Sound pressure level (SPL)

A measure of the ratio of a sound wave relative to a reference sound pressure. Sound pressure level in decibels is typically referenced to 20 μ Pa. When used alone, (e.g.,90 dBSPL) a given decibel level implies an unweighted sound pressure level

Threshold Shift

Audiometric monitoring programs will encounter two types of changes in hearing sensitivity namely: permanent threshold shift (PTS) and temporary threshold shift (TTS). As the name implied, any change in hearing sensitivity which is persistent is considered a PTS. Persistence may be assumed if the change is still observed on a 30-day follow-up examination. Exposure to loud noise may cause a temporary worsening in hearing sensitivity (i.e, a TTS) that may persist for 14 hours (or even longer in cases where the duration of exposure exceeded

12 to 16 hours). Audiologist need to recognize that not all threshold shifts represent decreased sensitivity, and not all temporary or permanent threshold shifts are due to noise exposure. When a permanent threshold shift can be attributed to noise exposure, it may be referred to as a noise-induced permanent threshold shift (NIPTS).

Sound Level Meter (SLM)

A device which measures sound and provides a readout of the resulting measurement.

Hearing Loss

Hearing loss is sometimes characterized by the area of the auditory system responsible for the loss. Hearing loss is referred to as a sensorineural loss. Noise can damage the tiny hair cells located in the cochlea, it causes asensorineural hearing loss. In this study it refered to as an air type conductive hearing loss.

Hz (Hertz)

The unit of measurement for audio frequencies. The frequency range for human hearing lies between 20 Hz and approximately 20000 Hz. The sensitivity of the human ear drops off sharply below about 500 Hz and above 4 000 Hz.

- Decibel (dB)** The unit used to express the intensity of sound. The decibel scale is a logarithmic scale in which 0 dB approximates the threshold of hearing in the mid frequencies of young adults.
- Pure Tone Audiometry (PTA)** Pure Tone audiometry is the measurement of an individual's threshold of hearing for pure tone in which the signal presentations, frequencies, and levels are controlled manually by the person administering the test.
- Masking** Masking occurs when any noise or sound of any type interferes with the audibility of another sound.
- Boardband Noise (BBN)** Broadband noise contains a wide band of frequencies at intervals of 1 Hz with approximately the same intensity
- Hearing Conservative Program** An effective hearing program is one that prevents hearing impairment as a result of exposure to noise while at work. With respect to existing workers

compensation laws, an effective hearing program is one that limits the amount of compensatory hearing loss in the frequency range over which normal hearing is necessary in order to communicate. For compliance with OSHA requirements, an effective hearing conservative program is required if an employee's noise exposure exceeds current limits as defined in the OSHA standard 29 CFR 1910.95

CHAPTER II

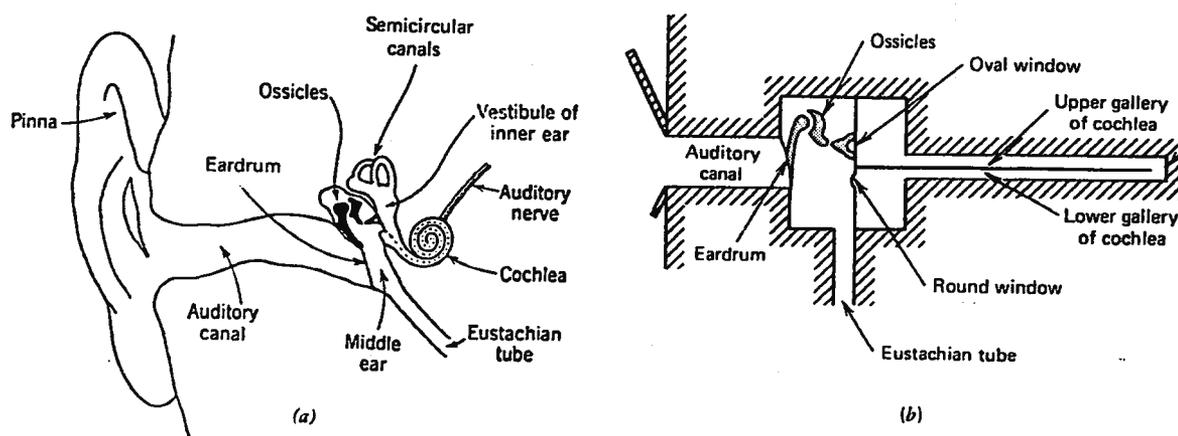
LITERATURE REVIEW

The ear (1) (9)

The properties of the human ear are phenomenal. The ear is capable of responding over a frequency range from approximately 20 Hz to 20 KHz, and at 1 KHz, sound that displace the eardrum only by one-tenth of the diameter of the hydrogen molecule can be detected. However, it is much more than a sensitive, broadband receiver. In conjunction with the nervous system, it acts as a frequency analyzer of enviable selectivity.

The human ear (Fig.2-1) is one of the most intricate and delicate mechanical structures in the human body. It consists of three main parts: the outer, middle, and inner ear.

Figure 2-1 Sketch of the ear.



The inner ear (labyrinth) has three parts: the vestibule (entrance chamber), the semicircular canals, and the cochlea. The vestibule connects with the middle ear through two openings, the oval window and the round window. Both of these windows are sealed to prevent the escape of the liquid filling the inner ear; the former by the stapes and its support, and the latter by a thin membrane. With these two exceptions, the entire inner ear is surrounded by bone. (The semicircular canals play no part in the process of hearing; they provide us with a sense of balance.) The cochlea is a tube of roughly circular cross section, wound in the shape of a snail shell. This tube makes about 2.5 turns and has a total length of about 3.5 cm. Its cross-sectional area decreases in a somewhat irregular manner from its base to its apex. Its volume is approximately 0.05 cm^3 .

The tube of the cochlea is divided by the cochlea partition into two longitudinal channels: the upper gallery (scala vestibuli) and the lower gallery (scala tympani). The only communication between the two galleries is through the helicotrema, a small opening at the apex of the cochlea. The other ends of the upper and lower galleries connect with the oval and round windows, respectively.

When the ear is exposed to a pure tone, the motion of the eardrum is transmitted by the bones of the middle ear to the oval window, creating a fluid (in cochlea) disturbance that travels up the upper gallery toward the apex of the cochlea, through the helicotrema, into the lower gallery, and back to the round window, which acts as a pressure-release termination point. The detailed properties of this disturbance and its role in the mechanism of hearing were elucidated in a Nobel-Prize winning series of investigations by Beskesy. His experiments demonstrated that the basilar membrane is driven into highly damped motion with a peak amplitude that increases

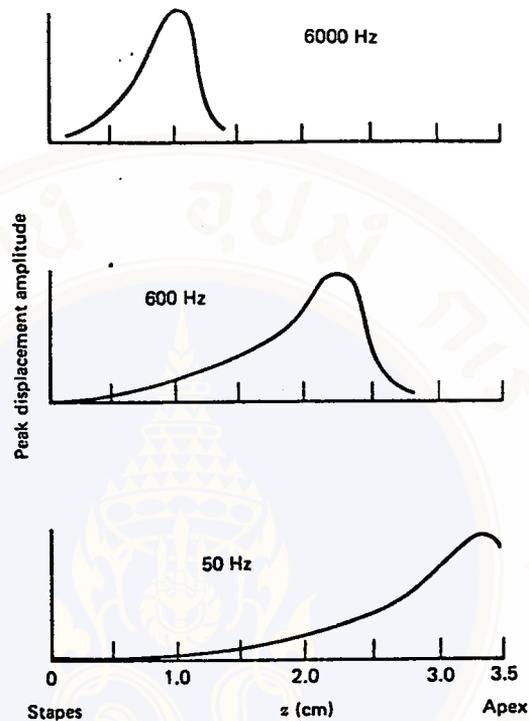
slowly with the distance away from the stapes, reaches a maximum, and then diminishes rapidly toward the apex of the cochlea. The peak amplitude maximizes closer to the apex of the cochlea for lower frequencies. A few examples are sketched in Fig.2-2 where “z” is the distance in centimetres from the stapes. The relationship of the position of the maximum peak amplitude to the frequency can be well-approximated by the following equation.

$$f = 2.5 \times 10^{4-0.72z} \quad (2.1)$$

for frequencies above approximately 200 Hz. For lower frequencies, the distance from the apex is underestimated by this equation (2.1). These motions of the basilar membrane occurs whether the mechanical excitation is produced by airborne sounds (through the eardrum, ossicles, etc.) or by sounds conducted through the skull.

Since the Organ of Corti is attached to the basilar membrane while the tectorial membrane is attached to the bony ledge, the relative motions generated between them flex the hairs, thereby exciting the nerve endings attached to the hair cells into producing electrical impulses. These nerves do not necessarily fire at the frequency with which they are excited, but quasi-randomly when they are stressed beyond certain limits, usually firing more often when highly stressed. These pulses form the information communicated from the cochlea to the brain. From each ear, information goes to a number of interlinked processing centers within the brain.

Figure 2-2 Peak displacement amplitude of the basilar membrane for pure tone



Masking (1)

Everyone is familiar with the difficulty of hearing and understanding speech in the presence of noise. The amount of masking is the amount the threshold of audibility of the signal is raised in the presence of noise.

It is simplest to begin by considering the masking of one pure tone by another. The subject is exposed to a single tone of fixed frequency and L_1 (The symbol L_1 is recommended by the International Standardization Organization (ISO) for IL re 10^{-12} W/m².) and then asked to detect another tone of a different frequency and intensity. Analysis yields the threshold shift, that is the increase in L_1 of the of the masked tone above its value for the threshold of audibility before it can be detected. Figure 2-3 gives representative results for masking frequencies of 400 and 2000 Hz. The

frequency range over which there is appreciable masking increases with the L_1 of the masker, the increase being greater for frequencies above that of the masker. This is to be expected because the region of the basilar membrane, excited into appreciable motion at moderate values of L_1 extends from the maximum further toward the stapes than the apex. For stronger excitation of the membrane both regions grow, especially the region toward the stapes more significantly; it is this region that covers the frequencies higher than that of the masker: low frequencies mask high frequencies.

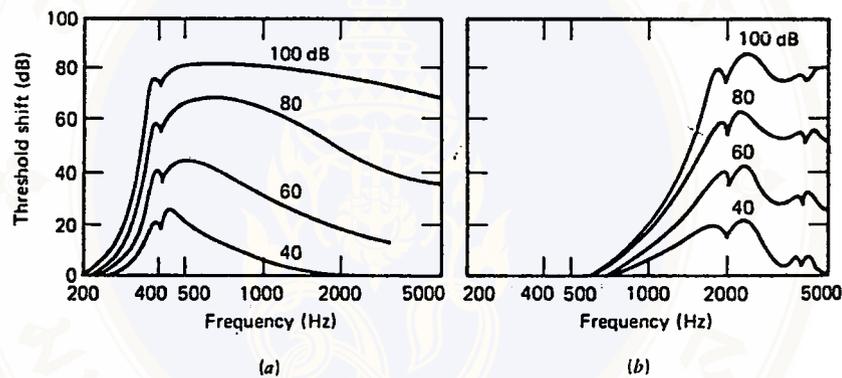


Figure 2-3 Masking of one pure tone by another. The abscissa is the frequency of the masked tone, and the curves are labeled with the L_1 of the masking tone. The frequency of the masking tone is 400 Hz in (a) and 2000 Hz in (b).

