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**NOISE-INDUCED HEARING LOSS
AMONG AUTOMOBILE WORKERS**

BY

USA WISUTHIPAT

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
REQUIREMENT FOR THE DEGREE OF
MASTER OF ARTS
(AUDIOLOGY)**

**IN THE
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OF**

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จาก

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This Thesis
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University for the Master of Arts degree on May 25, 1987.

Signature..... *Uka Wuthipat*
Candidate

..... *Sumalai Maroonog*
Preceptor

..... *Chamchit Tamir*
Coproceptor

..... *Wanyen Kulthipornchum*
Coproceptor

..... *Dedavuth Nityasuddhi*
Coproceptor

..... *M. Chulasamaza*
Dean
Faculty of Graduate Studies

..... *Al Pait Vejjajir*
Dean
Faculty of Medicine, Ramathibodi
Hospital, Mahidol University

EVALUATION OF THE FINAL EXAMINATION

THE DEFENSE OF THESIS

.....

We, the member of the supervisory Graduate Committee

for

USA WISUTHIPAT

unanimously approve the thesis entitled

NOISE-INDUCED HEARING LOSS AMONG AUTOMOBILE WORKERS

We further agree that she has satisfactorily defended

her thesis examination given by the

supervisory committee

on

May 25, 1987

We recommended therefore that

USA WISUTHIPAT

Be awarded the degree of Master of Arts in

Audiology

From Mahidol University

.....*Sumalai Maroonroge*.....
Sumalai Maroonroge, PhD.

.....*Cheamchit Tawin*.....
Assistant-Professor Cheamchit Tawin, M.A.

.....*Wanpen Kulertpornchareon*.....
Wanpen Kulertpornchareon, M.A.

.....*Dechavuth Nityasuddhi*.....
Assistant-Professor Dechavudh Nityasuddhi, M.Sc.

.....*M. Chulasamaya*.....
Assistant-Professor Montree Chulasamaya, M.D., Ph.D.
Dean

Faculty of Graduate Studies

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BIOGRAPHY

Name: USA WISUTHIPAT

Date of Birth: April, 21, 1960.

Place of Birth: Chantaburi, Thailand

Institutions Attended: Triam Udomsuksa ,Bangkok
March, 1978. Certificate of
Mathayom Suksa V
Mahidol University, Bangkok
Faculty of Public Health
April, 1983. Bachelor of Science
(Public Health)

VI

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บทคัดย่อ

การศึกษาผลกระทบของเสียงดังต่อการได้ยินในคนงานโรงงานผลิตรถยนต์ จำนวน 98 คน ที่สัมผัสเสียงอยู่ในช่วง 73-99 เดซิเบลเอ ผลการศึกษาพบว่า 65% ของกลุ่มคนงานมีการสูญเสียการได้ยินแบบประสาทหูพิการ ซึ่งสูงกว่าอุบัติการณ์ที่พบในโรงพยาบาล หรือในโรงเรียนแพทย์ สำหรับคนงานที่มีประสาทหูพิการเนื่องจากเสียง มีแนวโน้มเพิ่มจำนวนขึ้นตามระยะเวลาการทำงาน ผลการตรวจวัดการได้ยินของกลุ่มคนงานที่มีประสาทหูพิการเนื่องจากเสียง ได้ลักษณะกราฟออกมา 5 ประเภทคือ ประเภทที่ 1. ประสาทหูพิการสองข้างที่ความถี่ 3000 4000 หรือ 6000 เฮิรตซ์ ประเภทที่ 2. ประสาทหูพิการหนึ่งข้างที่ความถี่ 3000 4000 หรือ 6000 เฮิรตซ์ ประเภทที่ 3. ประสาทหูพิการสองข้างโดยรวมความถี่ที่ 8000 เฮิรตซ์ หรือสูญเสียเฉพาะที่ความถี่ 8000 เฮิรตซ์ เพียงความถี่เดียว ประเภทที่ 4. ประสาทหูพิการหนึ่งข้างโดยรวมความถี่ที่ 8000 เฮิรตซ์ หรือสูญเสียเฉพาะที่ความถี่ 8000 เฮิรตซ์ เพียงความถี่เดียว และ ประเภทที่ 5. แบบผสมระหว่างประเภทที่ 1 กับ ประเภทที่ 3 และยังพบว่าคนงานที่มีประสาทหูพิการประเภทที่ 1 และ 2 มีจำนวน มากกว่าประเภทที่ 3 และ 4 นอกจากนี้ยังได้พบว่าคนงานที่มีประสาทหูพิการหนึ่งข้าง มีจำนวนมากกว่า คนงานที่มีประสาทหูพิการสองข้าง ซึ่งในจำนวนของผู้ที่มีประสาทหูพิการหนึ่งข้างนี้ มีจำนวนผู้ที่หูพิการข้างขวามากกว่าข้างซ้าย

การคำนวณเปอร์เซ็นต์ความพิการของหู ถ้าหาความถี่ที่สูงกว่า 2000 เฮิรตซ์ ไปรวมในสูตร จะมีจำนวนร้อยละของผู้ที่มีความพิการเพิ่มมากขึ้น โดยเฉพาะอย่างยิ่งถ้าหาเอาความถี่ที่ 4000 เฮิรตซ์ รวมเข้าไปด้วย นอกจากนั้น เมื่อทำการเปรียบเทียบผลการตรวจการได้ยินในครั้งแรกและครั้งสุดท้าย พบว่าคนงานมีการสูญเสียการได้ยินมากกว่า 10 เดซิเบล ที่ความถี่ 4000 6000 8000 และ 3000 เฮิรตซ์ ตามลำดับ ส่วนที่ความถี่ 500 1000 และ 2000 เฮิรตซ์ พบว่ามีคนงานเป็นส่วนน้อยที่มีการสูญเสียการได้ยิน จากผลการศึกษาครั้งนี้ ได้เสนอแนะให้มีการจัดตั้งโครงการอนุรักษ์การได้ยินขึ้นในโรงงาน.

VIII

ABSTRACT

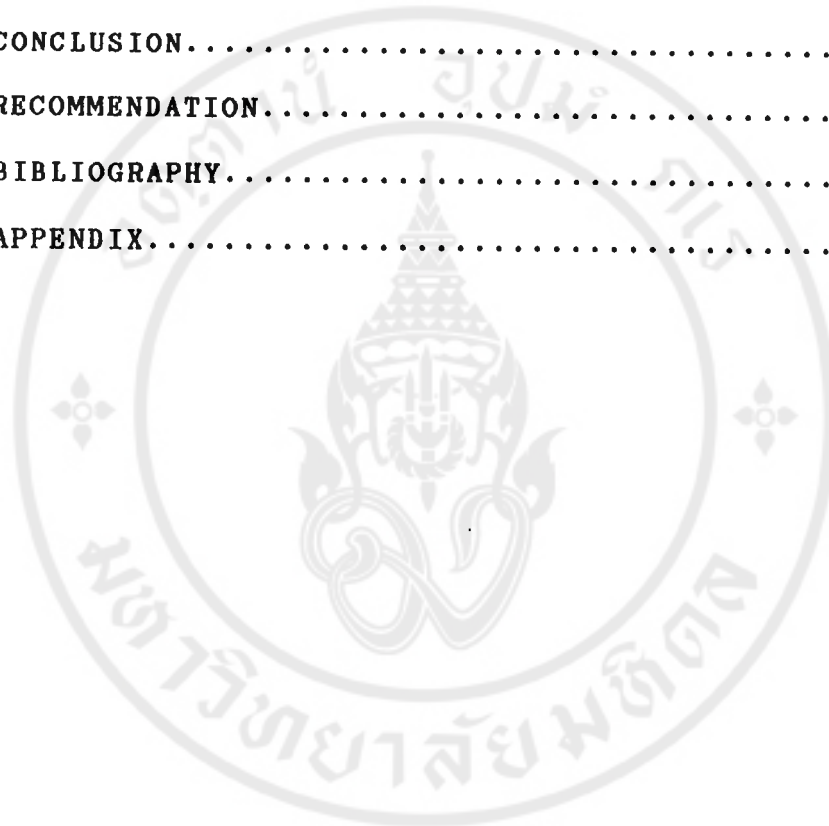
This study investigated the effect of noise on hearing of the automobile workers. The plant produced a combination of impact and continuous noise, the noise level ranged from 73-99dBA. 98 workers who returned for follow-up hearing evaluations served as subjects for the study. The results indicated that the 65% of the workers showed various degrees of sensorineural hearing loss, the prevalence was higher than those found among patients seen at hospitals or medical schools. The audiometric examinations showed the number of workers with noise-induced hearing loss tended to increase with the duration of employment. Five different audiometric configurations were found among the workers who exposed to noise: unilateral, bilateral noise-induced hearing loss, unilateral, bilateral high frequency hearing loss, and combinations of noise-induced hearing loss and high frequency hearing loss. There were more cases of unilateral hearing loss than bilateral hearing loss. The right ear was more affected than the left ear. The percentage of worker with occupational hearing handicaps increased when 4KHz was included in the formula for calculation. Threshold shifts were found at 4K, 6K, 8K, and 3KHz. Some elevation of hearing thresholds were found at .5K, 1K, or 2KHz. Based on the results, obtained from this study, a hearing conservation was highly recommended.

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CHAPTER 1

INTRODUCTION

Pure tone audiometry has dominated audiometric diagnosis. The test results provide useful descriptions of the magnitude of hearing loss throughout the major audible frequency range. Based on the results of the hearing evaluation, hearing loss is divided into three main classifications: conductive, sensorineural, and mixed hearing loss. Several otolaryngologists in Thailand collected audiometric data on patients seen at major medical centers around the country. These otolaryngologists reported the prevalence of conductive hearing loss ranged from 30-80%, and sensorineural hearing impairment range from 10-50%. Noise-induced hearing loss contributed to only 1% of the sensorineural hearing loss.

Noise of sufficient intensity and duration can permanently damage the inner ear. The hearing loss range from slight impairment to near total deafness. The change in hearing that follow sufficiently strong exposure to noise are complicated. This includes the loss of hearing sensitivity to tones and the distortions of speech sounds. Noise damage hearing at 3K-6KHz, and then spreads to both high and low frequencies. Industrial workers are at risk for hearing loss because of the daily exposure to high level of

noise at work, therefore, an audiometric monitoring is essential for this population. However, little information has been available on the nature of hearing loss among industrial workers in Thailand.

Kulertpornchareon (1980) studied the hearing loss of the workers in the Esso Oil Refinery. The prevalence of noise-induced hearing loss was found to be 19.63%. The prevalence of sensorineural hearing loss was higher than those found in the medical centers. The discrepancies between this study and previous researches in medical schools appeared to be from population and settings in which the studies were conducted.

Amartayakul (1979) was the first to subclassify noise-induced hearing loss. The sub-classification was based on audiometric configurations. The data from this study were collected in six industrial settings. The results showed 4% of workers had typical noise-induced hearing loss and 30% had high frequencies hearing loss. The detailed analysis of audiograms provided better understanding of noise on hearing and the nature of the hearing loss in industrial settings.

The effects of noise on hearing are compounded by factors such as intensity, frequency, and duration. It is difficult to isolate a single effect from those factors. Nixon and Glorig (1961) studied hearing loss in industrial settings. The noise levels were between 77-96 dB. The

frequency spectrum of noise had high energy concentration at 1200-2400Hz and 2400-4800Hz. The workers exhibited hearing loss after ten years of employment.

Kuzniarz, Swierczynski, and Lipowscan (1976) studied impulse noise-induced hearing loss among drop-forge workers. The background noise was 110-114 dBA. Hearing loss occurred after five years and further hearing loss was associated with subsequent years of employment.

Nixon and Glorig (1961); and Kuzniarz et al. (1976) documented the duration of noise exposure was an important factor, even when the intensity was within acceptable range. From these studies, there appeared to be an association between years of employment and the degree of hearing loss. Since Siam Motors Co. Ltd. had been established for approximately fourteen years. It would be interesting to investigate if the duration affected the hearing loss of workers in this plant.

Noise-induced hearing loss has been assumed to be a bilateral effect. There is a discrepancy in recent literature showing the effect could be unilateral. Chung, Willson, and Gannon (1983) indicated noise caused more damage to the left than the right ear in workers who claims for occupational hearing loss. They suggested the left ear was more susceptibility to noise. While, Charakorn (1976) found that noise induced more hearing loss in the right ear

than the left ear.

Helmkamp, Talbott, and Margolis (1984) documented noise-induced hearing loss to be a bilateral effect. Further studies are needed to resolve this controversy.

Noise-induced hearing impairment usually is accepted as a by product of modern technology. The Thai government has realized the hazard of noise on hearing and classified noise-induced hearing loss as an occupational disease. The Thai government adopted the American Academy of Ophthalmology and Otolaryngology (AAO, 1959) formula to calculate the hearing handicap. Gerber (1974) suggested 95% of speech energy lie in 500 to 8KHz. Cues in speech are found at frequencies as low as 100 Hz to as high as 8KHz. Most of the acoustic energy of speech are concentrated between 200 and 6KHz, but most important cue-bearing for speech is between 300 to 3KHz (Miller, 1978). Recent literature shows individuals with noise-induced hearing loss encountered difficulty in speech discrimination, specially in a noisy environment (Pascoe, 1975 ; Maroonroge and Diefendorf, 1985). Therefore, the AAO formula which was adopted by the Thai government might not be an appropriate measure of hearing handicap. It would be interesting to see if the number of workers exhibited hearing handicap increased when high frequencies were included in the calculation.

There is a need to reconsider the present formula,

since the guidelines for the evaluation of hearing handicaps use only the hearing thresholds for tones in the regions that are important to speech perception in quiet. There has been a debate over whether hearing handicaps existed if hearing thresholds above 2KHz are damaged. Recent literature documented that individuals with hearing loss above 2KHz experienced considerable difficulty in understanding speech in noise, even though their average hearing threshold at .5K, 1K, and 2KHz did not exceed 25 dB HL (Maroonroge and Diefendorf, 1985). People with hearing loss above 2KHz were found to have reduced ability to distinguish / p, t, k, s, θ, ∫ / (Owens and Schubert, 1977).