Masking of pure tones by a band of noise narrower than critical bandwidth is essentially the same as that of an equally intense pure tone having the same frequency as that at the centre of the band. Consequently, when the spectrum level is relatively constant, the intensity of a narrowband of noise is directly proportional to the bandwidth w and correspondingly, the masking expressed in decibels increases as $10 \log w$. Ultimately, the bandwidth will equal the critical bandwidth, beyond which any further increase in the bandwidth of the bandpass of the noise has little influence on the amount of masking of a pure tone at the centre of the band.

Masking Noise Used in This Study (2)

Noise has been defined as a completely unharmonic sound. Frequencies that vary randomly without any repetition in pattern are termed aperiodic. Noise consists of irregular frequencies and intensities without a clearly defined fundamental frequency as in a complex sound. The fundamental frequency is the first harmonic and exhibits the greatest energy.

Several types of noise have been used for masking over the years and each type of noise will be discussed : sawtooth (complex), white (broadband, wideband, thermal), narrowband and speech noise.

White noise is known as broadband or thermal noise. White noise contains a wide band of frequencies at intervals of 1 Hz, each with approximately the same intensity. The white noise spectrum shown in Figure 2-4 is relatively flat and is continuous until dropping rapidly beyond 6000 Hz.

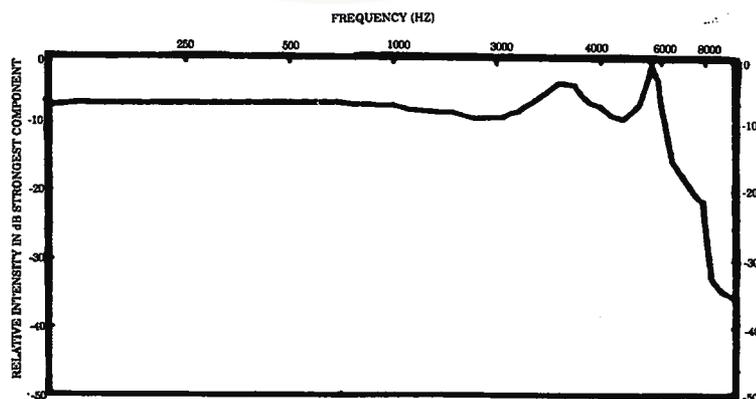


Figure 2-4 Acoustic spectrum of a broad band white noise through a TDH-39 earphone. Sanders and Rintelmann³⁶. Reprinted with the permission of the Archives of Otolaryngology.

Ambient Noise Levels in the Test Room (3)

If ambient noise levels in the test room are too high, the test signal may be masked by it. Acceptable ambient noise levels therefore depend on the type of test signal (tone, speech or other) and the test sound level to be used. How the test signals are presented is also of importance. Earphones provide a certain attenuation of the ambient noise. This frequency dependent attenuation varies with the mechanical construction of the earphone and its contact with the listener's ear or skull. The effects of the ambient noise level on puretone audiometry are most severe in the frequency range around 500 Hz.

When measuring the ambient noise levels in a test room to be used for pure-tone audiometry, it is desirable to measure in one-third octave band levels. The reason for this is that the masking of a tone by a broadband noise is mainly caused by that part of the noise which is contained in a rather limited frequency band around the test tone frequency namely, the critical band. The one-third octave band is a good technical approximation of the critical band. Sometimes only whole octave band filters may be available for the measurements. From the octave levels measured, an approximate evaluation of the usefulness of the test room for pure-tone audiometry can be made, but it will be less reliable than when one-third octave levels are known.

Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms(4)(10)

It is well known that excessive levels of ambient noise create an elevation in hearing thresholds due to masking, especially when testing listeners whose thresholds approach 0 dB HL. Unfortunately, exclusion of all ambient noise in an audiometric test room is not practical. Consequently, there is a need to specify the maximum permissible ambient noise levels (MPANLs) allowed in an audiometric test room that would produce negligible masking of sensations to pure tones presented at reference threshold levels under specified testing conditions.

MPANLs were originally specified in ANSI S3.1-1960 “Criteria for Background Noise in Audiometer Rooms” and were consistent with reference thresholds (ASA Z24.5-1951) in use at that time. ANSI S3.1-1960 was revised and ANSI S3.1-1977 “Critical for Permissible Ambient Noise During Audiometric Testing” was presented as a result of the acceptance of significantly lower reference threshold levels specified in ANSI S3.6-1969. The 1977 standard specified MPANLs in octave and one-third-octave band intervals for ears-not-covered and ears-covered conditions over a frequency range of 125-8000 Hz. Since then, additional information has become available concerning the influence of noise on hearing thresholds, the upward spread of masking, and earphone attenuation values. As a result, ANSI S3.1-1977 has been revised as ANSI S3.1-1991 “Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms.”

The MPANLs specified in ANSI S3.1-1991 were developed, taking into account new scientific information and current hearing testing practices. The new standard applies to all areas of hearing testing and also provides guidelines for distributors, installers, designers, and manufacturers of audiometric test rooms.

ANSI S3.1-1991 includes the description, specification, and measurement of MPANLs allowed in an audiometric test room that would produce negligible masking (≤ 2 dB) of test signals presented at 0 dB HL (re: ANSI S3.6-1989). The MPANLs are specified in both octave and one-third-octave band intervals for the two testing conditions and three test frequency ranges conventionally employed for audiometry. The MPANLs for each test condition and test frequency range are shown in Table 2-1 for octave and in Table 2-2 for one-third-octave band intervals. The octave band MPANLs for each test frequency range are also shown in Figure 1 for the ears-not-covered, along with the MPANLs previously specified in ANSI S3.1-1977 (for comparison).

Table 2-1 Maximum permissible ambient noise levels in octave band intervals centered at 125-8,000 Hz for ears-covered and ears-not-covered test conditions and test frequency ranges 125-8,000 Hz, 250-8,000 Hz, and 500-8,000 Hz as specified in ANSI S3.1-1991. Tabled values in dB (re: 20 μ Pa) rounded to the nearest 0.5 dB.

Octave Band Intervals	Ears Covered			Ears Not Covered		
	125-8000 Hz	250-8000 Hz	500-8000 Hz	125-8000 Hz	250-8000 Hz	500-8000 Hz
125	34.0	36.5	47.5	28.0	32.5	42.5
250	22.5	22.5	33.5	18.5	18.5	28.5
500	19.5	19.5	19.5	14.5	14.5	14.5
750	21.5	21.5	21.5	12.5	12.5	12.5
1000	26.5	26.5	26.5	14.0	14.0	14.0
1500	26.5	26.5	26.5	10.5	10.5	10.5
2000	28.0	28.0	28.0	8.5	8.5	8.5
3000	33.5	33.5	33.5	8.5	8.5	8.5
4000	34.5	34.5	34.5	9.0	9.0	9.0
6000	38.0	38.0	38.0	14.0	14.0	14.0
8000	43.5	43.5	43.5	20.5	20.5	20.5

Table 2-2 Maximum permissible ambient noise levels in one-third-octave band intervals centered at 125-8000 Hz for ears-covered and ears-not-covered test conditions and test frequency ranges 125-8,000 Hz, 250-8,000 Hz, and 500-8,000 Hz as specified in ANSI S3.1-1991. Tabled values in dB re: 20 μ Pa rounded to the nearest 0.5 dB.

1/3 Octave Band Intervals	Ears Covered			Ears Not Covered		
	125-8000 Hz	250-8000 Hz	500-8000 Hz	125-8000 Hz	250-8000 Hz	500-8000 Hz
125	29.0	31.5	42.5	23.0	27.5	37.5
250	17.5	17.5	28.5	13.5	13.5	23.5
500	14.5	14.5	14.5	9.5	9.5	9.5
800	16.5	16.5	16.5	7.5	7.5	7.5
1000	21.5	21.5	21.5	9.0	9.0	9.0
1600	21.5	21.5	21.5	5.5	5.5	5.5
2000	23.0	23.0	23.0	3.5	3.5	3.5
3150	28.5	28.5	28.5	3.5	3.5	3.5
4000	29.5	29.5	29.5	4.0	4.0	4.0
6300	33.0	33.0	33.0	9.0	9.0	9.0
8000	38.5	38.5	38.5	15.5	15.5	15.5

The two audiometric test conditions in the new standard are similar to those in the previous standard and are still known as ears-not-covered and ears-covered. The ears-not-covered MPANLs apply when either one or both ears are not covered with an earphone with a supra-aural cushion. Testing with one ear not covered would typically occur during bone-conduction audiometry when using mastoid placement of a bone vibrator with an earphone placed on the opposite ear for the purpose of masking. Testing with both ears not covered would typically occur during soundfield audiometry. The ears-covered MPANLs apply when both ears are covered simultaneously with earphones, as would typically occur during air-conduction audiometry.

In contrast with the previous standard, the new standard recognizes that hearing testing can be conducted for several purposes that do not require testing over the entire frequency range from 125 to 8000 Hz. Consequently, ANSI S3.1-1991 specifies MPANLs in reference to three test frequency ranges both for ears-not-covered and ears-covered test conditions. The three test frequency ranges are 125-8000 Hz, 250-8000 Hz, and 500-8,000 Hz. Inspection of Tables 2-1 and 2-2 and Figures 2-4 and 2-5 reveal that higher MPANLs are allowed at 125 Hz for the 250-8000 Hz range and at 125 and 250 Hz for the 500-8000 Hz range, compared with the MPANLs for the 125-8000 Hz range. This was done because excessive low-frequency ambient noise can influence hearing thresholds at higher frequencies due to the upward spread of masking. The MPANLs at 125 Hz for the 250-8000 Hz range and the MPANLs at 125 and 250 Hz for the 500-8000 Hz range are based on the

assumption that the upward spread of masking would produce negligible masking for the lowest frequency pure tone within the test frequency range. It was assumed, further, that the slope for the upward spread of masking function is 14 dB/octave below the lowest test frequency (Berry,1973). Consequently, the MPANL one octave below the lowest test frequency range (125 Hz for the 250-8000 Hz range, 250 Hz for the 500-8,000 Hz) is equal to the lowest test frequency MPANL plus 14 dB. Accordingly, the MPANL two octaves below the lowest test frequency (125 Hz for the 500-8,000 Hz range) is equal to the lowest test frequency MPANL plus 28 dB.

To elaborate on a point made previously, the ears-covered MPANLs apply when both ears are covered simultaneously by earphones, and the ears-not-covered levels apply when testing is conducted with either one or both ears not covered by an earphone. At each center frequency shown in Table 2-1 and 2-2, the ears-covered MPANL exceeds the ears-not-covered MPANL by the amount of attenuation supplied by a typical earphone in a supra-aural cushion. Figure 2-7 compares the earphone attenuation values used in the present and previous standards. In the present standard, the earphone attenuation values were derived from several studies (Aringer, 1986; Berger & Killion, 1989; Frank & Wright, 1990) that provide attenuation values using narrow bands of noise presented in a diffuse sound field, according to current standardized methods (ANSI S12.6-1984 or ISO 4869-1981). Furthermore, in each study the earphones were fitted by the experimenter, reflecting standard audiometric practice. Inspection of Figure 2-7 reveals that the ANSI S3.1-1991 earphone attenuation values are lower (less attenuation) than those used in ANSI S3.1-1997.

This occurs because the previous attenuation values were determined, for the most part, using pure tones presented in a free field and listener-fitting procedures to obtain maximum attenuation, a practice that does not reflect typical clinical procedure.