The primary measurement of hearing loss is based on the ability to the level of detect the tones that are just audible. A deterioration in a hearing sensitivity that results from exposure to noise is called a threshold shift. Some threshold shifts are temporary, while others are permanent with various degree of severities. When the threshold shifts exceed 10 dB HL, then it is considered significant shift. The topic of hearing threshold shift due to noise exposure is investigated extensively. Taylor, Pearson, Mair, and Burn (1965) found threshold shifts from noise-induced hearing loss first occurred at 3K-6KHz. The hearing loss increased within ten years. The loss of hearing sensitivity spreaded to frequencies below 3K-6KHz throughout

the entire exposure period. Detailed analysis of threshold shifts is essential to understand the effects of noise on hearing.

The present study investigated the effect of noise exposure on the nature of hearing loss among automobile workers. The hypothesis were as follows:

- 1 The prevalence of sensorineural hearing loss was high among the automobile workers.
- 2 The number of workers with noise-induced hearing loss increased with years of employment.
- 3 The noise-induced hearing loss was greater than those of high frequency hearing loss.
- 4 Noise-induced hearing loss caused more bilateral hearing loss than unilateral hearing loss.
- 5 The percentage of hearing handicapped workers increased when high frequencies were included in the calculations.
- 6 The distribution of threshold shift at high frequencies showed greater scatter than threshold shifts at the low frequencies.

CHAPTER 2

REVIEW OF LITERATURE

Anatomy and Physiology

The ear is the organ structure most sensitive to sound pressure changes. Anatomically, the ear has three divisions : the outer, middle, and inner portions. The functions of the outer and middle ear are to collect and transmit sound pressure to the inner ear. The outer ear acts as a conducting channel for the sound wave to travel to the ear drum. The middle ear has the three ossicles to transmit sound energy to the fluid in the cochlea. The reflex actions of the two middle ear muscles help to protect the inner ear, which contains the sensory and neural organs of hearing. When sound pressure is transmitted to the inner ear fluid, it sets up the hydrodynamic action to activate nerve impulses, this information is transmitted to the brain for interpretation.

Classification of Hearing Loss

Hearing loss is typically classified as: conductive, sensorineural, or mixed hearing loss. Conductive hearing loss is caused by either infection or mechanical problems in either the middle or the outer portions of the ear.

Conductive hearing loss can be treated by medication or surgery. Sensorineural hearing loss is caused by lesions in the cochlea or its nerve supplies. Sensorineural hearing loss can not be recovered by medical treatment once the system is damaged. However, hearing can be enhanced with the use of a hearing aid. Mixed hearing loss is caused by the combined effects of conductive and sensorineural impairments. Mixed hearing loss can be partially remediated.

Prevalence of Hearing Loss

Ruckphaopunt (1983) studied the prevalence of hearing loss among patients seen at Chiangmai Medical School. He found 22.08% of the patients have problems associated with the outer ear, 63.55% with the middle ear, 7.50% with the inner ear, and 6.86% of the problems were unknown cause of origin.

Sangsa-ad (1983) collected information on the prevalence of hearing loss in Khonkaen medical school between 1981-1983. He found 33.65% of patients had conductive hearing loss, 52.94% had sensorineural hearing loss, and 13.41% had mixed hearing loss. Noise-induced hearing loss was only 0.61% of the total sensorineural hearing loss.

Peeravuth (1983) investigated the patient treated in

the speech and hearing clinic at Prince of Songkla Hospital between 1982-1983. He found 302 cases of conductive hearing loss, and 405 cases of sensorineural hearing loss. There were only four cases of noise-induced hearing loss among the patients.

Prasansuk (1983) studied the prevalence of hearing loss in patients treated at Siriraj Hospital in 1982. She suggested that sensorineural hearing loss occurred more in males than females. There were only six cases of noise-induced hearing loss among the 202 cases.

Cutchavaree (1983) summarized the prevalence of hearing loss in patients from four different medical schools in Bangkok from 1969 to 1983. He found 38.08% had conductive hearing loss, 48.38% had sensorineural hearing loss, and 13.55% had mixed hearing loss. Noise-induced hearing loss contributed to 0.8% of the total sensorineural hearing loss population.

Antarasena, Antarasena, Lekagul, Lutakul (1986) studied the epidemiology of deafness in Thailand. They concluded the prevalence of middle ear problem to be 65.8% and sensorineural hearing loss to be 34.2%.

The prevalence of noise-induced hearing loss is low among patients treated at the medical schools and various hospitals. It is speculated that patients with noise induced-hearing loss will not seek medical treatment, unless

they have other symptoms that are associated with the hearing loss. Most noise-induced hearing loss is caused by long term exposure to noises on the job. Patients usually do not notice the problem until it interferes with communication. The studies cited above are from the medical schools and hospitals; few studies in Thailand have been conducted in the industrial settings.

Kulertpornchareon (1980) studied the prevalence of hearing loss in workers at the Esso Oil Refinery. 5.7% of the workers examined had conductive hearing loss. 19.63% had noise-induced sensorineural hearing loss. The study indicated that the development of noise-induced hearing loss occurred during the first ten years of exposure. The percentage of hearing impairment ranged from 2 to 33 % based on the AA00 1959 formula.

Several researchers studied the prevalence of noise-induced hearing loss and indicated that the loss is sensory in nature. The audiometric configuration exhibited a dip of hearing thresholds in the high frequencies. Few attempts were made on the detailed analysis of the audiometric patterns.

Amartayakul (1979) was among the first to classify different types of noise-induced hearing losses based on audiometric configuration. He collected data from six industrial settings that were examined in 1969-1979. He

concluded that although 4% of the workers had typical noise-induced hearing loss, 30% of the workers had high frequencies hearing loss. Unless attempts were made to reduce noise levels in the work areas, there was a high potential that these workers would suffer permanent hearing loss.

Effect of Noise on Humans

Because of the development of industry, the problem of noise-induced hearing loss has been recognized and published over the years. Noise is not a new hazard in working environments. The effects of noise on man were recognized centuries ago. The first report of occupational hearing loss came from Ramazzini in "De Morbis Artificum Diatriba" in 1700. In his study, Ramazzini described the hearing difficulties in workers who hammer copper.

Noise exposure can cause both non-auditory and auditory effects. Intense noise may effect mental and physical health. Noise causes interference, annoyance, a decrease in performance efficiency, and physiological changes. The mental hazard of noise is difficult to measure directly because it involves no pathology. A noise level greater than 80 dB is usually protected by middle ear musculature (Jepsen, 1963). The contraction of stapedius muscle will

pull the stapes away from the oval window. As a result, low frequency sounds are damped, so sound pressure is not transmitted to the inner ear directly (Moller, 1972). There is a limitation to the protective mechanism in muscle contraction. In maximum contraction, the muscles reduce 10-20 dB of sound transmission at low frequencies. Since the reaction time is .06 seconds for the stapedius and .15 seconds for the tensor tympani to contract, once it exposed to high level noise, the inner ear may be damaged before muscle contraction occurs (Wever and Lawrence, 1954). Additionally, prolonged noise exposure may result in decreased protection due to fatigue of the reflex muscle (Tonndorf, 1976).

Noise Affects Mid and High Frequencies

There are two main types of noise induced hearing loss: hearing loss that can be attributed to a single brief intense noise, and those that occur gradually over a period of years. Both types of noise-induced hearing loss cause injuries to the hair cells in the Organ of Corti. There are several reasons that noise induced-hearing loss affects high frequency perception. Tonndrof (1976) indicated that the outer ear and head enhance the mid and high frequencies perception. In addition, Zakrison (1975) reported that contraction of the middle ear muscles

attenuate low frequency energy. Finally, the nerve supply for mid and high frequencies are wrapped in the peripheral portions of the ear, so sensitivity is easily impaired. High frequency receptor cells that are damaged by noise are sensitive to perception of sound at 3000-4000 Hz (Ward, 1976). With increasing years of exposure, the severity of hearing loss increases and spreads to frequencies below 3000 Hz, primarily the speech frequencies (Taylor et al., 1965).

TTS vs. PTS

Direct observation of hearing loss is determined by an audiometer. The configuration of the audiogram shows loss in hearing acuity for pure tone frequencies relative to reference values, (25 dB HL based on ANSI standard). Differences in hearing sensitivity between pre and post exposure is called threshold shift. Noise-induced hearing loss may be temporary or permanent. Temporary hearing loss is usually called temporary threshold shift (TTS) which can be recovered. TTS recovery time is within one and half minutes; the maximum threshold shift is seen at two minutes post exposure, (Hirst and Ward, 1952).

TTS occurring several times per day for months, or years will eventually develop into permanent threshold shift (PTS). Permanent threshold shift is the loss in hearing

sensitivity through out the remaining lifetime of the effected person, and cannot be recovered. The mechanisms which produce PTS are caused by physiological or metabolic stress which over-stimulate the sensory cells (Lim and Melnick, 1971). The PTS is the basic condition for occupational noise induced-hearing loss. PTS can be compounded by ototoxicity, vascular accidents, aging, and / or noise from other sources outside the industrial environment (Kryter, Ward, Miller, and Eldrege, 1966). PTS may be predicted from TTS, but there is a large individual difference in the susceptibility to noise (Ward, 1965).

Compounding Factors of Noise Exposure

The degree of hearing loss due to noise exposure is varied by factors such as sound pressure level, frequency composition of noise, duration of noise exposure, temporal distribution of noise exposure, subject variables (age, years of employment, gender), and ear effects. Nixon and Glorig (1961) studied the hearing sensitivity at 2000 and 4000 Hz in male workers. The average sound pressure levels (SPL) ranged from 77-96 dB in the frequency range of 150-4800 Hz. The subjects worked in a noisy environment from one to twenty-five years. The median hearing levels were calculated at 2000 and 4000 Hz. A correction factor was made for the effect of aging, so noise-induced hearing loss

was the sole consideration in the study. It was found that as SPL increased, the median of hearing loss increased at 2000 and 4000 Hz. The study indicated that sound intensity of greater than 75 dB, in the frequency spectrum of 1200-2400 Hz or 2400-4800 Hz, produced permanent threshold shift at 4000 Hz. This type of hearing loss occurred within the first ten years. There was no hearing loss at 2000 Hz even when the noise levels for low frequencies exceeded 84 dB.

Sataloff, Vassallo, and Menduke (1965) studied the audiograms of thirty-three workers in a jet engine plant. The noise levels in the plant were between 95 and 105 dB. The research found that hearing loss was stabilized after eleven years of work.

Kenney and Ayer (1975) compared hearing sensitivity of workers from a sheet metal construction site and at a sheet metal fabrication shop. These workers were exposed to the noise level usually exceeded 85 dBA, for two to three hours each day. When electric or pneumatic hand tools were used, the noise level exceeded 125 dB. Audiometric evaluation showed that the construction workers had greater hearing loss than those from the fabrication shop. The majority of the loss occurred between 3000 and 6000 Hz.

Kuzniarz et al. (1976) studied the effect of impulse noise on workers who were employed for one to thirty years. The impulse noise was 134 dBA and the continuous

noise was 118 dBA. The results indicated that hearing loss, caused by industrial impulse noise, was in the frequencies of 4000 and 6000 Hz. Hearing loss occurred after five years of working in a noisy environment. Further hearing loss was seen for each subsequent year of employment. The hearing losses at 1000 and 2000 Hz were not significant until the worker reached thirty years of employment. The extent of hearing loss was individual dependence. There was a 20 dB difference between tough, normal, tender ears.

Rop, Raber, and Fischer (1979) studied the effects of intensity and duration of noise exposure on workers in different age groups. The main intent of the study was to investigate the influence of noise on the ears and study gender susceptibility. Hearing evaluation was performed at 1000 to 3000 Hz. The outcome of study indicated that the amount of hearing loss increased with age. Exposure to six years of 100 dBA noise was approximately equivalent to fifteen years exposure to 94.5 dBA noise. For the same age level, women had less hearing loss than men for a comparable intensity and duration of exposure. The right ear had more hearing loss than the left ear.

Actually, the change in auditory threshold from one time to another, especially over a period for years, is a complex function. Aging plays a role in the degeneration of hearing sensitivity. Hearing loss associated with aging

progress is called presbycusis. A gradual decrease of hearing acuity is seen in individual who are and are not exposed to industrial noise. It is very difficult to differential noise-induced loss from the aging process loss. Audiograms from cases of presbycusis and chronic noise exposure show significant gradual decrease of hearing sensitivity in the high frequencies. The effect of noise exposure is believed to be an important factor in causing early presbycusis (Hinchcliffe, 1959). Males have been shown to be more susceptible to occupational noise than females (Royster and Thomas, 1979).

Tawin (1978) studied the prevalence of hearing loss in Thais with various age groups. 19% of the subjects with hearing loss were in the 50-59 year age group, and 36% were in 60-69 year age group. The study showed a tendency for hearing loss to increase with age.

Berger, Royster, and Thomas (1977) studied hearing sensitivity of individuals who had not been exposed to noise. The data was compiled from two groups of the population. One group was the subjects from rural areas with the ages ranging from 16 to 59 years. The other group was from urban area with ages ranging from 15 to 79 years. Several conclusions were drawn from the data. At all tested frequencies, hearing deteriorated as a function of age. Females had poorer hearing sensitivity than males for

frequencies between 500 and 1000 Hz. For higher frequencies, the situation was reversed, especially for the 35 to 55 years group. Young white females had better hearing than young black females for all frequencies.

Taylor et al. (1965) studied two hundred fifty-one female weavers. The work experience ranged from 1 to 52 years. The workers were exposed to noise levels above 99 dBA. The results showed there was a decrease in hearing sensitivity at 3000 to 6000 Hz after one year of employment. Further exposure to noise deteriorated hearing at both above and below 3000-6000 Hz, especially at 2000 Hz.