The new MPANLs were derived using the same principles employed previously and are described in both documents. The ANSI S3.1-1991 ears-not-covered MPANLs, as shown in Figure 2-5, are the same as those previously specified in ANSI S3.1-1997 for the 125-8,000 Hz test frequency range. Obviously, this occurred because they were derived using the same values and calculations. The new ears-covered levels in the 1977 standard, except that the new earphone attenuation values were added. Figure 2-6 reveals that the ANSI S3.1-1991 MPANLs for the 125-8,000 Hz test frequency range are lower than previously specified in ANSI S3.1-1977. The differences are due to the fact that the earphone attenuation values used in the new standard are lower (less attenuation) than used in the previous standard. Thus, the ears-covered MPANLs specified in ANSI S3.1-1991 are lower than those previously specified in ANSI S3.1-1977.

It is important to point out that the MPANLs shown in Tables 2-1 and 2-2 are for monaural listening. When binaural listening occurs, 3 dB should be subtracted from the levels in Tables 2-1 and 2-2 to account for binaural summation. This typically would be case when neither ear is covered for sound-field testing or when both ears are covered by earphones and binaural thresholds or other binaural measurements are obtained.

Figure 2-5 ANSI S3.1-1991 ears-not-covered octave band maximum permissible ambient noise levels for each test frequency range and ANSI S3.1-1977 levels for comparison.

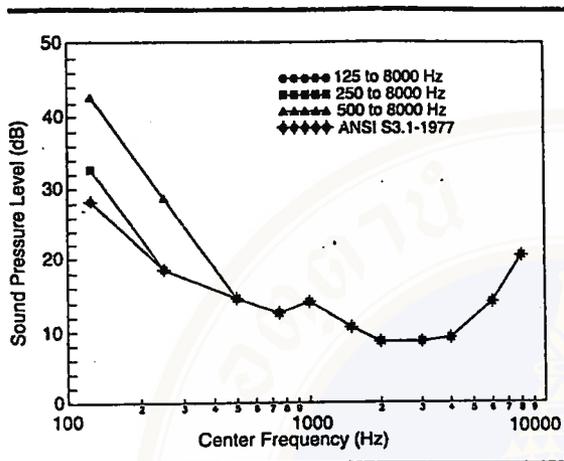


Figure 2-6 ANSI S3.1-1991 ears-covered octave band maximum permissible ambient noise levels for each test frequency range and ANSI S3.1-1977 levels for comparison.

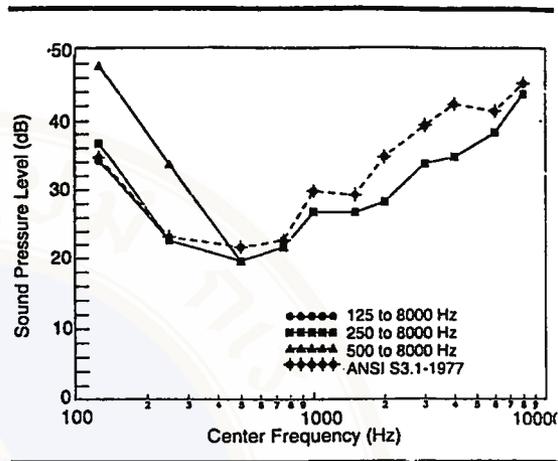
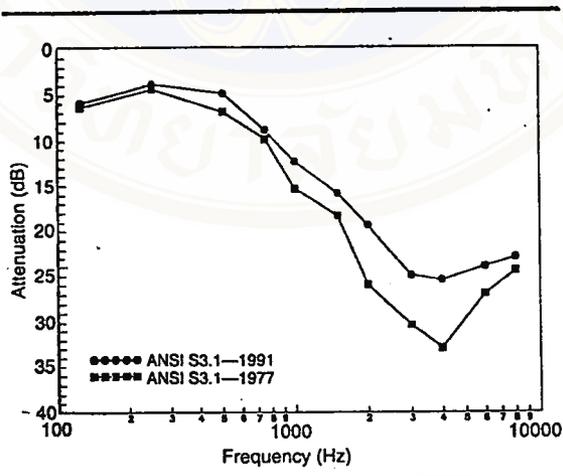


Figure 2-7 Earphone attenuation values used in ANSI S3.1-1991 and in ANSI S3.1-1977 for comparison.



ANSI S3.1-1991 assumes that hearing thresholds measured at 0 dB HL will not be masked if the ambient noise levels in an audiometric test room are equal to or less than the levels shown in Tables 2-1 or 2-2. However, when the unmasked thresholds, some listeners' masked thresholds might be elevated by as much as 2 dB (Berger & Kerivan, 1983; Berger, 1986, Berger & Killion, 1989). As such, the MPANLs shown in Tables 2-1 and 2-2 have a maximum uncertainty of 2 dB, as mentioned previously. Stated another way, a maximum threshold shift no greater than 2 dB may occur when pure-tone thresholds of 0 dB HL are obtained in an audiometric test room having ambient noise levels equal to those shown in Tables 2-1 or 2-2. The MPANLs previously specified had a maximum uncertainty of 1 dB.

Ambient noise levels in an audiometric test room should be measured annually and whenever any new noise source is operating within or in the vicinity of the test room. The measurements should be done with a Type I sound level meter (ANSI S1.4-1983) fitted with an octave or one-third-octave band filter or equivalent (ANSI S1.11-1986). The microphone of the sound level meter (SLM) should be placed at the location(s) normally occupied by the listener's head. All possible noise sources should be operating during the measurements, including intake and outtake exhaust fans and other ventilation systems, lights and any instrumentation inside and outside the audiometric test room. ANSI S3.1-1991 specifies that "octave or one-third-octave band measurements of the ambient noise must be obtained within the inclusive range of 125-8000 Hz regardless of the test condition or test frequency range to be employed" in the audiometric test room. Therefore, the mandated frequency range of measurement (125-8000 Hz) is independent of the test frequency range to be

employed, for example, 250-8000 Hz or 500-8000 Hz. Again, this is in deference to the upward spread of masking. If a SLM and filter are not available, a psychoacoustic check of the ambient noise levels using at least two listeners with normal hearing (as defined in ANSI S3.1-1991) can be substituted, but only for the ears-covered condition.

To verify compliance, the ambient noise sound pressure levels measured in the test room from 125 to 8,000 Hz are compared with the levels shown in Tables 2-1 or 2-2 in reference to the test condition and test frequency range to be employed in that test room. If the measured ambient noise sound pressure levels do not exceed the levels shown in Tables 2-1 or 2-2 for the test condition and test frequency range to be employed, the test room is acceptable for testing at hearing levels ≥ 0 dB. As a matter of fact, if the measured ambient noise levels do not exceed the MPANLs shown in Tables 2-1 or 2-2 ears-not-covered and the 125-8,000 Hz frequency range, the test room is acceptable for all test conditions and frequency ranges for testing at hearing levels ≥ 0 dB.

The new standard also describes how MPANLs should be adjusted if the maximum hearing level to be employed is other than 0 dB. Overall, a simple proportionality is assumed between the minimum hearing level to be employed and the MPANL (i.e., equal trade-off in dB). For example, if testing is going to be conducted down to -10 dB HL, then 10 dB should be subtracted from the levels shown in Tables

2-1 and 2-2. However, this might be very difficult to measure, given the low-end limitations of some SLMs, and difficult to achieve, given the attenuation of most test rooms (particularly below 750 Hz) and low frequency noise levels of most test room ventilation systems. As another example, if a hearing screening is to be conducted at 20 dB HL, then 20 dB can be added to the values shown in Tables 2-1 and 2-2.

For threshold or screening tests employing a single frequency range other than 500-8000 Hz, the MPANLs in an audiometric test room should not exceed those shown in Tables 2-1 or 2-2 and should correspond to the single or the lowest frequency within the test frequency range to be employed. For example, if earphone testing is done at 0 dB HL at 1000, 2000 and 4000 Hz, the MPANLs in the test room should not exceed the ears-covered levels shown in Tables 2-1 or 2-2 for the 500-8000 Hz frequency range. This too was done in deference to upward spread of masking phenomenon. Further relaxations of MPANLs were not deemed prudent, regardless of the lowest test frequency to be employed above 500 Hz. As another example, if earphone testing is done at 20 dB HL at 2000 and 4000 Hz, the MPANLs in the test room should not exceed the ears-covered MPANLs shown in Tables 2-1 or 2-2 for the 500-8000 Hz frequency range plus 20 dB.

MPANLs allowed in an audiometric test room for the purpose of hearing conservation testing have been specified by the Occupational Safety and Health Administration (OSHA, 1983). The OSHA MPANLs are those originally specified in ANSI S3.1-1960 and are considerably higher than the newly specified levels. ANSI

S3.1-1991 recommends that hearing conservation programs meet the ears-covered MPANLs shown in Tables 2-1 or 2-2 for the 500-8000 Hz frequency range. Recently, two studies (Berger & Killion, 1989; Williams, Frank, & Schmitt, 1992) reported that accurate hearing thresholds down to 0 dB HL cannot be obtained in a test room with ambient noise levels equivalent to MPANLs specified by OSHA (1983), using TDH-type earphones mounted in supra-aural cushions or in Audiocup noise-reducing earphone enclosures.

Standards are derived and revised to lend stability and reliability to clinical measurements. They should be readable, practical, and useful, and they should be based on the best available research. Hopefully, the working group has accomplished these goals in writing ANSI S3.1-1991. When necessary, standards should also supply readers with additional information. As done in the previous standard, the new standard contains appendices that detail the derivation of the MPANLs, discusses the physical measurements of ambient noise, and provides general considerations that can be used when planning the purchase of an audiometric test room.

Audiometric Test Rooms (5) (11)

Rooms used for audiometric testing should not have background sound pressure levels exceeding those in table 2-3 when measured by equipment conforming at least to the required American National Standard Specification for Sound Level Meters, S3.1- 1960 (R 1971)

Table 2-3 Maximum allowable octave-band sound pressure levels for audiometric test rooms

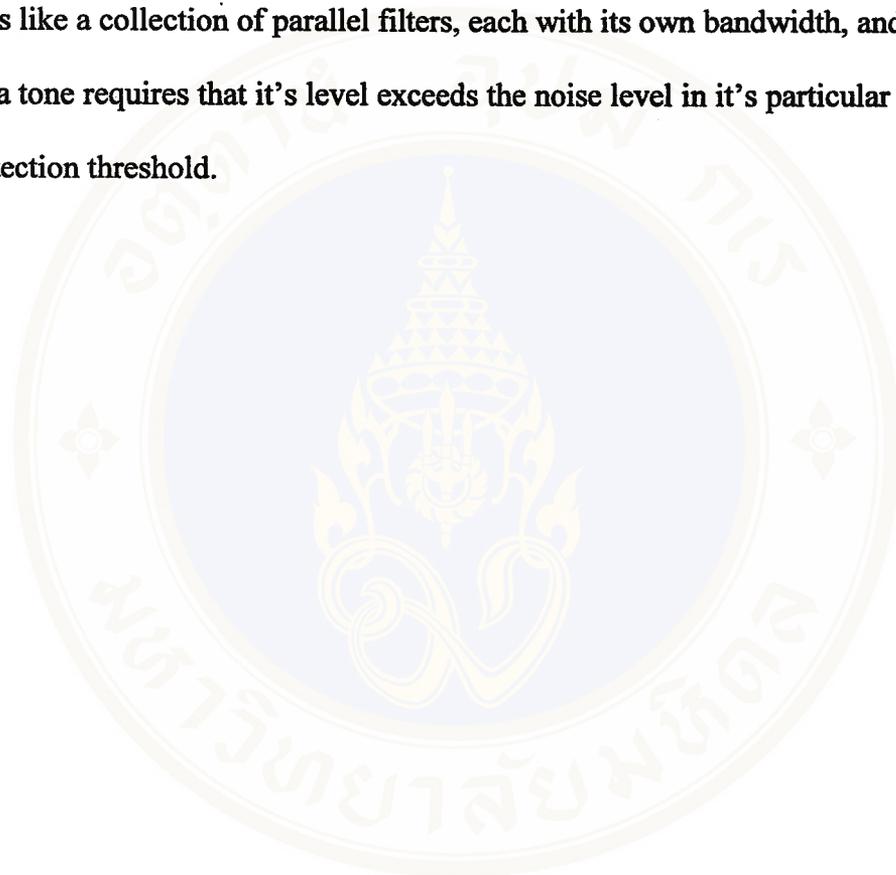
	Octave Band Center Frequency (Hz)							
	125	250	500	1000	2000	4000	6000	8000
Industrial or General Purpose								
ANSI S3.1-1960								
(R1971)	40	40	40	40	47	57	62	67
Proposed ISO – Based Standard								
Research & Diagnostic								
Room	31	25	26	30	38	51	52	56

Literature Cited

Michael and Bienvenue (1981) and Arlinger (1986) (6) found that the most commonly used audiometric earphone, Telephonics TDH-39 with cushion MX-41/AR, of supra-aural type. The sound attenuation is usually quite modest for frequencies up to 500-1000 Hz. Due to this and to the frequency dependence of the human hearing thresholds, the requirements for the ambient noise levels for pure-tone audiometry are most critical in the frequency range around 500 Hz.

Berry (1973); Shipton and Robinson, (1975) (7) stated that if ambient sound level in a test room can be varied experimentally while the hearing thresholds of a listener are being measured, the following will occur: when the ambient noise is inaudible, the hearing threshold measured is the true one; if the ambient noise level is increased gradually, the hearing threshold level recorded will start to increase. This is caused by masking and occurs when the noise level in the third octave band, the center of which corresponds to the test tone frequency, has reached the level of a few decibels below the test tone level as measured in the listener's ear. If the ambient noise level continues to increase, the hearing threshold value recorded will also increase; however, this does not occur at the same rate but more slowly at first. Not until the third octave noise level is in the range 10-20 dB SL will the hearing threshold value recorded increase at the same rate as the increase of the ambient noise level.

Fletcher and Munson (1937) (1) found that the masking of a tone by a broadband noise is independent of the noise bandwidth until the bandwidth becomes smaller than some critical value that depends on the frequency of the tone. The ear acts like a collection of parallel filters, each with its own bandwidth, and the detection of a tone requires that its level exceeds the noise level in its particular band by some detection threshold.



CHAPTER III

MATERIALS AND METHODS

This research is an experimental study which aims to find the relationship between normal hearing threshold and hearing threshold masked by ambient noise in audiometric test at the test frequencies of 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz. Various masks of broadband noise were generated into the test booth in this order: 40, 50, 60, 70 and 80 dB(A) in order to investigate the impact on pattern of hearing threshold.

3.1 Samples for Audiometric Test

This experimental study was conducted on 61 subjects selected from college students. The subjects were both male and female with ages range from 17-23 years old. The hearing threshold levels of the subjects were less than 25 dB at all frequencies as measured by a standard audiometer.

3.2 Instrumentation

The instruments used in this experimental studies were listed as the following:

1. Audiometer, Starkey Model AA30 Serial Number 0436
2. Audiometric test booth

3. Sound level meter, CASTLE Model GA121 Serial

Number 031180, Calibration No CN 031180

4. Octave band analyzer CASTLE Model GA121 Serial Number 031180

5. Audiometric Calibrator QUEST Model 155-145 Precision OBA system

6. Thermometer

3.3 Test Procedures

In this study, establishment of the adjusted correction factor for audiometric testing entailed subject selection and audiometric testing by masking with broadband noise levels.

3.3.1 Selection of Subjects

3.3.1.1 Interview method was used during the test experiments to exclude those having health problems. The history of ear diseases and records of taking medications that might affect hearing were also interviewed.

3.3.1.2 Subjects free from conditions in (1.1) were recruited for the next step of testing. The audiometric measurement with masking of noise was performed on each subject. The test frequencies were performed at the levels of 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz.

3.3.1.3 The subjects who had hearing threshold level not more than 25 dB at all test frequencies were selected as subjects in this study.

3.3.2 Protocol for Audiometric Test

The protocol for audiometric test used in this study was designed specifically as the following:

a) Preparation Before The Test

1. Fourteen hours must have elapsed since the subject was last exposed to high noise levels such as environmental noise.
2. Each subject had to obtain a complete case history from the subjects.
3. Eye glasses, hair ribbons, headbands, clips, gum, etc., should be removed out prior to testing.

b) Instruction For The Subjects

1. A seat was positioned optimally for each subject. The subject's face must be on the opposite side of audiometer.
2. Introduce a simple introduction to audiometric testing to the subject.
3. Tell the subjects that they will hear a series of tones with different loudness and frequency.

4. They should respond immediately by pressing the response key when they hear a tone.
5. They should respond every time they hear a tone.
6. Any questions which were not clear must be responded before the test begun.

c) Operations of Instrument

1. Warm-up the audiometer before use.
2. Perform a functional check.
3. The researcher make sure that noise in the test area is not excessive (refer to ANSI S3.1 – 1971 criteria for permissible ambient noise during audiometric testing).
4. Turn on the audiometer and check it's operation carefully.
5. Obtain an adequate supply of response forms to record results.

d) Test Protocols

1. Place the headphones on the subject very carefully and make sure that the diaphragm of the headphone is directly over the ear canal (red: right ear; blue: left ear).
2. Begin testing at 1000 Hz in the better ear, or the left ear, if the better ear is not known.

3. Present the tone at 40 dB HL, with a duration of 1-2 seconds.(The duration of test tone presentation must be 1-2 times in all the following procedures.)
4. If no response at this initial presentation, present the tone at 50 dB HL and successively increase the intensity in 10-dB steps until a “clear” response is obtained or the maximum limit of the audiometer is reached.
5. Following the initial response, decrease the intensity in 10-dB steps until the listener is unable to hear the tone and thus fail to respond.
6. After each failure to respond to the test tone, increase the intensity in 2-dB steps until a response to test signal is observed. Then decrease the tone in 5-dB steps. Remember and follow this rule (up 2, down 5 dB) strictly.
7. Repeat the “up 2, down 5 dB” procedure until threshold has been determined. Threshold is defined as the lowest level at which the listener has been able to correctly indentify the test tone in at least half of a series of ascending trials with a minimum of three responses required at a single level.
8. Test frequencies in the following:
 - 1000 Hz,
 - 2000 Hz,
 - 3000 Hz,
 - 4000 Hz,
 - 6000 Hz,



8000 Hz,

1000 Hz, (retest)

and 500 Hz.

9. Avoid rhythmic presentations.
10. If retest at 1000 Hz, the hearing threshold is ± 10 dB or more, then re-instruct and retest.
11. Test the other ear using the same procedure.
12. Remove the headphone themselves.
13. Record hearing thresholds on the form record.

3.3.3 Audiometric Testing by Masking with Broadband Noise Levels

- 3.3.3.1 Introduce ambient noise masking (broadband noise) into audiometric test booth in the following:

40 dB (A)

50 dB (A)

60 dB (A)

70 dB (A) and

80 dB (A)

- 3.3.3.2 Repeat the test procedure according to step in conducting audiometric testing.
- 3.3.3.3 Record the hearing threshold shift levels.

3.4 Data Collection

- 3.4.1 Information obtained from self administered questionnaires were used for screening only those in good health condition, free from diseases and abnormalities which may effect hearing level.
- 3.4.2 Ambient noise levels in an audiometric test room were measured to confirm with ANSI S3.1-1971.
- 3.4.3 The hearing threshold of subjects were tested to confirm that they have normal hearing (<25 dB all frequencies 0.5, 1, 2, 3, 4, 6 and 8 KHz). The total of 61 subjects with normal hearing were recruited for next step (step 5).
- 3.4.3 Masking ambient noise levels in an audiometric test room were measured.
- 3.4.5 The hearing threshold masked by broadband noise in 61 listeners were measured at five broadband noise levels (40, 50, 60, 70 and 80 dB (A)).

3.5 Data Analysis

The data was analyzed by using the following statistics.

3.5.1 Descriptive Statistics

To describe the characteristics of subjects and all measurements, mean \pm S.D. was applied.

3.5.2. Inferential Statistics

To describe relationship between normal hearing threshold and hearing threshold shift masked by ambient sound level in term of pair t-test

3.5.3 Adjusted correction factor was employed in the analysis with the quadratic equation of Linear Regression Model as the following;

$$\hat{Y} = b_0 + b_1X + b_2X^2$$

Whereas \hat{Y} = change in hearing threshold shift

X = ambient noise level

CHAPTER IV

RESULTS

The results of this study were presented in two parts as the following:

- Part 1 The characteristic of subjects and normal hearing threshold from audiometric test.
- Part 2 The relationships between normal hearing threshold and hearing threshold shift when masking by ambient noise level.

Part 1 The Characteristics of Subjects

In this study, sixty-one subjects comprising of 30 males and 31 females were randomly selected and trained for audiometric testing. The range of age of subjects was 17 - 23 years old and the mean was 20.96 years old. The distribution of subjects' age was shown in table 4-1.

Table 4-1 The age distributions of subjects

Ages	Frequency	Percent
17	1	1.6
18	2	3.3
20	16	26.2
21	24	39.3
22	14	23.0
23	4	6.6
Total	61	100.0

Mean \pm S.D. = 20.96 \pm 1.07

According to the test results, the values of normal hearing threshold in left ear is significantly different from normal hearing threshold in right ear at test frequencies 500 Hz and 1000 Hz with p-value <0.0001 as shown in table 4-2.

Table 4-2 Comparisons of normal hearing threshold on left ear and normal hearing threshold on right ear at the frequency of 500-8000 Hz (n = 61)

Test frequencies	Left ear		Right ear		P-value
	\bar{X}	S.D.	\bar{X}	S.D.	
500 Hz	13.90	5.34	16.42	5.79	< 0.0001
1000 Hz	13.24	5.34	9.60	5.30	< 0.0001
2000 Hz	11.81	6.94	11.36	5.93	0.504
3000 Hz	10.06	6.93	8.32	6.74	0.052
4000 Hz	10.06	8.35	9.85	7.37	0.815
6000 Hz	13.50	8.76	12.32	8.05	0.339
8000 Hz	1.98	6.90	3.18	7.88	0.223

Part 2 The Relationships between normal hearing threshold and hearing threshold shift when masking by ambient noise level

At all test frequencies, the mean values of hearing threshold, which were masked by ambient noise were significantly higher than the mean values of normal hearing threshold. The different started at 60 dB, except for the test frequencies of 1000 Hz and 8000 Hz, which started at 50 dB. At 2000 Hz and 3000 Hz, the mean values of normal hearing threshold was higher than the mean values of hearing threshold masked by ambient noise and started at 40 dB. The result was similar on both ears except for the test frequencies of 2000 Hz and 3000 Hz, the different started at 50 dB on the right ear. The maximum hearing threshold with masked by ambient noise level was 38.66 dB (S.D. 7.29) on the left ear at the test frequency of 1000 Hz with 80 dB(A) ambient noise level as shown in table 4-3 and 4-4.