Grabowski and Miller (1977) studied audiometric configuration in 99 drop-forge hammer workers. The subjects were divided into three subgroups based on work experience : one to seven, eight to nine, and twenty to forty years. The audiometric results indicated that workers showed increased hearing impairment with increased duration of noise exposure. The greatest degree of hearing impairment occurred after nine to twelve years. The audiometric configuration of drop forge noise-induced hearing loss were not similar to the steady state noise-induced hearing loss.

Martin and Crowder (1978) studied hearing levels of aerospace workers with various years of experience. Changes in the hearing thresholds were considered significant when

the shift was greater than 10 dB. No practical or medical significance was found for the aerospace workers or the general U.S. population below the age of forty five. Occupation hearing loss was noted in workers with ten years, or more, employment.

Moschi, El-Sadik, and El-Dakhakny (1979) studied hearing loss in aerospace workers with various years of employment. The workers were selected from either the central air conditioning plant or the glass blowing shop. The later group was exposed to a higher noise level. The glass blowing worker showed a greater threshold shift at 125 to 2000 Hz. For high frequencies, the hearing threshold for both groups were similar.

Szanto and Ionescu (1983) compared the audiometric test results of male and female workers. The study concluded the hearing loss was more pronounced in males than in females; the hearing loss was occurred in the 2000-6000 Hz frequency range; and that occupational hearing loss occurred when exposed to noise of 98 dBA.

Chavalitskulchai, Kongmuang, and Sangrattanagul (1984) studied the hearing loss of textile workers who were exposed to continuous steady noise. The noise level was more than 90 dBA. There was a direct correlation between hearing loss and age; hearing loss and duration of exposure.

Skulsuksai (1982) studied the change in hearing acuity

in workers with ten years of noise exposure. The results showed that hearing loss increased significantly after 10 years. The hearing loss in older workers was greater than in younger workers. Hearing loss in the left ear was mainly in the frequencies of 4000 to 6000 Hz. For the right ear hearing loss mainly affected perception of tones at 500-2000 Hz. The amount of hearing loss increased with year of employment, especially in workers who did not use hearing protection.

Sataloff, Sataloff, Vassallo, and Menduke (1984) investigated the effects of prolonged intermittent noise exposure on hearing. Two hundred ninety-five workers who met the criteria were used as subjects for the study. Most subjects were exposed to jack-hammer noise of 118 dBA. The results showed that occupation noise-induced hearing loss occurred in high frequencies first, then spreaded to lower frequencies as the years of employment increased.

Taylor, Lampert, Pelmeur, Hamstock, and Kershaw (1984) determined noise levels and hearing thresholds of hammer workers, press operators, and normal subjects. The noise level for the hammers was 108 dB and the press operating was 99 dB. The results revealed hammer workers had hearing loss from 500 to 3000 Hz. The two groups showed similar threshold shift at 4000 to 6000 Hz.

From detailed examination of the above studies,

there was a close relationship between the level of noise exposure and the severity of hearing loss. However, the exact duration of noise exposure before the onset of hearing loss is still unknown, there was a need for research in this area.

Noise induced-hearing loss is thought to be bilateral in nature. However, there was some contradiction among researchers on the ear effect.

Charakorn (1976) reported hearing impairment in users with sport shooting. The subjects used Pistols, Rifles, and Shotgun as weapons. The results of audiometric evaluation revealed the users had high frequency hearing loss at 4K to 8KHz. 47.25% of the subjects had hearing impairment in the right and 41.75% in the left. 11.00% had an same degree of hearing loss in both ears.

Chung et al. (1983) studied the ear effect from audiograms of individuals exposed to noise. The left ear was found to be affected more by noise than right ear. 4.7% of the workers had asymmetric hearing loss of 20 dB or more at 2KHz. No information was given for other frequencies.

Hemlkamp, Talbott, and Margolis (1984) studied the effects of chronic noise exposure in factory. The audiometric configuration showed bilateral loss of hearing sensitivity at 3K to 6KHz.

Noise-Induced Hearing Loss and Laws

Auditory impairment usually produces two major types of receptive disorders: one is the loss which is associated with auditory sensitivity, and the other is the reduction in speech discrimination. In practice, the magnitude of hearing loss is usually determined from the threshold of hearing for pure tones at selected frequencies within the major useful range of human hearing, (125-8000 Hz). Occupational hearing loss not only affects loss of sensitivity, in many occasions, comprehensive of speech is also impaired. Although speech tests have been widely accepted for use in the diagnosis, several objections have been raised as to their validity in industrial testing. The objections include speech test items, procedures of administration, and scoring of the test. Because of the limitations in speech audiometry, the American Medical Association (AMA, 1961), and the Subcommittee on Noise of the American Academy of Ophthalmology and Otolaryngology (AAOO, 1959), developed the formula for speech to be determined from pure tone averages at 500, 1000, and 2000 Hz. In the determination of hearing impairment, an average for the above frequencies is obtained. A low fence of 25 dB HL is used as correction for normal hearing and aging effects. The average is then converted into percent of impairment by

using a multiplication factor of 1.5. The restriction of the formula to the "three central speech frequencies" is based upon the assumed relationship of these frequencies and conversational speech. However, the National Institute of Occupational Safety and Health (1972); Kryter, Williams, and Green (1978); and Suter (1978) all provided data indicating that people with reduced hearing sensitivity above 2000 Hz had difficulty in discriminating speech in noise. They objected the AA00 and AMA formula on the basis that the ability to hear in quiet environments is not the same as the ability to hear in the noisy listening situations. These investigators advocate the inclusion of 3000 Hz in the formula. The AMA, in 1979, recognized the deficiencies of the 1959 formula and recommended that 3000 Hz be added to the computation of hearing impairment.

Thai Worker Compensation Law

Although the problem of noise pollution has been recognized for many years in Thailand, it was not until 1972 that the Thai Ministry of Interior adopted a ruling law to protect workers from the harmful effects of noise. The laws were developed to provide workers had to a legal remedy for hearing losses which resulted from injuries sustained on the job. The worker had to demonstrate that the injury was associated with the type of job performed in claiming an

award compensation. The Thai government established compensation for occupational hearing loss based on the AA00 and AMA (1959) formula. The employers have been bound to pay an amount of money to compensate for the degree of hearing loss. For unilateral hearing loss, the compensation is calculated from the amount of money earned in ten months. For bilateral hearing loss, the workers obtain twenty-four months salary as compensation for the handicap.

Problems with the Present Law

Several researchers have indicated that the perception of consonants is essential to speech understanding. Acton (1970) indicated that significant loss in speech intelligibility occurred when hearing loss was at 2000 Hz. Gerber (1974) concluded that 95% of speech intelligibility lied in 500 to 8000 Hz; with 13% is in the frequency of 2000 to 4000 Hz and 12% of information in 4000 and 8000 Hz. Sher and Owen (1974) suggested that frequencies above 2000 Hz assisted the extraction of meaning from sentences. Pascoe (1975); and Skinner (1980) concluded that the large amount of speech energy is in 200 to 6000 Hz. Maroonroge and Diefendorf (1984) documented that speech discrimination was poor in individuals with noise-induced hearing loss because information was missing in the high frequencies.

Based on the above studies, high frequencies were

crucial for speech perception. There is a need for the Thai law to adopt high frequencies into the formulae. It was interesting to observe if inclusion of high frequencies affect the claims for occupational hearing loss.

Brainerd and Frankel (1985) studied the relationship between definitions of handicap base on a number of arithmetic formulae and self-report questionnaires. Calculated handicaps were based on six formulae; .5K,1K,2K, 4KHz (AMA, 1947), .5K-2KHz (AA00, 1959), .5K-3K Hz (AA00-AMA, 1979), 1K-3K (CHABA), 1K-4KHz (ASHA Task Force, 1981), and .5K-4K Hz (Ohio State, 1980). The perceived handicap was measured by Denver Scale of Communication Function and English version of the Social Hearing Handicap Index (SHI). The results indicated the Ohio State (1980), and AMA (1947) formula showed high number of subjects with handicap. In addition, the AMA 1947, and the Ohio State 1980 formula had the highest correlation with perceive handicap.

Noise and Threshold Shift

The auditory system is sensitive to sound. The small pressure change is able to initiate nerve impulses to the brain for interpretation. Exposure to noise of sufficient intensity for long periods of time can produce detrimental changes in the inner ear and seriously decrease the hearing ability.

An unusually thorough study was done in jute weavers

by Taylor et al. (1965). The weavers were all women with little exposure to noise other than that received on the job. The workers had worked in the mills from 1-52 years. All audiogram was obtained by trained technicians with a properly calibrated instrument. Hearing thresholds were measured after a weekend away from the job. As the exposures were repeated year after year, the ear was less and less able to recover from the temporary threshold shift. Most of the weavers had a chronic threshold shift of 25-55 dB at 4000 Hz. As duration of noise exposure increased, the frequencies above and below 4000 Hz were affected, especially at 2000 Hz.

Similar data has been gathered on workers in noisy industries in the United States by Nixon and Glogig (1961); Sataloff et al. (1964); Kenney and Ayer (1975). All studies indicated the relationship between threshold shift and the years of employment. According to Miller, the amount of threshold shift at 4000 Hz from occupational exposures showed no further increases after about 10 years of exposure, although the threshold shifts for lower frequencies continue to increase. There was a need to study the threshold shift at various frequencies, so reduction of noise levels by engineering control or ear protection could be can be provided.

CHAPTER 3

METHODOLOGY

In this study, the effects of noise exposure among the automobile workers were determined. The parameters investigated were: 1) The prevalence of hearing loss, 2) The duration of employment, 3) The detailed analysis of audiograms into group, and 4) The threshold shifts. This section described the experimental procedure.

Subject

The subjects consisted of workers from Siam Motors Co. Ltd. They were subjected to an audiological evaluation at the Speech and Hearing Clinic, Department of Otolaryngology, Ramathibodi Hospital between 1975 and 1985.

Criteria for Subject Selection

1. The workers who worked in noise environment.
2. The workers who returned for follow-up audiometric evaluation in 1985.
3. The workers had no conductive and/or mixed hearing loss.

Based on the above three selection criteria, the 93 cases were selection from 98 cases. Five subjects with external and/or middle ear pathology were eliminated from the study, since the purpose of the paper was to investigate the nature of noise-induced hearing loss.

Instrumentation

Impedance Audiometer

Impedance audiometry was conducted to confirm the status of the middle ear condition. Madsen Model ZO 73 was used in this study. The test consisted of tympanogram, static compliance, and acoustic reflex.

Audiometer

Audiometric testing was carried out by using clinical audiometer which was calibrated to American National Institute Standard (ANSI, 1969). Table 1 shows the sound pressure levels for TDH 39 earphone from .25 to 8KHz. The test was performed in a sound-treated booth that met ANSI standard for audiometric testing room (see Table 2).

Table 1 Reference Level for 0 dB HL Based On American National Standard Institute (ANSI, 1969).

Frequency (Hz)							
.25K	.5K	1K	2K	3K	4K	6K	8K
95.5	81.5	77.0	79.0	80.0	79.5	85.5	83.5

Table 2 Allowable Ambient Noise Level in Audiometric Room (ANSI, S.1.4-1971).

Frequency							
Overall	.125K	.25K	.5K	1K	2K	4K	8K
40	40	40	40	40	47	57	67

Procedure

The audiometric evaluation was scheduled in the morning prior to the changing of work shifts. The purpose was to prevent contamination of temporary threshold shift. Each worker had a rest period of at least 14 hours from work period. This time was sufficient for recovery of temporary threshold shift (OSHA,1981). The procedures for the test were as follow:

- 1 The workers were interviewed by using to filled out the questionnaires which consisted of medical history, previous, and current noise exposure information (see Table A-1, Page 72).

- 2 The workers were tested by using an impedance audiometer. Tympanogram indicated the status of the middle ear system. Static compliance showed equivalent volume of air between the probe and tympanic membrane. The acoustic reflex assessed the contraction of the stapedius muscle. Otoscopic examination was performed in subjects whose ear could not be sealed (see Fig. A-1, Page 73).

- 3 The workers were subjected to pure tone audiometric evaluation. The hearing test consisted of air and bone conduction thresholds, Weber and Rinne tests, speech reception thresholds, and speech discrimination testings. Audiometry and Impedance audiometry were performed by the audiologists or well trained audio-technicians.

4 The auditory thresholds was determined by ascending or decending techniques. The orders of test frequency were as follow: 1K,2K,3K,4K,6K,8KHz; then returned to the low frequencies of .5K,.25KHz. The hearing threshold for 1KHz was reestablished for inter test reliability. The threshold was defined as the minimal intensity level which a sound could be heard 50% of the time. Table A-2 (Page 74) showed the raw data of 93 subjects.

5 Bone conduction was determined after air conduction thresholds were complete. A Bone vibrator was placed on the mastoid bone behind the auricle. Bone conduction thresholds were determined at frequencies of .5K,1K,2K,3K, and 4KHz by using the same procedure as in the air conduction test. Masking was used when necessary.

6 The automobile plant was inspected in order to study the working enviroment. The plant could devided into several sections: chief press, chief die making, chief hand work, chief cutting, storage room, admistration office. Noise levels were measured by the Occupational Health Center 1 by using a sound level meter,(B&K type 2205, serial no. 315406). Fig. A-2 (Page76) showed the lay out of sound measurement in A-weighting scale.

Data Analysis

Table 3 showed the conceptual framework for data

analysis in this study:

1 The audiograms from all subjects were classified into types of hearing loss which consisted of normal hearing, conductive hearing loss, mixed hearing loss, and sensorineural hearing loss. The percentage of each type was compared to previous published data in Thailand.

2 The subjects with no external or middle problem were further classified into different groups. The groups consisted of normal hearing, abnormal hearing, and registered hearing loss based on the most recent audiogram. The number of workers in each groups were compared among the different work years by using chi-square test.

3 For the subjects who were classified into registered cases, further analysis was obtained by dividing these into five subgroups, (see Table 4, Page 36). The number of workers who had noise-induced hearing loss were compared with high frequency hearing loss.