Table 4-3 Comparisons of normal hearing threshold and hearing threshold with masked by ambient noise on the left ear at the frequency of 500-8000 Hz (n = 61)

Test Frequency (Hz)	Mean (S.D.) of Ambient Noise Level dB(A)				
	40	50	60	70	80
500					
Normal hearing threshold	13.9 (5.34)				
Hearing threshold shift	13.21(4.84)	14.26(5.27)	18.11(4.74)	24.21(6.55)	32.11(6.09)
P-value	.123	.540	<.0001	<.0001	<.0001
1000					
Normal hearing threshold	13.25(5.35)				
Hearing threshold shift	13.00(5.40)	15.34(5.10)	21.67(5.75)	29.72(7.03)	38.66(7.29)
P-value	.600	.002	<.0001	<.0001	<.0001
2000					
Normal hearing threshold	11.82(6.94)				
Hearing threshold shift	10.67(6.72)	12.15(6.82)	15.46(7.41)	23.92(7.90)	32.28(7.96)
P-value	.021	.624	<.0001	<.0001	<.0001
3000					
Normal hearing threshold	10.07(6.94)				
Hearing threshold shift	8.39(7.17)	10.34(7.09)	13.06(8.83)	20.26(8.49)	29.48(8.99)
P-value	.003	.706	.012	<.0001	<.0001
4000					
Normal hearing threshold	10.07(8.35)				
Hearing threshold shift	10.02(8.80)	10.61(8.51)	12.89(8.98)	18.07(8.68)	26.0(12.36)
P-value	.914	.355	.005	<.0001	<.0001
6000					
Normal hearing threshold	13.51(8.76)				
Hearing threshold shift	13.08(9.98)	12.7(10.03)	17.62(13.2)	22.3(12.65)	30.89(13.3)
P-value	.658	.470	.034	<.0001	<.0001
8000					
Normal hearing threshold	1.98 (6.90)				
Hearing threshold shift	2.68(8.21)	3.90(8.17)	4.62(8.91)	8.16(11.10)	15.31(13.6)
P-value	.391	.031)	.013	<.0001	<.0001

Table 4-4 Comparisons of normal hearing threshold and hearing threshold with masked by ambient noise on the right ear at the frequency of 500-8000 Hz (n = 61)

Test Frequency (Hz)	Mean (S.D.) of Ambient Noise Level dB(A)				
	40	50	60	70	80
500					
Normal hearing threshold	16.43(5.79)				
Hearing threshold shift	16.46(5.74)	17.48(5.54)	20.67(4.47)	27.90(5.47)	36.75(6.01)
P-value	.940	.070	<.0001	<.0001	<.0001
1000					
Normal hearing threshold	9.60 (5.31)				
Hearing threshold shift	9.55 (5.34)	12.75(5.32)	18.54(5.45)	27.38(6.25)	38.07(6.14)
P-value	.903	<.0001	<.0001	<.0001	<.0001
2000					
Normal hearing threshold	11.36(5.93)				
Hearing threshold shift	10.77(7.04)	12.74(6.38)	18.46(6.33)	26.28(6.72)	36.49(7.52)
P-value	.222	.025	<.0001	<.0001	<.0001
3000					
Normal hearing threshold	8.32(6.75)				
Hearing threshold shift	8.21(6.83)	10.08(6.63)	13.57(8.38)	21.23(8.32)	31.25(8.20)
P-value	.846	.006	<.0001	<.0001	<.0001
4000					
Normal hearing threshold	9.85(7.37)				
Hearing threshold shift	9.59(7.05)	10.33(6.60)	12.57(7.96)	18.41(8.56)	27.23(7.85)
P-value	.665	.419	.003	<.0001	<.0001
6000					
Normal hearing threshold	12.33(8.05)				
Hearing threshold shift	12.93(8.69)	14.13(8.94)	17.61(10.6)	22.67(12.0)	30.20(12.4)
P-value	.475	.075	<.0001	<.0001	<.0001
8000					
Normal hearing threshold	3.18 (7.88)				
Hearing threshold shift	3.55(9.04)	4.08(8.57)	7.45(10.58)	10.25(12.3)	16.64(13.6)
P-value	.659	.331	.002	<.0001	<.0001

Table 4-5 Mean and standard deviation of hearing threshold shift on left ear and right ear at the frequency of 500-8000 Hz (n = 61)

Frequency(Hz)	Ambient Noise Level dB(A)	Mean (S.D.)	
		Left Ear	Right Ear
500	40	-0.69 (3.43)	0.03 (3.36)
	50	0.36 (4.57)	1.05 (4.44)
	60	4.21 (4.91)	4.24 (5.52)
	70	10.31 (6.60)	11.47 (6.59)
	80	18.21 (6.17)	20.32 (7.82)
1000	40	-0.25 (3.64)	-0.05 (3.14)
	50	2.09 (5.15)	3.15 (4.89)
	60	8.42 (6.35)	8.94 (7.40)
	70	16.47 (8.35)	17.78 (7.97)
	80	25.41 (9.31)	28.47 (8.23)
2000	40	-1.15 (4.00)	-0.59 (3.73)
	50	0.33 (5.19)	1.37 (4.68)
	60	3.63 (6.81)	7.09 (7.54)
	70	12.09 (9.14)	14.91 (8.33)
	80	20.46 (9.83)	25.13 (9.50)
3000	40	-1.67 (4.24)	-0.11 (4.59)
	50	0.27 (5.74)	1.75 (4.77)
	60	3.00 (9.04)	5.24 (7.47)
	70	10.19 (9.91)	12.90 (7.81)
	80	19.40(10.33)	22.91 (8.92)
4000	40	-0.05 (3.56)	-0.26 (4.71)
	50	0.54 (4.53)	0.47 (4.55)
	60	2.81 (7.64)	2.72 (6.78)
	70	8.00 (8.44)	8.55 (7.82)
	80	15.93(10.06)	17.37 (7.36)
6000	40	-0.42 (7.49)	0.60 (6.59)
	50	-0.80 (8.60)	1.80 (7.70)
	60	4.11 (14.82)	5.27 (9.95)
	70	8.78 (13.18)	10.34 (12.82)
	80	17.37 (13.53)	17.86 (13.53)
8000	40	0.70 (6.37)	0.37 (6.64)
	50	1.91 (6.77)	0.90 (7.17)
	60	2.63 (8.09)	4.27 (10.25)
	70	6.18 (9.85)	7.06 (13.00)
	80	13.32 (12.73)	13.45 (14.64)

Table 4-5 showed the mean and standard deviations of hearing threshold shift on the left ear and the right ear. It was found that the trend of hearing threshold shift value on both ears increased with the ambient noise at the range of 50 dB – 80 dB. The maximum hearing threshold shift with significant difference (higher than normal hearing threshold) were 28.47 dB(S.D. 8.23) on right ear (test frequency 1000 Hz, ambient noise level 80 dB) and the minimum was 1.37 dB (S.D. 4.68) on right ear (test frequency 2000 Hz, ambient noise 50 dB).

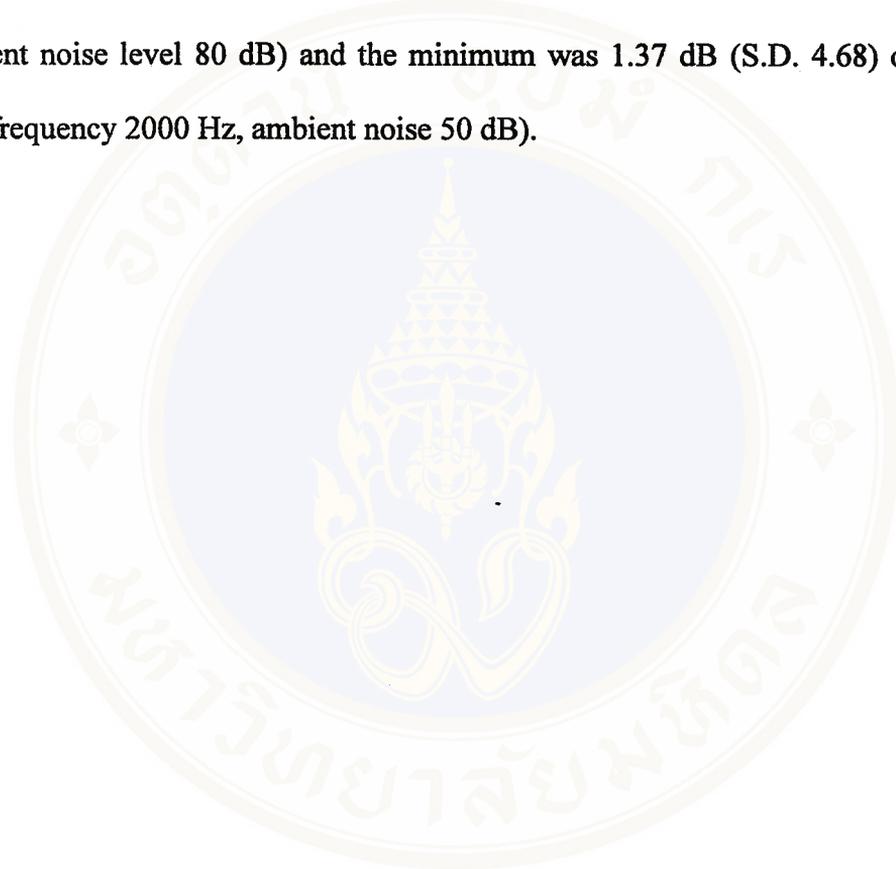


Table 4-6 Comparisons of hearing threshold shift on left ear and right ear at the frequency of 500-8000 Hz (n = 61)

Test Frequency (Hz)	Ambient Noise Level DB (A)	Mean (S.D.)				P-value
		Left Ear		Right Ear		
500	40	-0.6885	(3.43)	0.032	(3.36)	0.241
	50	0.36	(4.57)	1.04	(4.44)	0.331
	60	4.21	(4.91)	4.24	(5.52)	0.967
	70	10.31	(6.60)	11.47	(6.59)	0.300
	80	18.21	(6.17)	20.32	(7.82)	0.044
1000	40	-0.245	(3.64)	-0.049	(3.14)	0.709
	50	2.09	(5.15)	3.14	(4.89)	0.087
	60	8.42	(6.35)	8.93	(7.40)	0.543
	70	16.47	(8.35)	17.77	(7.97)	0.207
	80	25.40	(9.31)	28.45	(8.23)	0.004
2000	40	-1.21	(4.00)	-0.59	(3.73)	0.383
	50	0.32	(5.19)	1.37	(4.68)	0.138
	60	3.63	(6.81)	7.09	(7.54)	0.001
	70	12.09	(9.14)	14.91	(8.33)	0.023
	80	20.45	(9.83)	25.13	(9.50)	0.000
3000	40	-1.67	(4.24)	-0.11	(4.59)	0.025
	50	0.27	(5.74)	1.75	(4.77)	0.069
	60	3.00	(9.04)	5.24	(7.47)	0.069
	70	10.19	(9.91)	12.90	(7.81)	0.045
	80	19.40	(10.33)	22.91	(8.92)	0.014
4000	40	-0.049	(3.56)	-0.26	(4.71)	0.770
	50	0.54	(4.53)	0.47	(4.55)	0.933
	60	2.81	(7.64)	2.72	(6.78)	0.933
	70	8.00	(8.44)	8.55	(7.82)	0.643
	80	15.93	(10.06)	17.37	(7.36)	0.222
6000	40	-0.42	(7.49)	0.60	(6.59)	0.264
	50	-0.80	(8.6)	1.80	(7.7)	0.026
	60	4.11	(14.82)	5.27	(9.95)	0.530
	70	8.78	(13.18)	10.34	(12.82)	0.391
	80	17.37	(13.53)	17.86	(13.53)	0.798
8000	40	0.70	(6.37)	0.37	(6.64)	0.770
	50	1.91	(6.77)	0.90	(7.17)	0.375
	60	2.63	(8.09)	4.27	(10.25)	0.202
	70	6.18	(9.85)	7.06	(13.00)	0.539
	80	13.32	(12.73)	13.45	(14.64)	0.934

The pair t-test was used to show the difference of hearing threshold shift between left and right ear. Significant different was found at the test frequencies of 500 Hz [(80 dB p-value = 0.044)], 1000 Hz [(80 dB p-value = 0.004)], 2000 Hz [(60 dB p-value = 0.001),(70 dB p-value = 0.023), (80 dB p-value <0.0001)], 3000 Hz [(40 dB p-value = 0.025), (70 dB p-value = 0.045), (80 dB p-value = 0.014)], and 6000 Hz [(50 dB p-value = 0.026)] as shown in table 4-6

Table 4-7 The coefficients of determination (R^2) and the Quadratic Equations calculated from various test frequencies

Test Frequency (Hz)	The Quadratic Equation	R^2
500, 1000, 2000 and 3000 Hz	$HTS = 17.9986 - .9883ANL + .0131ANL^2$.939
4000 and 6000 Hz	$HTS = 22.4775 - 1.0576ANL + .0124ANL^2$.983
8000 Hz	$HTS = 18.5546 - .8285ANL + .0095ANL^2$.980

HTS = Hearing Threshold Shift

ANL = Ambient Noise Level

Regarding to table 4-7 three groups of test frequencies were categorized for available field practice which include;

Group I Speech frequencies (4 frequencies) 500, 1000, 2000 and 3000 Hz

Group II Hearing conservative frequencies (2 frequencies) 4000 and 6000 Hz

Group III Presbycusis frequency (1 frequencies) 8000 Hz.

The quadratic equation applied to estimate hearing threshold shift level. The coefficient determination (R^2) was 0.983 at the frequency of 4k-6kHz group. The relationship between ambient noise levels and hearing threshold shift was plotted as shown in figure 4-1 – 4-3.

Figure 4-1 Relationship between ambient noise levels and hearing threshold shift at test frequencies of 500, 1000, 2000 and 3000 Hz

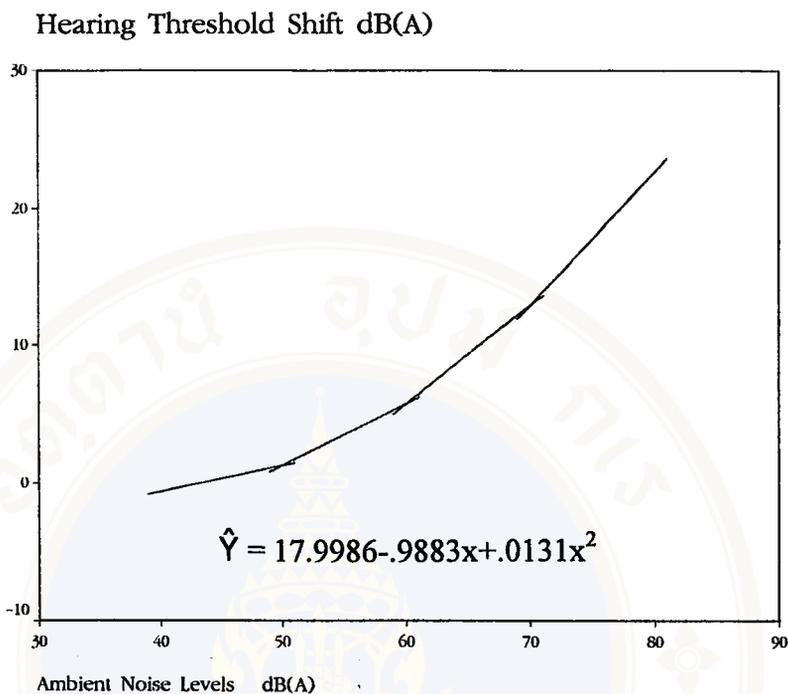


Figure 4-2 Relationship between ambient noise levels and hearing threshold shift at test frequencies of 4000 and 6000 Hz

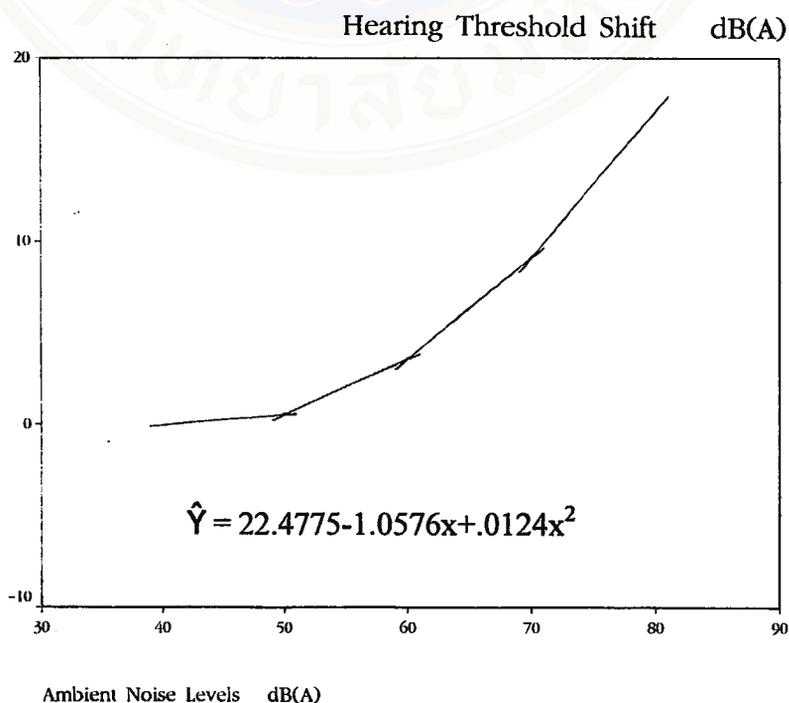
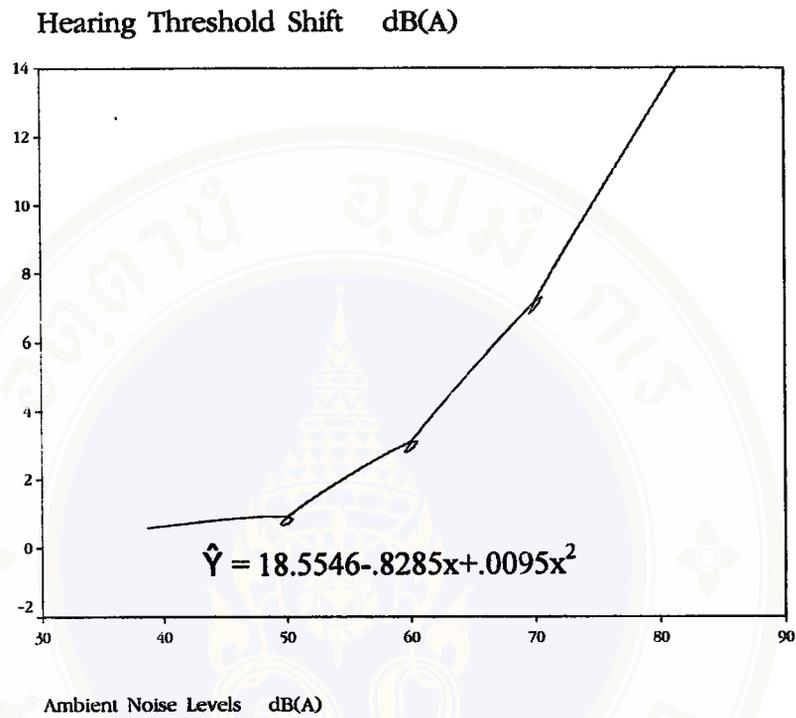


Figure 4-3 Relationship between ambient noise levels and hearing threshold shift
at test frequency of 8000 Hz



CHAPTER V

DISCUSSION

In order to control the intraobserver variations, all experiments were measured by only one researcher. According to the experiments, it was clearly found that hearing thresholds are affected by the ambient noise levels. This result could get along with the criteria of ANSI S3.1-1960 (R 1971) (11); which concerns of the maximum allowable octave-band sound pressure levels in audiometric test rooms. Those tests at all frequencies (500, 1000, 2000, 3000, 4000, and 6000 Hz) complied with the ANSI requirement except for the test frequency 8000 Hz. However, there are some conditions that might have caused irregular significantly findings such as better hearing threshold after masking and irregular significant pattern at test frequencies of 2000 and 3000 Hz.

5.1 Normal Hearing Threshold of The Subjects

According to table 4-2, the values of normal hearing threshold on left ear was significantly different from normal hearing threshold on the right ear at test frequencies of 500 Hz (left ear \bar{x} = 16.42, right ear \bar{x} = 13.90) and 1,000 Hz (left ear \bar{x} = 13.2, right ear \bar{x} = 9.6) with 95 % CI (p-value <0.0001). This might due to different efficiency of the earphone on each side as shown in Table A-1. At test frequency of 500 Hz the calibration value on left ear is higher than right ear (80.0 dB(A) and 79.2 dB(A), different value 0.8 dB(A)). At test frequency of 1000 Hz the calibration value

on right ear is higher than left ear (79.4 dB(A) and 78.6 dB(A), different value 0.8 dB(A)).

5.2 Hearing Threshold Shift after Introducing of Ambient Noise

Table 4-5 showed that at the frequencies of 2000 and 3000 Hz the hearing threshold were better while ambient noise was 40 dB. Both frequencies started significant difference at ambient noise level 50 dB(A) on the right ear and 60 dB(A) on the left ear. This might due to the limitation of the audiometric measurement according to the audiometric calibration (Table A-1); at the frequencies of 2000 and 3000 Hz sound level at the earphone are very close to the tolerance limit.

According to broadband noise measurements at different frequencies (as indicated in Appendix B) it was found that the highest $L_{eq}(1 \text{ min.})$ was at 2000 Hz and gradually decreased at frequencies away from 2000 Hz. Thus, at test frequencies of 2000 Hz of hearing threshold was disturbed maximumly (Table B-1). It was also found that the same pattern was occurred in the frequency of 3000 Hz.

At the test frequencies of 2000 and 3000 Hz, the hearing threshold would be disturbed by resonance phenomenon in ear canal. This will result in showing the irregular of hearing threshold shift patterns (16).

5.3 Comparison Hearing Threshold Shift in Left and Right Ear

Regarding to table 4-6, the test frequencies of 2000 Hz and 3000 Hz had significant differences at several ambient noise levels [2000 Hz (60 dB, 70 dB and 80 dB)] [3000 Hz (40 dB, 70 dB and 80 dB)] this might due to same reasons as in the previous paragraph such as calibration values are very close to the tolerance limit, maximumly disturbed and the resonance effect in ear canal.

5.4 The Quadratic Equation

For available using, the adjusted correction factors were employed in the analyses of Linear Regression Model in three groups of frequencies as the followings,

Group I Speech frequencies (500, 1000, 2000 and 3000 Hz)

Group II Hearing Conservative frequencies (4000 and 6000 Hz)

Group III Presbycusis frequency (8000 Hz)

However, \bar{X} was used to established the Quadratic Equation. This results in giving very high value of R^2 . Thus, they are likely to be considered for using those equations for prediction of hearing threshold shift.



CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This research is an experimental study about hearing threshold shift pattern at test frequencies of 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz masked by ambient noise (broadband noise) in audiometric test. The broadband noise was generated by the audiometer at five different levels including 40, 50, 60, 70 and 80 dB(A). The results from this experiment were summarized as follow:

1. At all frequencies the hearing threshold shift was started to be significantly different from normal hearing threshold at 60 dB(A) ambient noise level, however, at test frequencies of 1000 Hz (50 dB(A) in both ear), 2000 Hz (50 dB(A) in right ear), 3000 Hz (50 dB(A) in right ear) and 8000 Hz (50 dB(A) in left ear).
2. The maximum hearing threshold shift was found at test frequency of 1000 Hz at 80 dB ambient noise level ($\bar{x}=28.47$, S.D.=8.23).
3. Hearing threshold shift masked by ambient noise on the left ear is significantly different from that of the right ear at frequencies of 500 Hz (80 dB(A) ambient noise level), 1000 Hz (80 dB(A) ambient noise level), 2000 Hz (60, 70 and 80 dB(A) ambient noise level), 3000 Hz (40, 70 and 80 dB(A) ambient noise level) and 6000 Hz (50 dB(A) ambient noise level).
4. The quadratic equations were applied to estimate hearing threshold shift level as follows:

Test frequencies

500, 1000,

2000 and 3000 Hz $HTS = 17.9986 - .9883ANL + .0131ANL^2$ ($R^2 = .939$)

4000 and 6000 Hz $HTS = 22.4775 - 1.0576ANL + .0124ANL^2$ ($R^2 = .983$)

8000 Hz $HTS = 18.5546 - .8285ANL + .0095ANL^2$ ($R^2 = .980$)

HTS = Hearing Threshold Shift

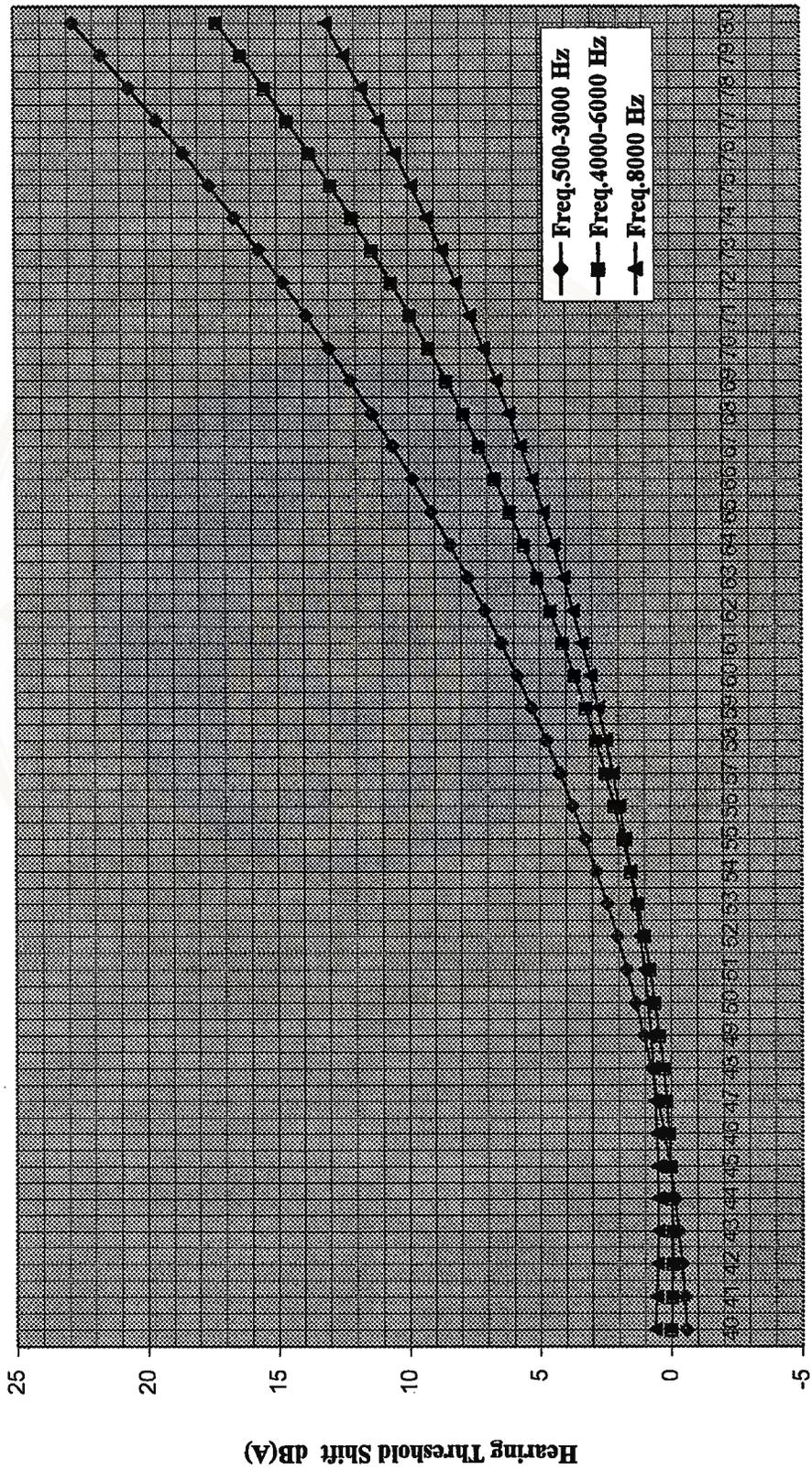
ANL = Ambient Noise Level

5. The quadratic equations were applied to estimate hearing threshold shifts in terms of the correction factors and also show the relation between the hearing threshold shifts and the ambient noise levels as a graphic form (see table 6-1 and figure 6-1).

Table 6-1 The Adjusted Corrective Constant Factor For Audiometric Test [dB(A)]

Ambient Noise Levels	Set Freq. 500,1000,2000,and 3000 Hz	Set Freq. 4000,and 6000 Hz	Set Freq. 8000 Hz
40	-0.6	0.0	0.6
41	-0.5	0.0	0.6
42	-0.4	-0.1	0.5
43	-0.3	-0.1	0.5
44	-0.1	-0.1	0.5
45	0.1	0.0	0.5
46	0.3	0.1	0.5
47	0.5	0.2	0.6
48	0.7	0.3	0.7
49	1.0	0.4	0.8
50	1.3	0.6	0.9
51	1.7	0.8	1.0
52	2.0	1.0	1.2
53	2.4	1.3	1.3
54	2.8	1.5	1.5
55	3.3	1.8	1.7
56	3.7	2.1	2.0
57	4.2	2.5	2.2
58	4.7	2.9	2.5
59	5.3	3.2	2.7
60	5.9	3.7	3.0
61	6.5	4.1	3.4
62	7.1	4.6	3.7
63	7.7	5.1	4.1
64	8.4	5.6	4.4
65	9.1	6.1	4.8
66	9.8	6.7	5.3
67	10.6	7.3	5.7
68	11.4	7.9	6.1
69	12.2	8.5	6.6
70	13.0	9.2	7.1
71	13.9	9.9	7.6
72	14.8	10.6	8.2
73	15.7	11.4	8.7
74	16.6	12.1	9.3
75	17.6	12.9	9.9
76	18.6	13.7	10.5
77	19.6	14.6	11.1
78	20.6	15.4	11.7
79	21.7	16.3	12.4
80	22.8	17.2	13.1

Figure 6-1 Graph presents the relation of hearing threshold shift and ambient noise at various levels in the test room



Ambient Noise Levels dB(A)

6.2 Recommendations

- 6.1 For the precision, this method showed the low level of precision in test frequencies of 6000 and 8000 Hz (see Table 4-5). The standard deviations of hearing threshold shifts are rather high. It is recommend that the Quadratic Equations be used.
- 6.2 The audiometric calibration showed that the substandard values at the frequencies of 125, 250 Hz which are closed to the tolerance limit at the frequencies of 2000 and 3000 Hz. Thus, to provide precision instrument in this case, we should try to adjusting the audiometer before use.
- 6.3 In selection step for the subjects, the middle ear function test should be used to assess the middle ear pathology by the otologist. The subjects should be free from pathology and then be recruited for the next step.
- 6.4 For further study, it is recommended that hearing threshold shifts would change with various types of ambient noise (i.e. narrowband noise, pure tone). Further study should take this variations into consideration. In general, the ambient noise in workplaces will vary when containing different frequencies and different levels at each frequency. Therefore, in practical point of veiw, the hearing threshold study should be utilized according to the

interference of ambient noise in workplace. Field investigation to determine the actual hearing threshold shift by using the quadratic equation or correction factor in the workplace should also be undertaken.



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APPENDIX A

Demonstration of audiometer calibration values

(Earphone TDH – 39 @ 70 dBHL)

Audiometric Calibration Chart (ANSI S3.6-1969)

Interconnections Showing calibrator Quest Model 155-145

Table A-1 Demonstration of audiometer calibration values (Earphone TDH – 39 @ 70 dBHL)

Frequencies	Standard	Left ear	Right ear	tolerance
125	115.0	101.4	101.6	5*
250	95.7	88.2	87.4	3*
500	81.5	80.0	79.2	3
750	77.5	77.5	77.8	3
1000	77.0	78.6	79.0	3
1500	76.5	79.1	78.3	3
2000	79.0	81.4	81.3	3
3000	79.8	82.4	82.7	3
4000	79.0	80.0	80.5	4
6000	86.5	86.4	86.3	5
8000	83.5	79.2	79.6	5

* exceed tolerance limit

Table A-2 Audiometric Calibration Chart

(ANSI S3.6-1969)



510 Worthington St.,
Oconomowoc, Wisconsin 53088
Phone: (414) 587-9157

AUDIOMETRIC CALIBRATION CHART

Date April 4, 1986

For Quest model 155 Sound Level Meter S N DL6030012

Model 7023 Microphone S N 8447, Preamp 1504

Used with the EC-9A Earphone Coupler

This calibration chart is based on ANSI hearing levels and is given for the Telephonics TDH-39, 49 & 50, and the Telex-1470 & 1470A earphone. The dB levels given in the chart are corrected sound pressure level readings for the SLM at ANSI 70 dB HL. If another earphone is used, it will be necessary to determine the correction values for that particular type of earphone, and apply the microphone pressure correction obtained by comparing the standard HL with the levels noted below for this particular Sound Level Meter.

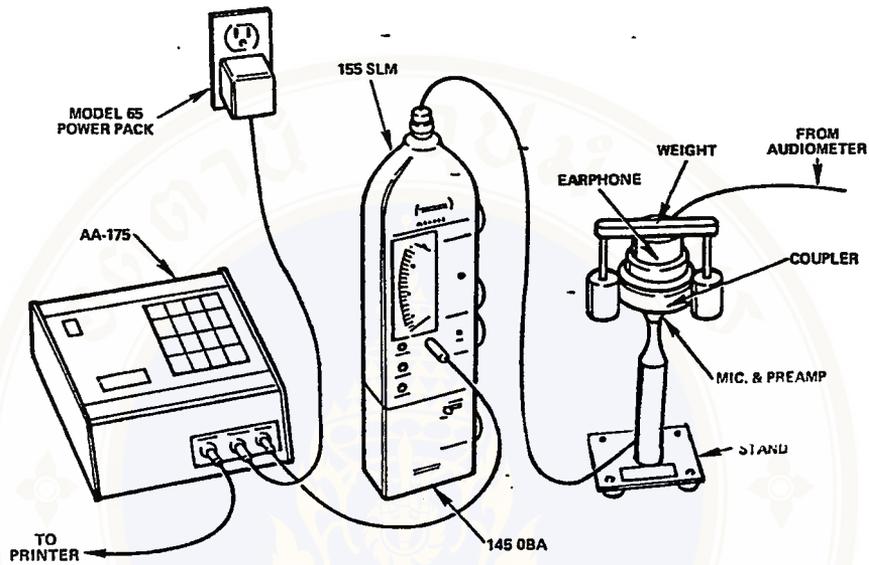
- Calibration in decibels is referenced to 20µN/m².
- Decibel levels are given for the LIN FLAT response position on the SLM.
- If you are using the Octave Band Filter add 0.7dB to meter reading when testing non center band frequencies, that is 750, 1500, 3000 and 6000 Hz, because of filter slope. Also be sure to set the Filter selector to the next higher frequency position to be within the measuring band. For example, measure the 1500 Hz tone with the Octave Band Filter set at 2kHz
- If you need to calibrate at 90dB HL, merely add 20dB to the given 70dB HL corrected values.