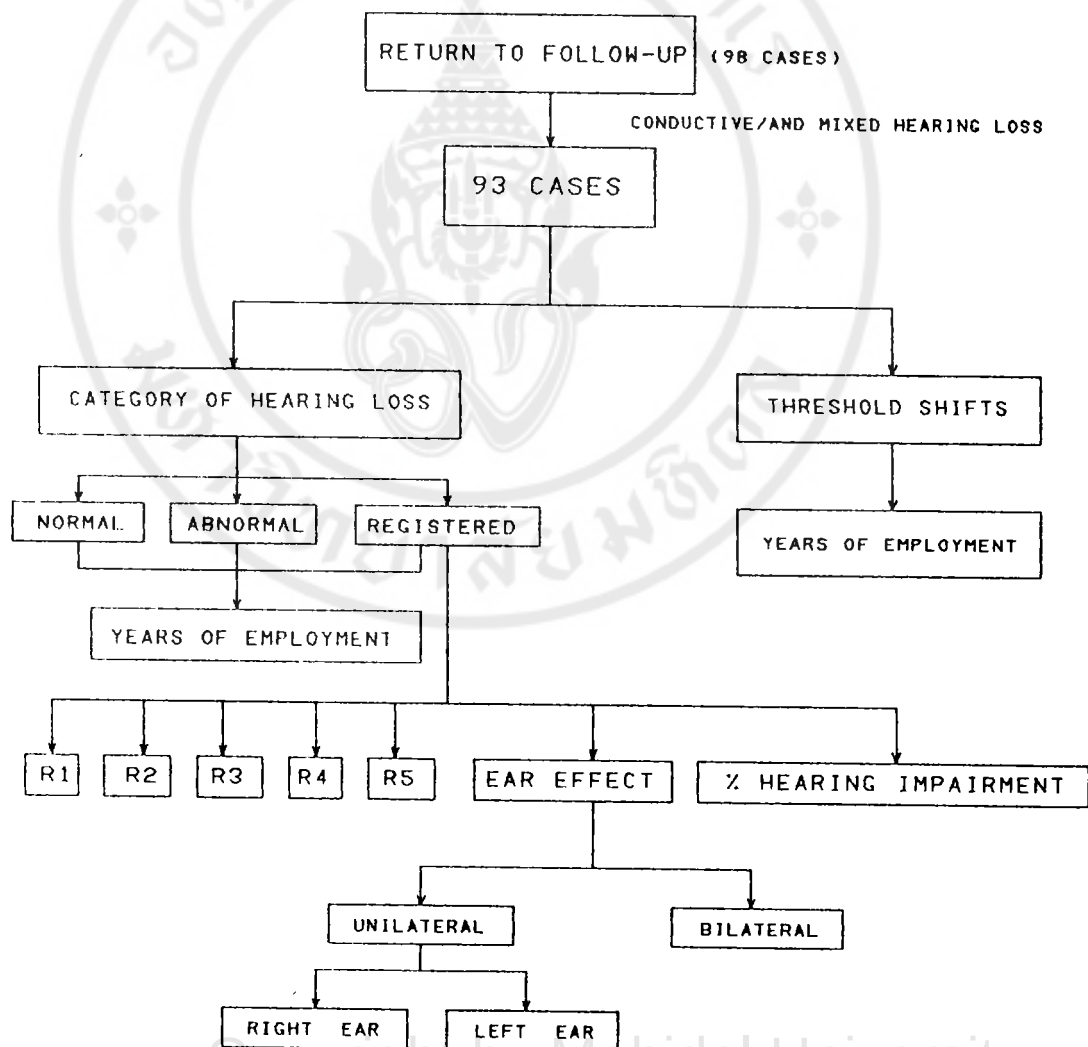
3. Unilateral and bilateral hearing loss were analyzed in subjects with hearing impairment. The effect of noise on hearing of the right ear and the left ear were compared.

4 The percentage of hearing handicaped was obtained by using hearing impairment formula based on; A) .5K,1K, and 2KHz (AA00, 1959); B) .5K,1K,2K, and 3KHz (AA00-AMA, 1979); C) .5K, 1K,2K,3K, and 4KHz; D) .5K,1K,2K,3K,4K, and 6KHz. Table A-3, Page 78 described the procedure to calculate

hearing impairment.

5 The distribution of threshold shifts at .5K-8KHz and years of employment were studied.

Table 3 The Conceptual Framework





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CHAPTER 4

RESULTS

The purpose of this study was to investigate the nature of hearing loss among automobile plant workers. The results of this study were described in six parts.

1. Prevalence of Hearing Loss

98 workers who returned for annual audiological evaluation were studied. Hearing sensitivity was examined by pure tone audiogram and impedance audiometry. The prevalence of hearing loss is shown in Fig.1. 29 cases (29.59%) were found to have normal hearing, five (5.10%) cases had conductive hearing loss, and 64 cases (65.31%) had sensorineural hearing loss. No mixed hearing loss was observed.

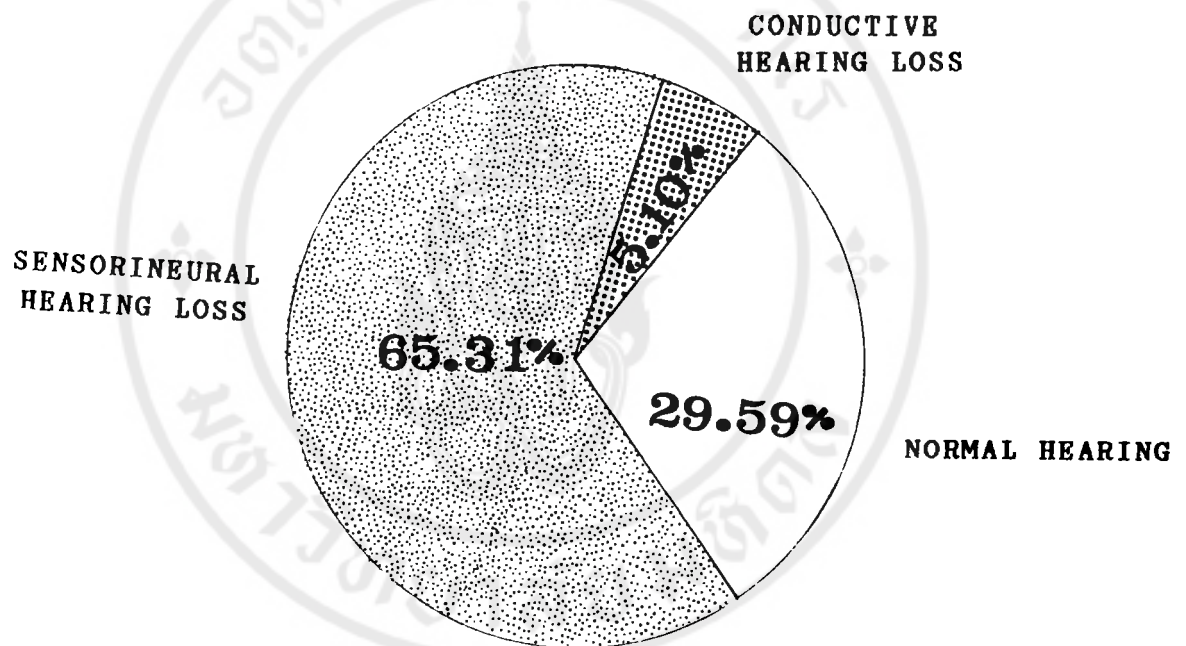


Figure 1 Distribution of Hearing Loss by type (n=98)

2 Noise-Induced Hearing Loss and Duration of Employment

Since the purpose of this paper was to investigate the nature of noise-induced hearing loss among workers in an automobile plant, five workers with middle ear pathology were eliminated from the study. 93 workers with normal hearing and sensorineural hearing loss were included in the final analysis.

Detailed analysis of hearing sensitivity was performed on the audiograms of 93 workers. The subjects were divided into three groups.

1. Normal hearing (N): The average hearing threshold at .5K, 1K, and 2KHz were less or equal than 25 dB. The hearing thresholds at 1K to 8KHz were less or equal than 25 dB and at .5KHz was 30 dB.

2. Abnormal hearing (A): The hearing threshold at .5K, 1K, and 2KHz more than 25 dB. No noise-induced patterns were included in this group.

3 Registered hearing loss (R): This category consisted of detailed analysis of noise-induced hearing loss as well as high frequency hearing impairment. Registered hearing loss was classified into five subgroups (See table 4).

Table 4 Subgroups of Registered Hearing Loss

Audiogram	Definition
	Registered type 1 (R1) Bilateral sensorineural hearing loss with a dip at 3K, 4K or 6K Hz with better hearing at 8K Hz.
	Registered type 2 (R2) unilateral noise-induced hearing loss.
	Registered type 3 (R3) Bilateral high frequency hearing loss.
	Registered type 4 (R4) Unilateral high frequency hearing loss.
	Registered type 5 (R5) Unilateral noise-induced hearing loss and unilateral high frequency hearing loss.

Table 5 classifies 93 workers into three groups. 31.18% (29) of workers showed normal hearing, 9.68% (9) of workers had abnormal hearing, and 59.14% (55) of workers had registered hearing loss.

Table 5 The Distribution of Workers With Normal Hearing, Abnormal Hearing, and Registered Hearing Loss Based On the Most Recent Audiometric Findings.

Group	Number of Workers	Percentge of Workers
Normal Hearing	29	31.18
Abnormal Hearing	9	9.68
Registered Hearing Loss	55	59.14
TOTAL	93	100.00

The workers with three different groups were classified by years of employment and are shown in table 6. There was no significant difference between the number of workers in each group and work years as indicated a by chi-square test. However, the number of workers with normal hearing and abnormal hearing loss workers tended to decrease when work years increased. The number of workers with registered hearing loss tended to increased with years of employment.

Table 6 The Number and Percentage of Workers With Normal Hearing, Abnormal Hearing, and Registered Hearing Loss Classified by Years of Employment.

Year of Employment	Normal Hearing	Abnormal Hearing	Register Hearing Loss	Total
less than or equal 5	6 (37.50%)	3 (18.75%)	7 (43.75%)	16
6 - 10	19 (35.85%)	4 (7.55%)	30 (56.60%)	53
11 - 15	4 (16.67%)	2 (8.33%)	18 (75.00%)	24
Chi - square = 5.59 df = 4 P > 0.05				

3. Noise-Induced Hearing Loss and High Frequency Hearing Loss

The workers with registered hearing loss were subclassified into five categories and shown in Table 7. 29.09% (16) of workers showed bilateral noise-induced hearing loss, 45.45% (25) of unilateral noise-induced hearing loss, 5.46% (3) of bilateral high frequency hearing loss, 10.91% (6) of unilateral high frequency hearing loss, and 9.09% (5) a combination of unilateral noise-induced hearing loss and unilateral high frequency hearing loss.

5 times greater than bilateral high frequency hearing loss; unilateral noise-induced hearing loss was about 4 times as much as unilateral high frequency hearing loss.

In summary, the percentage of workers with noise-induced hearing loss was higher (74.54%) than those with high frequency hearing loss (16.37%).

**Table 7 The Number and Percentage of Subgroups With
Registered Hearing Loss.**

Subgroups	Number of Workers	Percentage of Workers	Total
Bilateral Noise-Induced Hearing Loss	16	29.09	41 (74.54%)
Unilateral Noise-Induced Hearing Loss	25	45.45	
Bilateral High Frequency Hearing Loss	3	5.46	9 (16.37%)
Unilateral High Frequency Hearing Loss	6	10.91	
Combination of Unilateral Noise-Induced and High Frequency Hearing Loss	5	9.09	5 (9.09%)
Total	55	100.00	

4. Ear Effect

Data from registered hearing loss were further divided into unilateral and bilateral hearing losses.

Fig. 2 shows 56.36% (31) of the workers had unilateral hearing loss and 43.64% (24) of the workers showed bilateral hearing loss. Audiograms the unilateral hearing loss was 13% more greater than bilateral hearing loss.

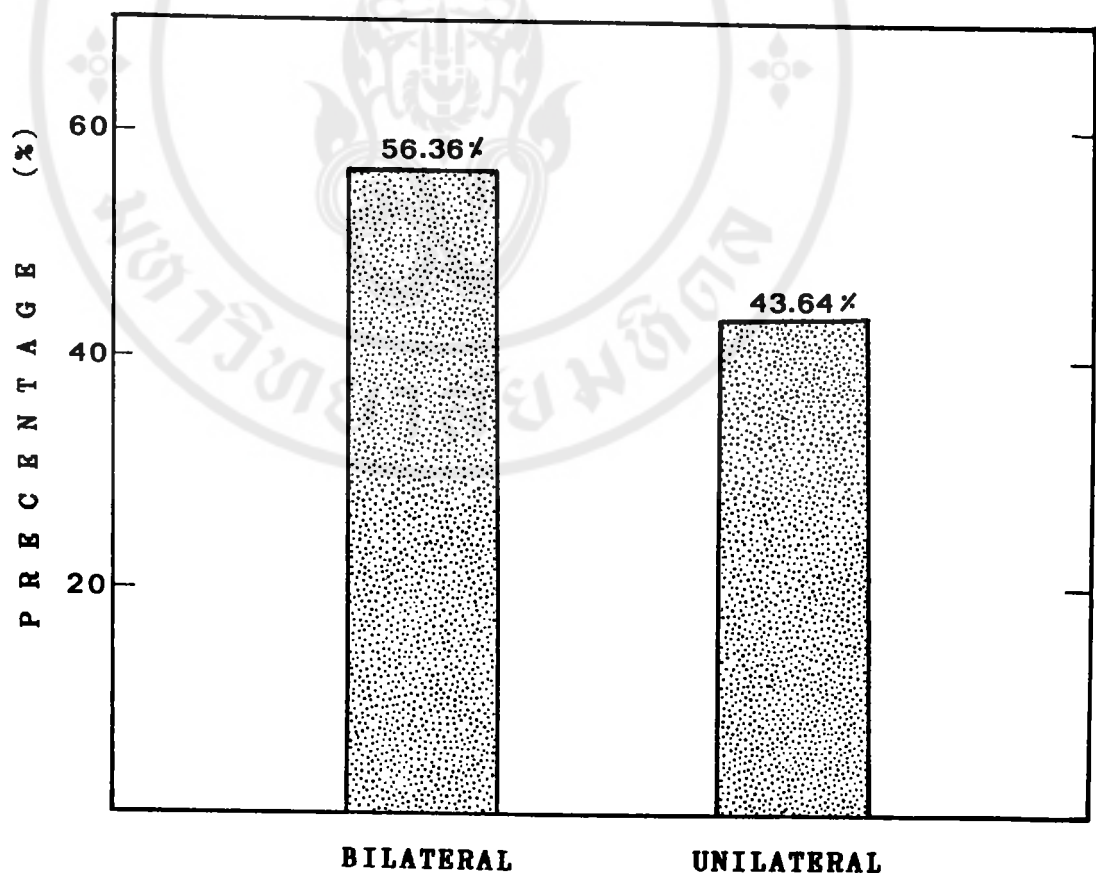


Figure 2 Percentage of Workers With Unilateral and Bilateral Hearing Loss (n=55)

For workers with unilateral hearing loss, 54.84% (17) of the workers had right ear impairment and 45.18% (14) had left ear hearing loss as shown in Fig. 3.