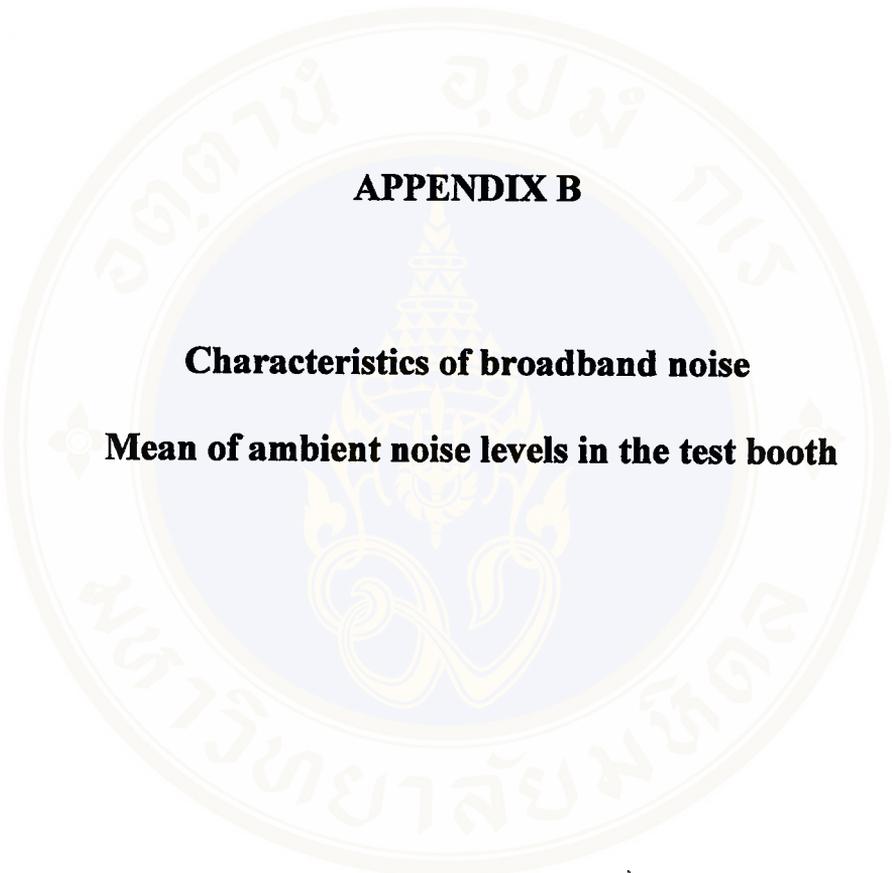
Frequency-Hz		125	250	500	750	1000	1500	2000	3000	4000	6000	8000
TDH-39 Earphone @ 70dB HL	dB	115.0	95.7	81.5	77.5	77.0	76.5	79.0	79.8	79.0	86.5	83.5
TDH-49 & 50 @ 70dB HL	dB	117.5	96.7	83.5	77.5	77.5	77.5	81.0	79.3	80.0	84.5	83.5
TELEX-1470 @ 70dB HL	dB	115.0	95.2	80.0	76.5	73.0	75.0	74.0	74.8	75.5	78.5	79.5
TELEX-1470 A @ 70dB HL	dB	117.0	97.7	83.0	78.5	76.5	75.0	78.0	77.3	78.0	88.5	88.0
Audiometer Tolerance ANSI S3.6-1969	dB	±5	3	3	3	3	3	3	3	4	5	5

*750 Hz is not given in the ANSI Standard and is therefore an interpolated setting.
98-28
8 84

CALIBRATED BY _____

Figure A-1 Interconnections Showing calibrator Quest Model 155-145





APPENDIX B

Characteristics of broadband noise

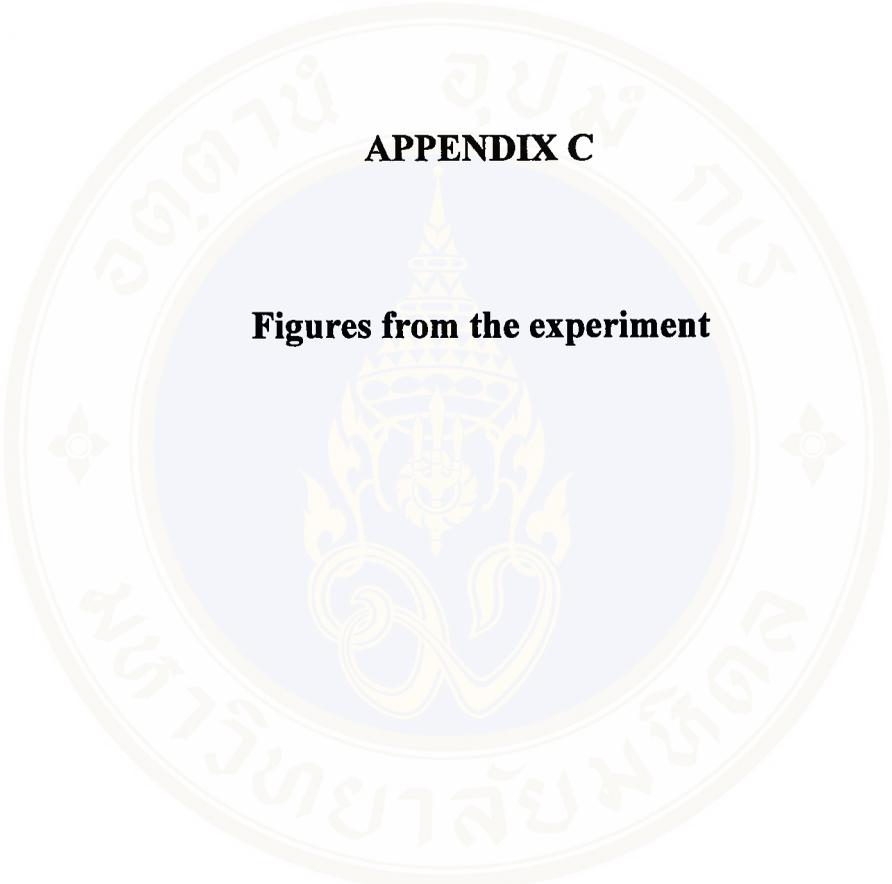
- **Mean of ambient noise levels in the test booth**

Table B-1 Characteristics of broadband noise

SPL dB(A)	Sound Level at each Frequencies dB(A)						
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
40	32.5	31.6	33.5	34.2	35.9	33.2	29.5
50	32.2	31.4	40.5	42.7	44.5	41.7	38.9
60	32.3	31.8	50.5	52.3	54.1	51.3	49.4
70	32.0	34.0	60.5	62.1	63.9	61.5	59.0
80	32.4	40.8	70.5	72.1	73.5	71.2	69.0

Table B-2 Mean of ambient noise levels in the test booth

Sound Level at each Frequencies dB(A)						
125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
32.1	32.1	28.9	27.0	26.0	20.1	17.8

The image features a large, faint watermark of the Mahidol University logo in the background. The logo is circular and contains the university's name in Thai script: "มหาวิทยาลัยมหิดล" (Mahidol University) at the bottom and "จุฬาลงกรณ์มหาวิทยาลัย" (Chulalongkornrajavidyalaya University) at the top. In the center of the logo is a golden emblem depicting a seated figure, likely a deity or a royal figure, surrounded by ornate patterns.

APPENDIX C

Figures from the experiment

Figure C-1 Demonstration of the instrument settings for the experiment



Figure C-2 Illustration of the audiometer being used to measure hearing thresholds

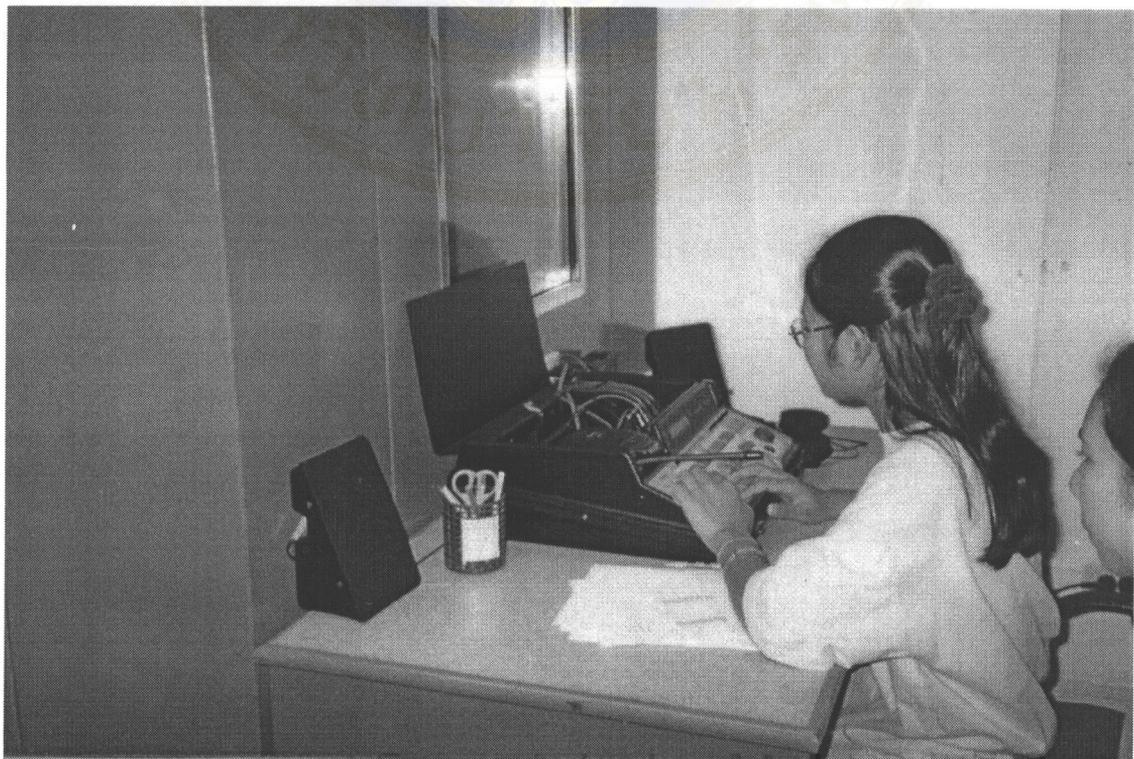


Figure C-3 Demonstration of the sound level meter which was used for measuring ambient noise levels in the audiometry test room



Figure C-4 Demonstration of the audiometric calibration set-up





BIOGRAPHY

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