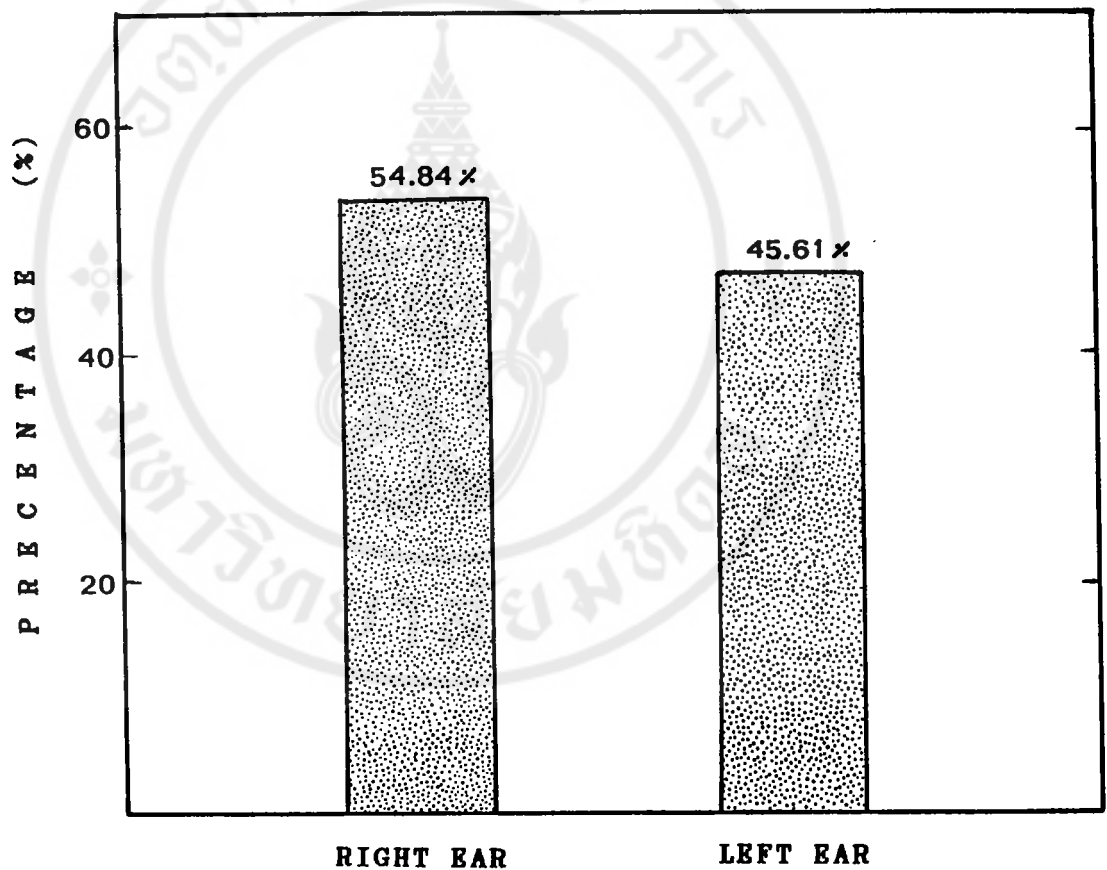


Figure 3 Percentage of Workers With Right and Left Ear Affected by Noise (n=31)

The percentage of hearing impairment was studied in subjects with registered hearing loss (n=55). Hearing impairment was defined as threshold shift of greater than 25 dB HL or more. The formulae used in calculation were included: .5K-2KHz (AA00, 1959), .5K-3KHz (AA00-AMA, 1979), .5K-4K Hz, and .5K-6K Hz.

The percentage of workers who exhibited hearing handicaps, based on four different formulae as shown in Fig.4. 7.27% (4) of workers were found to have hearing handicaps with the .5K-3KHz formula, 27.27% (15) of the workers had hearing handicaps based on the .5K-4KHz formula, and 29.09% (16) of the workers showed impairment if 6KHz was included in the calculation. No worker was found to have hearing impairment when the frequency range of .5K to 2KHz were used in calculation.

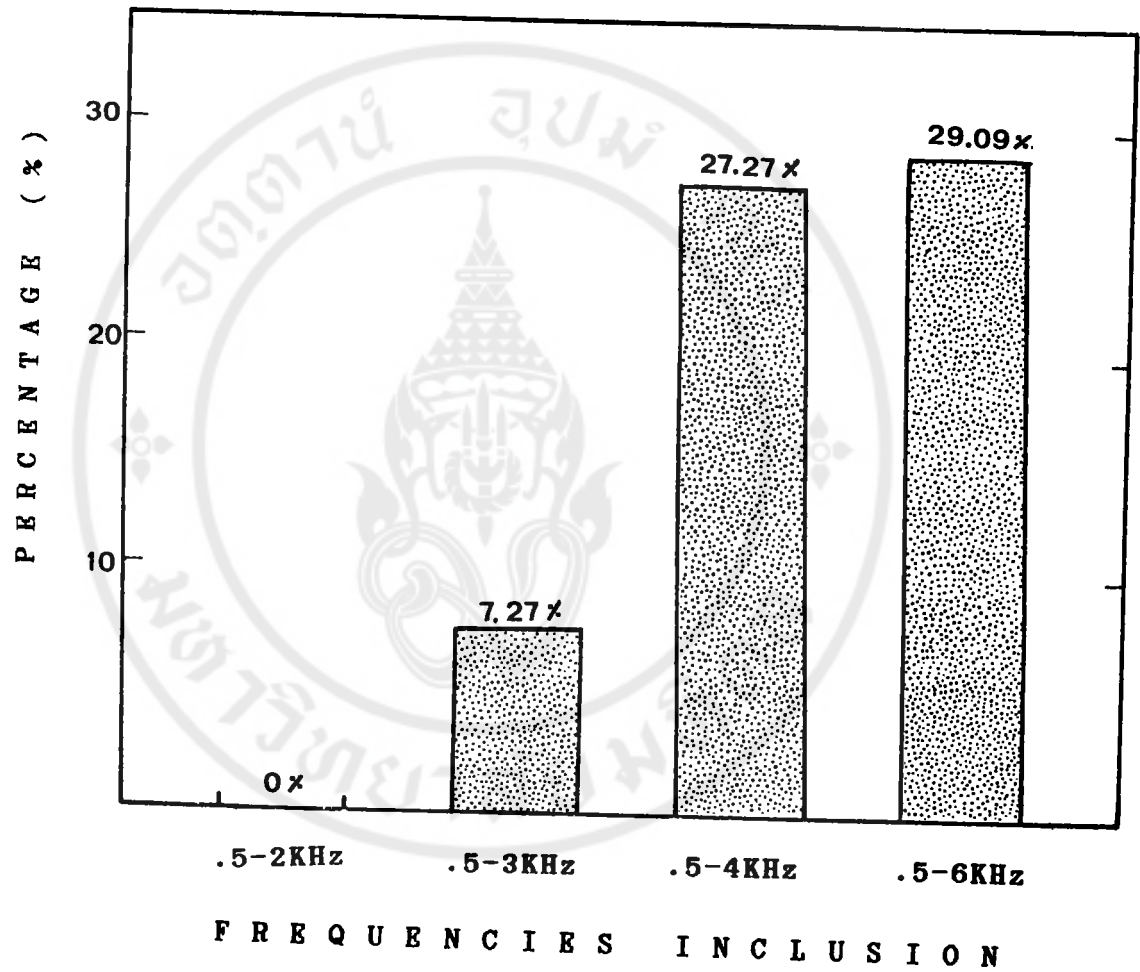


Figure 4 Percentage of Workers With Hearing Handicaps Based On Various Formula (n=55)

6. Threshold Shifts

The audiograms of 93 workers were study further for threshold shift due to noise exposure. The differences in hearing thresholds between the baseline audiogram and the most recent audiograms were used for making comparisons. Threshold shift was defined as any changes of the hearing sensitivity in the two test results. The distribution of threshold shift in the worst ear was plotted as a function of years of employment. The distribution is shown in Fig. 5 through 11.

The majority of threshold shifts were within 10 dB for frequencies of .5K (Fig.5), 1K (Fig.6), and 2K Hz (Fig. 7). There was a tendency for greater threshold shift at 3KHz, compared to 1K and 2KHz (Fig.8). The dB differences between the two audiograms ranged from 0 to 40 dB. The greatest threshold thift was obtained for 4KHz, after five years of employment. The threshold distribution shows a scattered plotting for all workers with regrad to years of employment. For workers who were employed greater than ten years, more threshold shifts were seen at 4K,6K,8K, and 3KHz. The thresholds at low and mid frequencies (.5K,1K,2KHz) showed minimal shift across years of employment.

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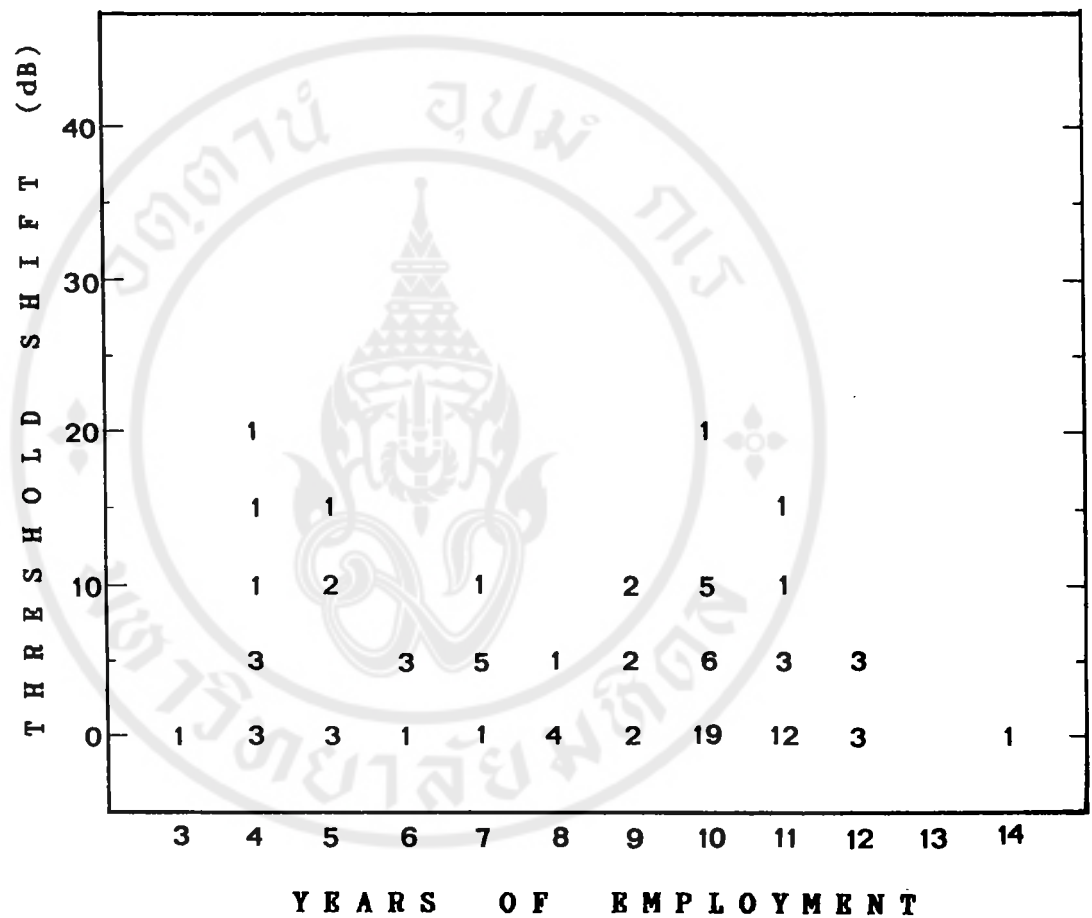


Figure 5 The Number of Workers With Threshold Shift in the Worst Ear at .5KHz Classified by Years of Employment (n=93)

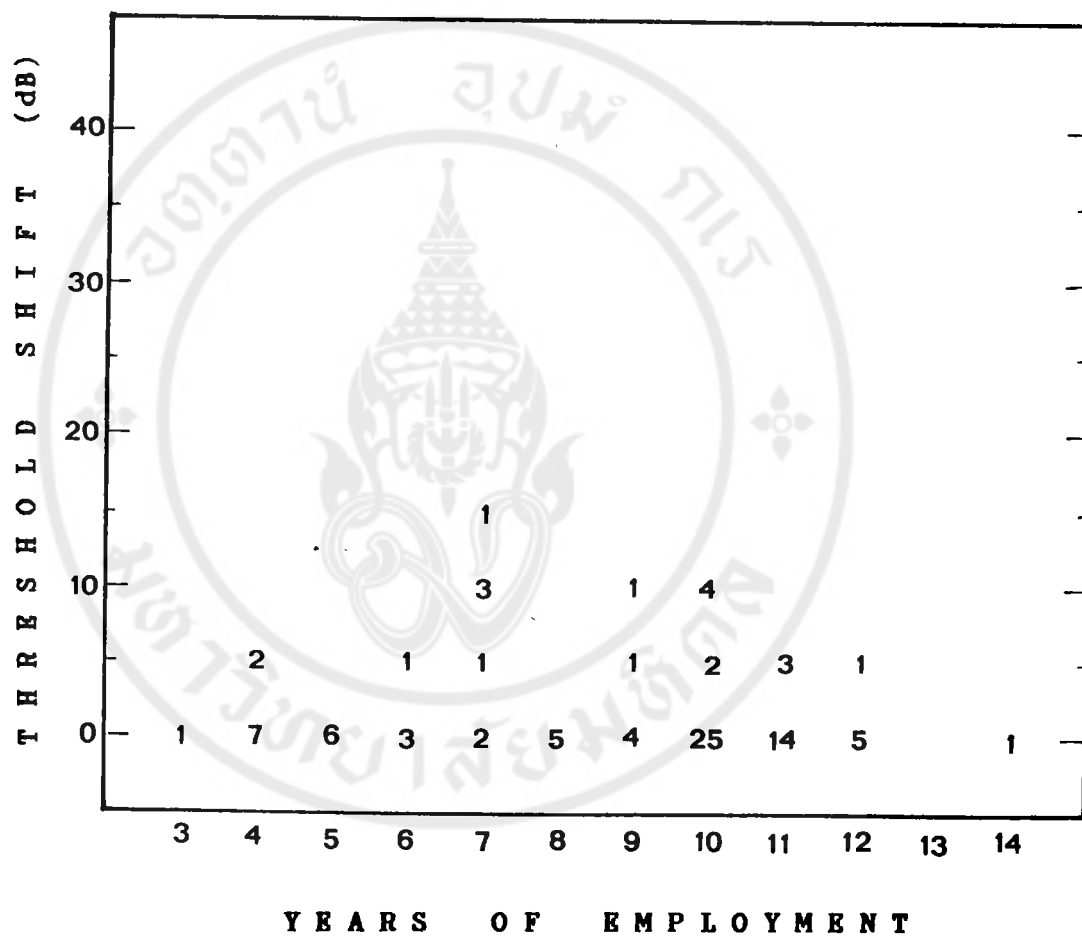


Figure 6 The Number of Workers With Threshold Shift in the Worst Ear at 1KHz Classified by Years of Employment (n=93)

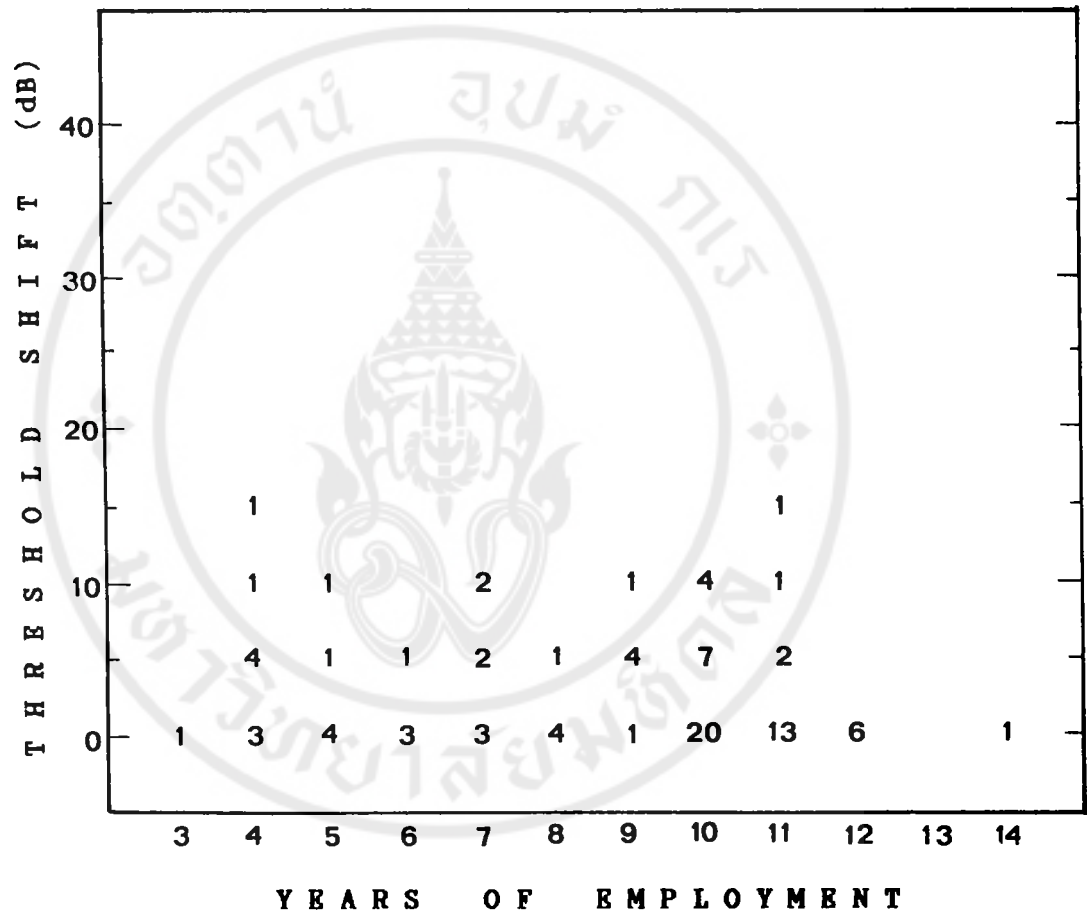


Figure 7 The Number of Workers With Threshold Shift in the Worst Ear at 2KHz Classified by Years of Employment (n=93)

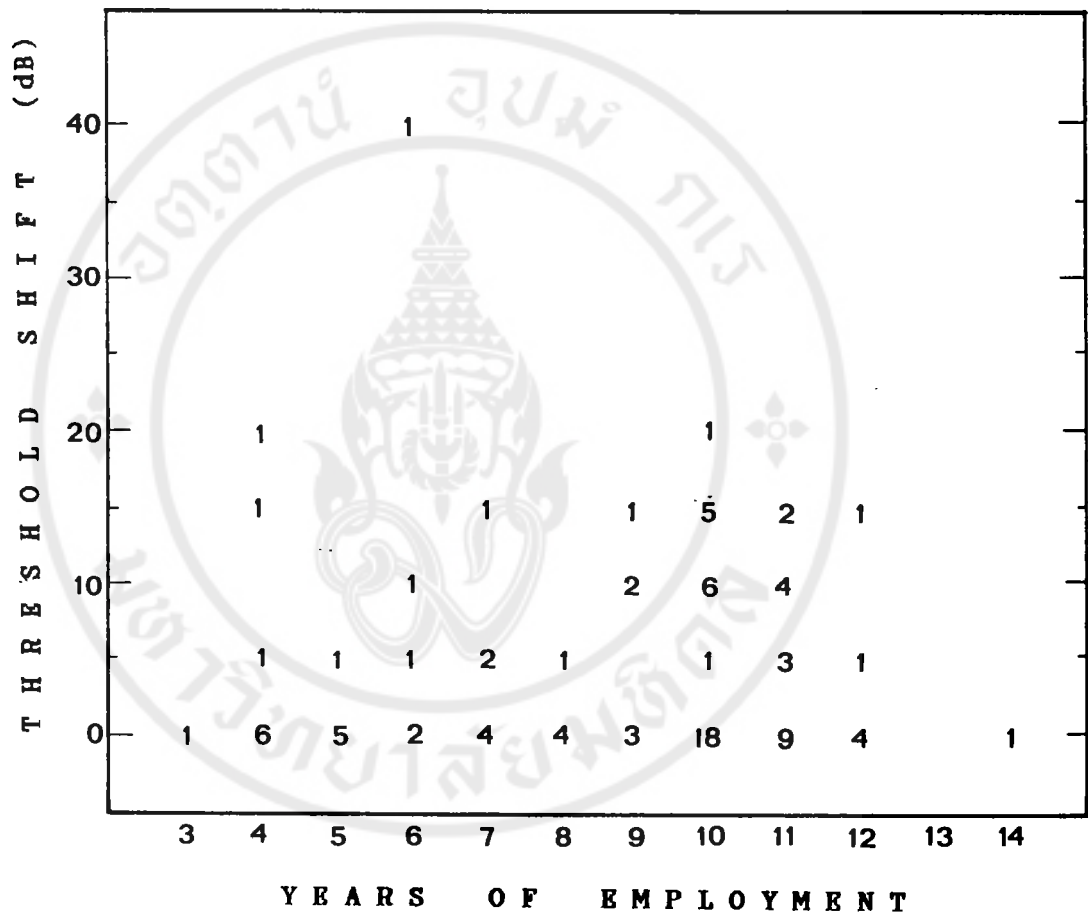


Figure 8 The Number of Workers With Threshold Shift in the Worst Ear at 3KHz Classified by Years of Employment (n=93)

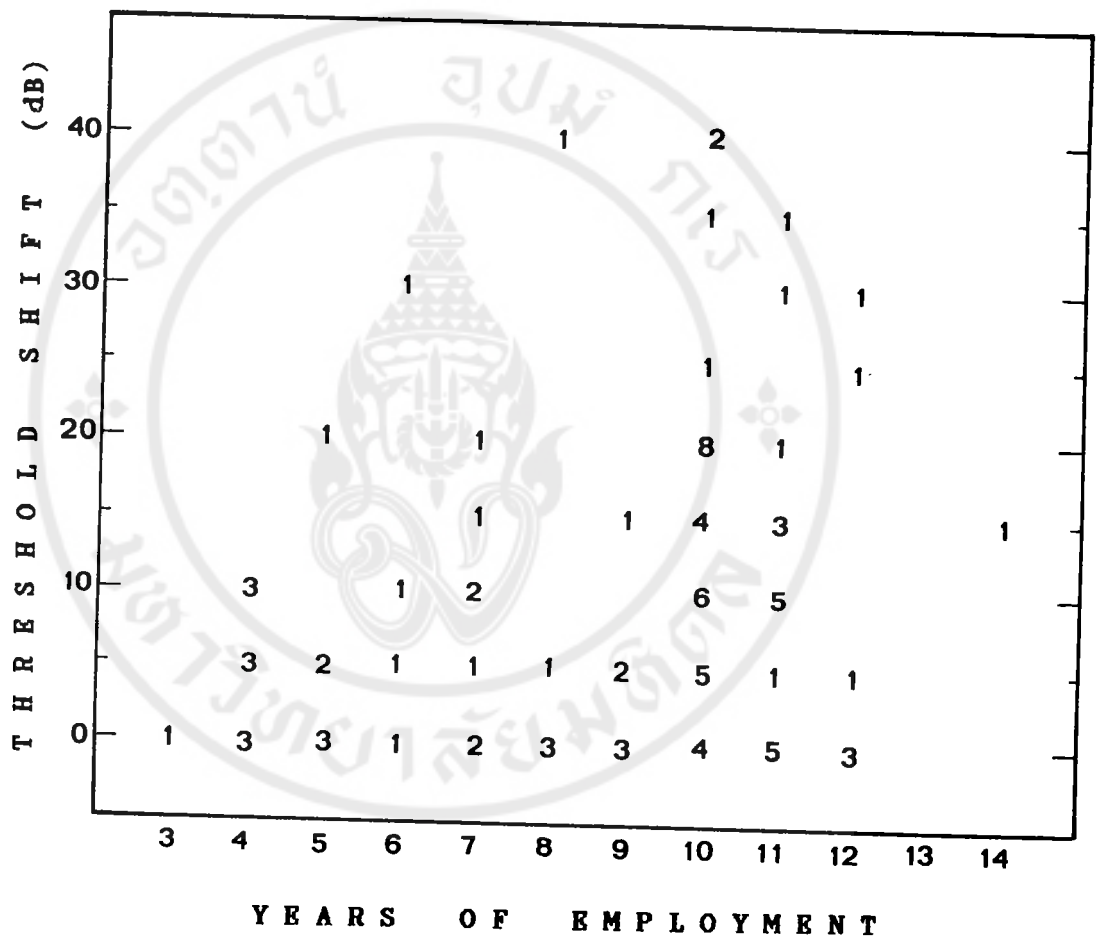


Figure 9 The Number of Workers With Threshold Shift in the Worst Ear at 4KHz Classified by Years of Employment (n=93)

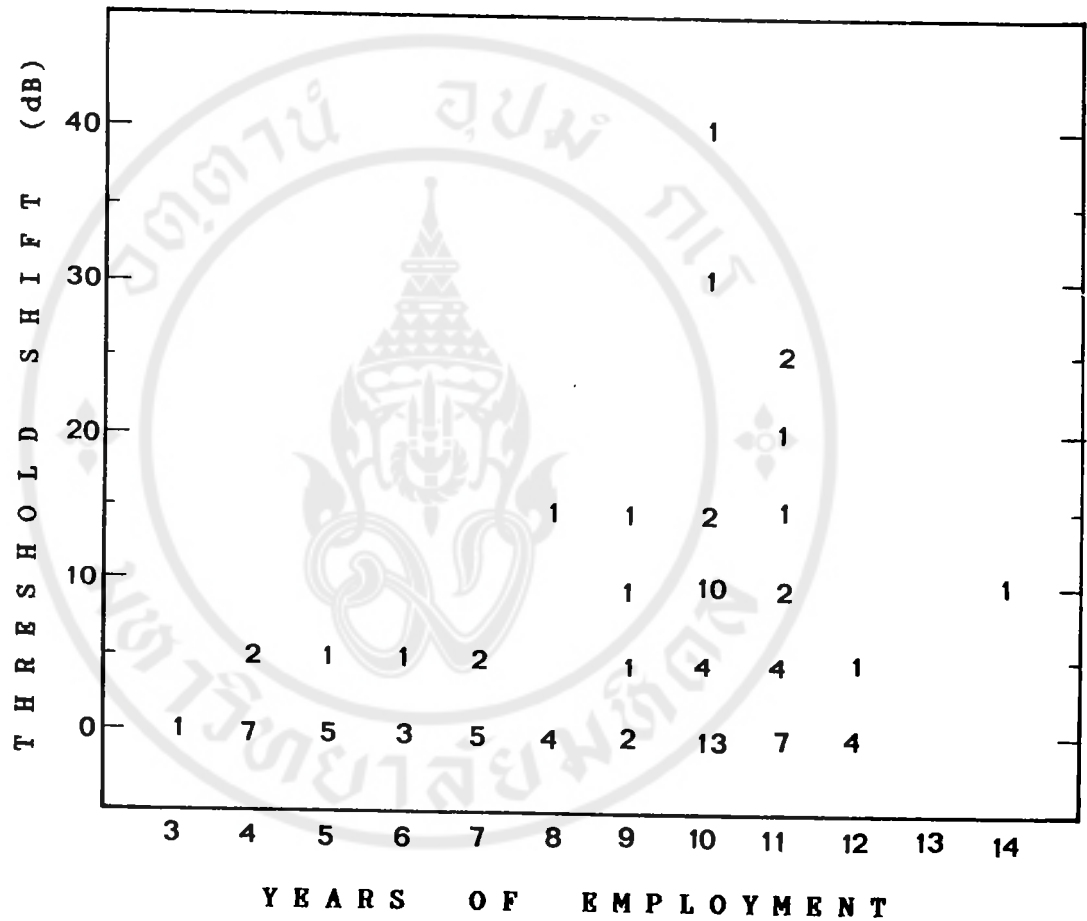


Figure 10 The Number of Workers With Threshold Shift in the Worst Ear at 6KHz Classified by Years of Employment (n=93)

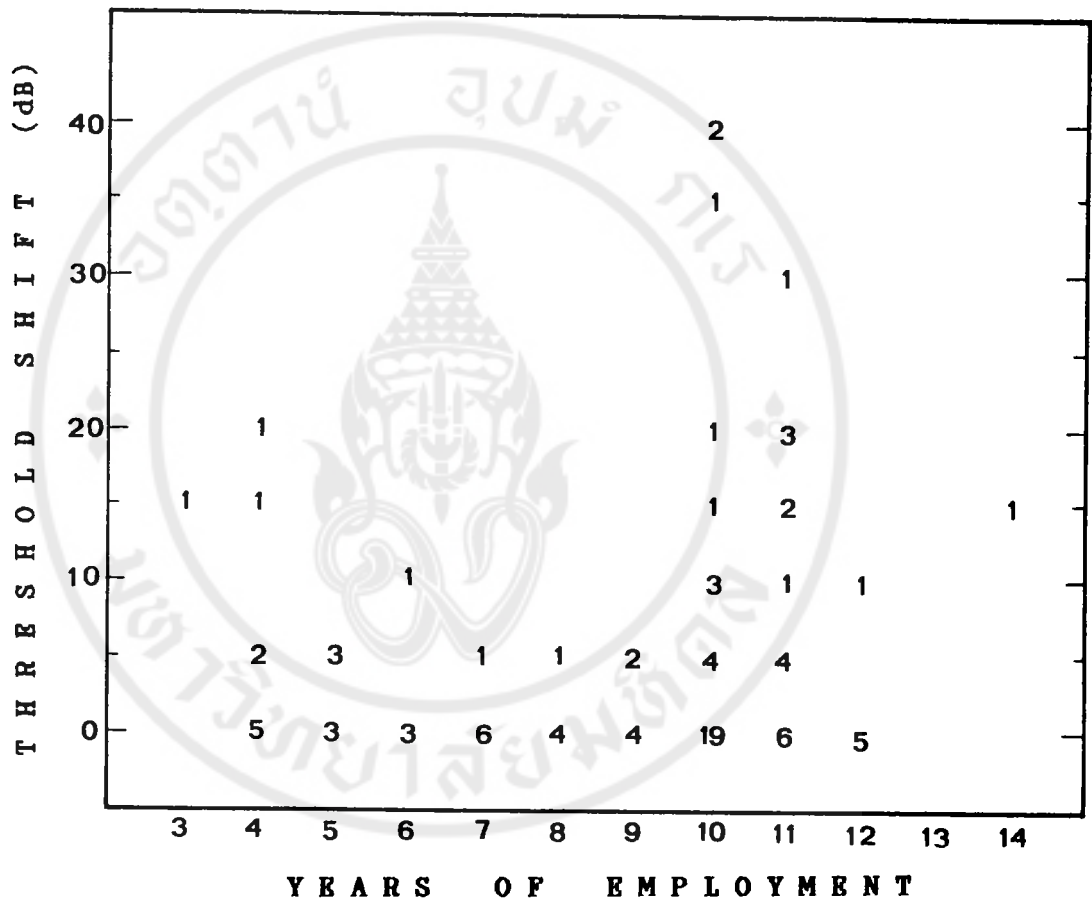


Figure 11 The Number of Workers With Threshold Shift in the Worst Ear at 8KHz Classified by Years of Employment (n=93)

CHAPTER 5

DISCUSSION

1. Prevalence of Hearing Loss

The purpose of the present study was to investigate the nature of hearing loss among workers in an automobile plant. The prevalence of hearing loss was based on information obtained from their most recent audiograms. The prevalence of sensorineural hearing loss was 65.31%. This prevalence was high compared to conductive hearing loss (5.10%) and normal hearing (29.59%).

Kulertpornchareon (1980) studied the prevalence of hearing loss among workers in an Esso Oil Refinery. 5.7% of the workers were found to have conductive hearing loss. The percentage was similar to the present study. However, the incidence of sensorineural hearing loss in Kulertporncharoen's study was 19.63%. The present study showed 65.31% of the workers exhibited various degrees of sensorineural hearing loss. The difference between the two studies could be attributed to the differences in the hearing conservation program and the population being studied.

When the data from this study were compared to the study of epidemiology of deafness in Thailand. It was found that this study had higher prevalence of sensorineural

hearing loss than those incidence reported by Antarasena et al. (1986). Since this study was conducted in general population, the percentage should be varied from studies conducted in the industrial settings.

Ruckphaopunt (1983); Sangsa-ad 1983); Peeravuth (1983); Prasansuk (1983); Cutchavaree (1983) studied the prevalence of hearing loss of patients treated in various hospitals in Thailand. The prevalence of conductive hearing loss ranged from 32% to 85%. Sensorineural hearing loss ranged from 7% to 48%. The ranges of hearing loss were large among studies. When the above results were compared to the present study, the prevalence was dissimilar. Three reasons were speculated for these discrepancies:

- 1) The patients who came to hospitals for medical treatment usually showed middle ear problems, therefore, the incidence of conductive hearing loss was high in the hospital settings.

- 2) The patients with mild sensorineural hearing loss such as those exposed to noise might not seek medical consultation because the hearing loss had not yet interfered with communication.

- 3) Occupational hearing loss was caused by long term exposure to noise at work. Patients were usually not aware of the hearing loss, unless the patients had tinnitus or communication problems.

2. Noise-Induced Hearing Loss and Duration of Employment

When the most recent audiogram of the whole group was analyzed, five workers with conductive hearing loss were eliminated from the study, 29 workers had normal audiograms, and nine workers had abnormal audiograms that were not related to noise. The remaining workers (55) had audiograms which could be classified into registered group. This classification consisted of workers with typical noise-induced hearing loss or hearing loss mainly in the high frequency region. Table 5 (Page 37) showed the percentage of workers with registered hearing loss was greater than normal hearing or abnormal hearing loss.

The results of a chi-square test (Table 6, Page 38) indicated no differences between duration of employment and the number of workers in the three groups. The non-significant effect of work duration was possible due to small sample size and the division of workers into three periods of working duration. However, the number of workers with registered hearing loss tended to increase when years of employment increased, whereas the number with normal hearing or abnormal hearing tended to decrease in number. Taylor et al. (1965); Kuzniarz et al. (1975); and Grabowski and Miller (1977) found duration of employment influenced hearing loss. It was possible that the studies cited above used subjects with more than 30 years of noise exposure. The

maximum years of employment of in the present study was 14 years, (See Table A-4 Page 78). This could account for some of the differences among this study and previous research.

Furthermore, this study analyzed the effect of employment duration on the number of workers with normal hearing, abnormal hearing, and registered hearing loss. This method was to classify the audiograms into three groups. No emphasis was placed on the amount of threshold shift as study by other investigators. Since data analysis was different, direct comparison could not be made.

From the review of literature, researchers found individuals with presbycusis had high-frequency sloping hearing loss. When the age range of the workers was examined, the results indicated the maximum age was 48 years. 90% of workers were less than 39 years old (See table A-5, Page 79). Since Tawin (1978) found presbycusis occurred at age of 50, therefore, high frequency hearing loss shown by workers could not be related to aging process.

3. Noise-Induced Hearing Loss and High Frequency Hearing Loss

Sound measurements in the work area were obtained by Occupational Health Center 1. The type of noise at Siam Motors Co. Ltd. plant were combinations of continuous noise and impulse noise. The noise level in the chief press section, chief die making section, and chief hand work area exceeded 85 dBA (See Fig. A-2, Page 76). The maximum noise

level was approximately 99 dBA when press machines were in operation. This level was considered harmful by the standards of the National Instituted of Occupational Safety and Health (NIOSH) as shown in Table A-6 (Page 80). Table A-7 (Page 81) showed 60% of workers worked in areas where noise exceeded the recommended standard. 31% of workers did not have fixed duty; they were rotated among various areas.

The audiometric configuration of noise-induced hearing loss was studied by Nixon and Glorig (1961); Kenny and Ayer (1975). The results indicated that noise damage hearing sensitivity at 3K-6KHz while other frequencies remained intact. Grabowski and Miller (1977) found audiograms of the workers exposed to impact noise had high frequency sloping hearing loss (3K-6KHz). Sataloff et al. (1984) documented occupational hearing loss occurred in high frequencies (3K-8KHz) before spreading to low frequencies.

Since the automobile plant in this study produced continuous and impluse noise, both noise-induced hearing loss and high frequency patterns were expected (See Table 4, Page 36).

The audiograms of registered hearing loss were organized into five subgroups 1) bilateral noise-induced hearing loss, 2) unilateral noise induced hearing loss, 3) bilateral high frequency hearing loss, 4) unilateral high frequency hearing loss, and 5) a combination of noise-

induced hearing loss and high frequency hearing loss. The results of the five subgroups were compared in table 7 (Page 40). The number of workers with bilateral noise-induced hearing loss (29.09%) was greater than those with bilateral high frequency hearing loss (5.46%). Unilateral noise-induced hearing loss (45.45%) was higher than unilateral high frequency loss (10.91%). It was concluded that there were more audiograms with noise-induced hearing loss (75.54%) than those with high frequency hearing loss (16.37%).

Two reasons were offered to explain why noise-induced hearing loss was seen more frequently than high frequency hearing loss in industrial workers: 1) Tonndorf (1976) suggested 3K to 4KHz perception was enhanced by the outer ear and the head. If the ear was sensitive in the regions, then the possibility of damaging these areas was great. 2) Ward (1978) indicated the nerve supplies for 3K-6KHz are wrapped in the peripheral portion of the ear, so sensitivity was easily damage.

4. Ear Effect

The audiograms of the right and the left ear were compared to determined ear effect. If both ears showed hearing loss, the ear effect was considered to be bilateral. If only one ear was involved, then the problem was

considered as unilateral hearing loss. The term "ear effect" referred to the ear with a hearing loss of greater than 25 dB HL. The results in Fig.2 (Page 41) revealed 56.36% of workers had unilateral hearing loss, and 43.64% had bilateral hearing loss. Hemlkamp et al. (1984) studied audiograms from workers with chronic noise exposure. The study indicated that both ears were equally affected by noise. The discrepancy in finding might due to subject selection and nature of noise exposure among the two studies.

Fig. 3 (Page 42) revealed the right ear was more effect than the left ear. Charakorn (1976) found that a high percentage of sportshooters had hearing loss in the right. The use of right hand in pistol shooting caused damage to the right ear, since it was the side which turned to ward the source. However, the use of shoulder weapon caused hearing loss in the left ear. The right shoulder was used to support the gun and left ear was to face toward the noise source. Charakorn (1976) speculated that head shadow was responsible for this ear effect. The diffraction of sound generated by the gun was attenuated in the ear which was located away from the source. This present study supported his finding.

5. Hearing Handicaps

The hearing thresholds of each worker were calculated

by using the following formulae: 1) .5K-2KHZ (AA00, 1959) 2) .5K-3KHZ (AMA-AA00, 1979) 3) .5K-4KHZ and 4) .5K-6KHZ. The results indicated that when high frequency thresholds were included in the calculation, the number of workers with hearing handicaps increased (Fig.4, Page 44). None of workers had handicap with the .5K- 2KHz formula. Sataloff et al. (1984) investigated the percentage of hearing handicaps caused by intermittent noise. They compared the percentage of hearing impairment by using the AMA formula (.5K-2KHz) and AA00-AMA formula (.5K-3KHZ). More workers with hearing handicaps were found with AA00-AMA formula than with AMA procedure. In addition, the percentage of workers with hearing handicaps increased with the duration of employment. Brainerd and Frankel (1985) studied the relationships of formulae for calculation of hearing handicaps and the Denver Scale of Communication Function or the Social Hearing Handicap Index. The AMA (1947) and the Ohio State (1980) formulae showed high correlation between hearing handicaps and perceived handicaps. A similarity was found between the present investigation and previous researches. Hearing loss from noise exposure occurred at high frequencies first, the most prominent loss was at 4KHZ as suggested by Taylor et al. (1965). Therefore, more workers were found to have handicaps when 4KHZ was included in the formulae. Since researchs have indicated that high frequency information is

essential for speech recognition (Gerber, 1947; Skinner, 1980; Pascoe, 1984; and Maroonroge and Diefendorf, 1984). It was logical to include high frequency in the calculation formula. The results in this study indicated that the present formula (.5K-2KHz) employed by the Thai Government might not be a valid measure of hearing hadicaps.

6. Threshold Shifts

The threshold shifts were studied by comparing the differences between baseline audiograms and the most recent audiograms for the worst ear. According to the occupational Safety and Health Act (OHSA), 1981 guideline, changes in hearing thresholds which exceeded 10 dB at any test frequency other than .5KHz were considered significant. From the scattergrames (Fig. 5 through 11, Page 46-52) threshold shifts occurred at 4KHz after five years of employment. Further exposure to noise, elevated threshold shifts at 6K, 8K, and 3KHz. The majority of workers showed threshold shifts of less than 10 dB at 1K-2KHz (Fig. 5 and 6)

A study of threshold shifts in jute weavers was carried out by Taylor et al. (1965). The first frequency with hearing deterioration was found at 4KHz. The hearing loss at 3K-6KHz occurred with repeated noise exposure. Hearing loss at 3K-6KHz rapidly increased within the first ten years then reached a plateau. The hearing loss at .5K-2K Hz occurred

after 25 years of employment and increased slowly throughout the entire expose period. The present study found similar threshold shifts at high frequencies but no significant hearing loss was found at .5K, 1K and 2KHz. Table A-4, Page 78 shows our subjects had work durations of less than 14 years, this duration might be too short for low frequency hearing loss to develop. Weaver and Lawrence (1954) and Zakrison (1975) indicated that the effect of middle ear muscles contraction attenuated low frequency sound transmission, therefore the noise might not damage the low frequencies since they were protected by the acoustic reflex mechanism.

The threshold shifts at .5KHz showed greater scatter than at 1K and 2KHz. This effect was unknown at this point future research is needed in this area.

CONCLUSION

1. The prevalence of sensorineural hearing loss among automobile workers was higher than those found in the hospital and medical schools. The results suggested that patients who sought medical assistance at the hospitals usually had a symptom or sign of hearing difficulties. However, noise-induced hearing loss is a long term process. The problem is not detected, unless appropriate tests are given.

2. The number of workers with noise-induced hearing loss tended to increase with years of employment. Tawin (1978), documented presbycusis for Thais occurred at 50 years of age. The maximum age of workers in this study was 48 years. This suggested presbycusis could not be the sole factor that affecting the hearing sensitivity of the workers. Noise was responsible for hearing loss in this study.

3. Most audiograms for noise-induced hearing loss showed deterioration of hearing loss at 3K-6KHz. However, some of workers exhibited high frequency hearing loss. This finding suggested several audiometric variations of noise-induced hearing loss.

4. Noise-induced hearing loss caused 13% more unilateral hearing loss than bilateral hearing loss. This finding did not support those of Hemlkamp et al. (1984). The

discrepancy was possible due to variation among subject selection and nature of noise exposure. For unilateral hearing loss, the percentage of right ear impairment was greater than of the left ear. The results suggested preference in lateralization.

5. The percentage of hearing impairment was obtained from four arithmetic formulae. The percentage of worker with hearing handicaps increased when high frequencies were included in the calculation.

6. The deterioration in hearing sensitivity occurred at 4KHz during the fifth work years and the hearing loss spread to 6K, 8K, and 3KHz with further noise exposure. Some of workers showed threshold shifts at .5K, 1K or 2KHz. The threshold shifts at .5KHz was more deviated than at 1K and 2KHz. The effect of noise on the nature of low frequency hearing loss requires further investigation.

RECOMMENDATION

This study investigated the prevalence of hearing loss, groups of hearing loss, ear effects, percentage of hearing handicaps, and threshold shifts in automobile workers. For the future studies, the following recommendation should be considered.

1. The percentage of hearing handicaps increased when high frequencies were included in the formulae for calculation. Future studies should investigate the relationship between hearing handicaps and speech perception.

2. Threshold shift at low frequencies (.5KHz) was observed in the automobile workers. The relationship between the nature of the noise and hearing loss in low frequencies is controversial.

3. Since a high percentage of workers exhibited noise-induced hearing loss, appropriate action must be taken to prevent future hearing degeneration. A Hearing Conservation Program is suggested for the workers. The programs consist of a noise survey, hearing measurement, noise control, hearing protection, hearing education, and administrative control.

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Table A-1 Questionnaire

The Ear Nose & Throat Clinic
1182 Nakorn Chai Sri Road
Dusit District, Bangkok, 10300
Telephone 241-3301

NOISES & HEARING

EAR NOSE THROAT & AUDIOLOGIC RECORDS
PRE AND POST EMPLOYMENT
PLACE OF WORK

PART 1 General Informations :

Name of employee.....Present age.....Date Record.....
Home address.....Employee No.....

PART 2 Medical History & Previous Noise Exposures :

Date Record /...../.....
 d m y

Last 3 places of work before present employment :

1. Type of work Time

2. Type of work Time

3. Type of work Time

Post Head trauma	Yes ☐	No ☐	Post C.N.S. Disorders	Yes ☐	No ☐
Hearing loss in family	Yes ☐	No ☐	Used of ototoxic drugs	Yes ☐	No ☐
Trauma of the ear	Yes ☐	No ☐	Otorrhea history	Yes ☐	No ☐
Previous ear surgery	Yes ☐	No ☐	Side RT ☐ LT ☐	Type.....	Time.....
Military service	Yes ☐	No ☐	Type of work.....	Time.....	

Others history of noise exposure.....Time.....
Present Pre-employment Hearing Condition Poor ☐ Fair ☐ Good ☐
Experience of tinnitus Yes ☐ No ☐ Experience of Vertigo-Dizziness ☐ Yes ☐ No ☐

PART 3 Current Noise exposure at present employment :

Present Job Title..... Department..... Area Code.....

Date started at present employment/...../..... Approximately.....Years....Months

Type of noise exposure Steady ☐ Impulse ☐ Mixed Steady & Impulse ☐

Period of working Hours/day Days/week Time pause interval.....

Ear protection Was recommended ☐ Never been recommended ☐

Type of protecters Ear plug ☐ Ear muff ☐ Home made ☐ Foreign made ☐

Period of time worn Years months

Wearing Always ☐ Sometimes ☐ Never wear ☐

PART 4 Audiologic Analysis :

[illegible]

Figure A-1 Impedance Audiometry

IMPEDANCE AUDIOMETRY

Name _____ Age _____ H.N. _____ Code _____ Date _____ Test No. _____

STATIC COMPLIANCE

COMPLIANCE IN CC

0	1	2	3	4	5
0	1	2	3	4	5

Peak Compliance Pressure	
Rt	Li

Acc stic Stapedius Reflex Decay		
(Time 10 Seconds)		
Hz	Rt	Li
500		
1000		

Ear	C _{0m}	C1	C2	Diff
Right				
Left				

Stapedius Reflex

Rt	250	500	1000	2000	4000	8000	BP	HP
SRT								
FTT								
Diff								
IESI								

PTA	BSN	CORR	SPAR	LP-HP

Li	250	500	1000	2000	4000	8000	BP	HP
SRT								
FTT								
Diff								
IESI								

PTA	BSN	CORR	SPAR	LP-HP

Audiologist _____

Tympanogram Pressure : mm Water

EAR TIP _____

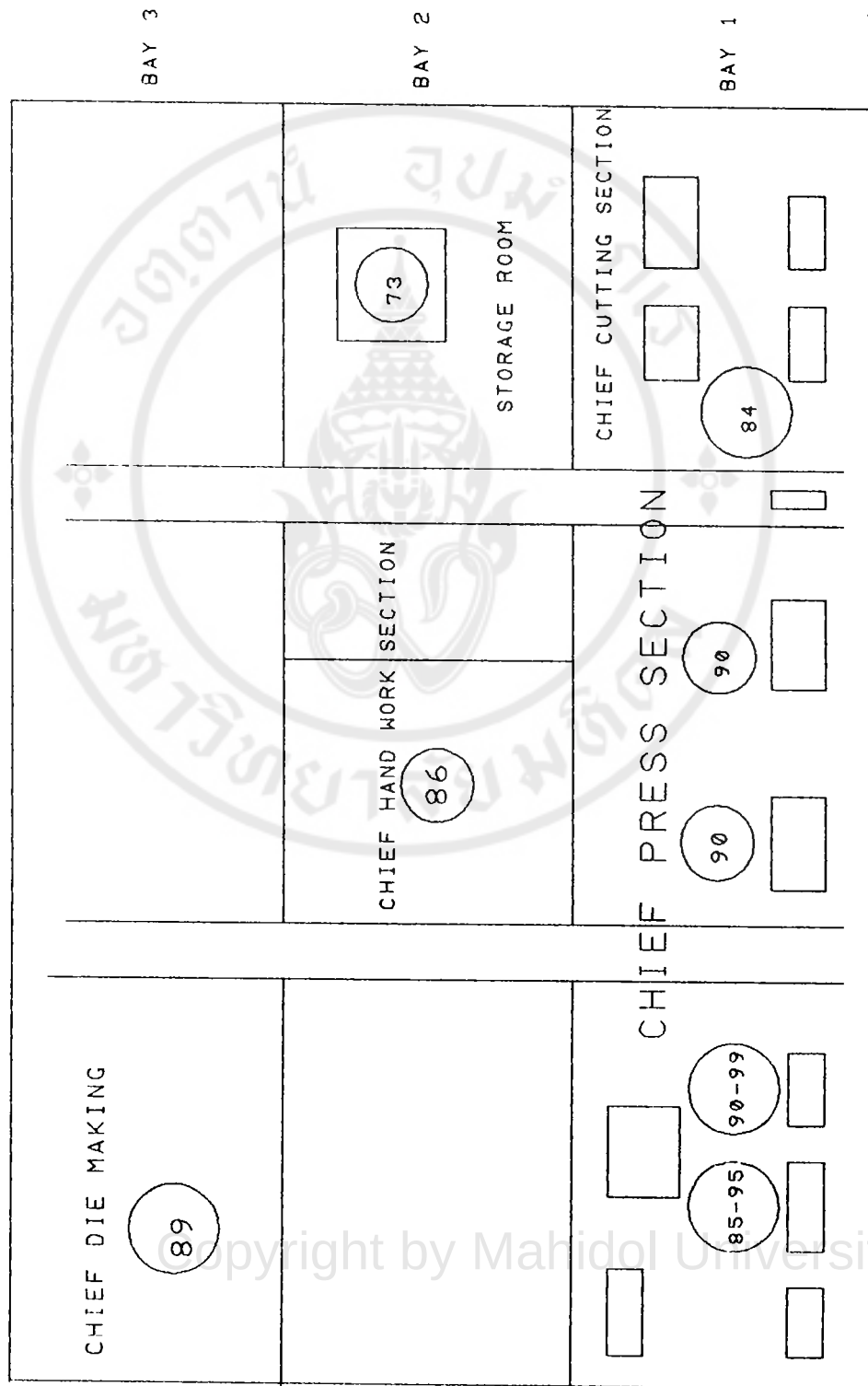
Remark _____

Table A-2 Audiometric Results

WORK YEAR	AGE	BASELINE AUDIOGRAM																RECENT AUDIOGRAM															
		RIGHT EAR								LEFT EAR								RIGHT EAR								LEFT EAR							
		.5	1	2	3	4	6	8	:.5	1	2	3	4	6	8	:	.5	1	2	3	4	6	8	:.5	1	2	3	4	6	8			
1	3	25	:20	20	10	5	0	10	5	:15	15	10	10	10	45	20	:	15	20	5	5	5	0	5	:15	10	5	0	5	15	35		
2	4	27	:25	15	25	25	20	10	10	:30	20	25	25	30	30	20	:	25	20	25	20	15	10	5	:30	15	15	25	25	35	20		
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WORK YEAR	AGE	BASELINE AUDIOGRAM																RECENT AUDIOGRAM															
		RIGHT EAR								LEFT EAR								RIGHT EAR								LEFT EAR							
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FIGURE A-2 LAY OUT OF SOUND MEASUREMENT IN AN AUTOMOBILE PLANT



IN dB(A)

Table A-3 Determination of Hearing Impairment Using AMA Guild

1. Add the hearing threshold for the frequencies most important to speech (.5K, 1K, and 2KHz).
2. Divided by three to find the average hearing threshold for each ear.
3. To convert the Average Hearing Threshold for the speech frequencies to percent hearing impairment, subtract the Low Fence (25 dB) from Average the Hearing threshold for speech. Then multiply the result by 1.5% for each decibel the Average Hearing Threshold exceeds 25 dB.
4. To convert the monaural impairment to percent of binaural impairment, proceed as follow:
 - a. Percent of hearing impairment in better ear times 5.
 - b. Add percent of hearing impairment of worst ear.
 - c. Divide the total by 6.

Table A-4 Distribution of Workers Classified by Years of Employment.

Years of Employment	Number of Workers	Percentage of Workers
less than or equal 5	16	17.20
6-10	53	56.99
11-15	24	25.81
Total	93	100.00
Mean	8.81	
Minimum	3.00	
Maximum	14.00	
SD.	2.25	

Table A-5 Distribution of workers classified by age

Age	Number of Workers	Percentage of Workers
25-29	23	24.73
30-34	35	37.63
35-39	28	30.11
40-44	4	4.30
44-49	3	3.23
Total	93	100.00
Mean	33.02	
Minimum	25.00	
Maximum	48.00	
SD.	4.54	

Table A-6 Threshold Limit Value

Duration per day, Hours	Sound Level dBA*
16	80
8	85
4	90
2	95
1	100
1/2	105
1/4	110
1/8	115**

* Sound level in decibels as measured on a sound level meter, confirming as a minimum to the requirements of the American National Standard Specification for Sound Level Meters sl.4 (1971) type S2A, and set to use the A-weighted network with slow meter response.

** No exposure to continuous or intermittent in excess of 115 dBA

Table A-7 Distribution of Workers by Work Area

Work	Section	Number of Workers	Percentage of Workers
Chief Press		29	31.18
Chief Die Making		17	18.28
Chief Hand-Work		11	11.83
Chief Cutting		7	7.53
Other		29	31.18
Total		93	100.00



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