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Contribution of non-occupational exposure factors and non-noise occupational exposure to loss of hearing sensitivity among Anniston Army Depot worker.

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CONTRIBUTION OF NON-OCCUPATIONAL EXPOSURE FACTORS AND NON-NOISE OCCUPATIONAL EXPOSURE TO LOSS OF HEARING SENSITIVITY AMONG ANNISTON ARMY DEPOT WORKERS

by

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CONTRIBUTION OF NON-OCCUPATIONAL EXPOSURE FACTORS AND NON-NOISE OCCUPATIONAL EXPOSURE TO LOSS OF HEARING SENSITIVITY AMONG ANNISTON ARMY DEPOT WORKERS

KATRINA WRIGHT

ABSTRACT

BACKGROUND: In 1987, workers employed at the Anniston Alabama Army Depot (ANAD) were enrolled in a hearing conservation program based on an 85 dBA criterion level for an 8-hour day with a 5 dB exchange rate. Under these criteria, 500-700 employees were removed from the program. In 2001, these employees were re-enrolled in the hearing conservation program because of a Department of the Army mandate that exposures be measured with a 3 dB exchange rate and if the 95% upper tolerance limit for measured exposures were above 85 dBA. A previous study has determined that workers at the ANAD who were removed from the hearing conservation program in 1987 and re-enrolled in 2001 did not experience significant changes in hearing sensitivity due to occupational noise, nevertheless there were significant changes in hearing sensitivity in this group (Norman, 2005). The purpose of this study was to determine what factors were associated with measured hearing levels in this group in 2001. METHODOLOGY: The study population was defined as: a worker who was employed by the ANAD from January 1987 until January 2001; the worker was removed from the hearing conservation program in 1987 and re-enrolled in 2001; the worker had an audiogram ± 1 year of January 1, 2001; the hearing threshold level for either ear was ≥ 25 dB; and the worker completed a questionnaire concerning medical history, military noise exposures, home and recreational noise exposures, and non-noise occupational exposures. The association between the responses to questions and measured hearing sensitivity in 2001 was tested by linear regression and principal component analysis. RESULTS: Forty three participants met the criteria to be included in the study. The linear regression model found a significant association between measured hearing levels, age, and military weapons fire. Results of the principal component analysis indicated military weapons fire and recreational hunting significantly affected measured hearing levels. CONCLUSIONS: Hearing threshold levels among Anniston Army Depot workers in 2001 were significantly associated with non-occupational noise exposure factors but were not associated with non-noise occupational exposure factors. These results concur with results of previous studies.

DEDICATION

I would like to dedicate this dissertation to my parents, Mr. and Mrs. Nehemiah. Thank you for all of the love and support you've faithfully shown throughout my studies. I also dedicate this dissertation to my eight siblings: Milton Gooch, Sherron Wright, Toni Wright, Nehemiah Wright, Sereta Thames, Shelia Wright-Henry, Terrence Wright, and Kenric Wright.

ACKNOWLEDGEMENTS

"Trust in the Lord with all thine heart; and lean not to thine own understanding. In all thy ways acknowledge Him, and He shall direct thy paths" (Proverbs 3:5-6 KJV). First I would like to thank and praise my Lord and Savior Jesus Christ for without Him completing this degree would have been impossible. It has been a long road and I am so grateful to God that this journey is ending as a new one swiftly approaches.

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In addition, I would like to thank every faculty and staff member at the University of Alabama at Birmingham who has supported and encouraged me along with Drs. Cristie McCullum-Hill and Melissa Norman for inspiring me to move forward and for being great friends. Finally, I would like to thank Darnelle Howell, Joseph C. Andrews, and all of my family, friends, and co-workers for their continuous love and support. Thank you.

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LIST OF ABBREVIATIONS

AAO	American Academy of Otolaryngology
ACGIH	American Conference of Governmental Industrial Hygienists
ANAD	Anniston Army Depot
ANSI	American National Standards Institute
dB	decibels
dbA	decibels measure using A-frequency weighting
HPD	hearing protection device
NIOSH	National Institute for Occupational Safety and Health
NRR	noise reduction rating
OSHA	Occupational Safety and Health Administration
PTS	permanent threshold shift
SLM	sound level meter
TTS	temporary threshold shift
TWA	time-weighted average

CHAPTER 1

INTRODUCTION

Background

Sound is a vibrating motion (oscillation) that occurs in the air's pressure. Over a specific time or distance, sound produces pressure fluctuations in the air known as sound waves. Sound waves are what enter our ears and allow us to hear (Talty, 1988).

Sound ranges from loud to soft; however, some sounds are deemed as annoying or unwanted. Annoying or unwanted sound is known as noise. Loud noise or high noise levels can be harmful, resulting in physical and mental stress, fatigue, hypertension, accidents, and hearing loss. At present, an estimated 30 million Americans are exposed to harmful noise (Berger et al., 2000).

Three characteristics of sound make it harmful: duration, intensity also called amplitude, and frequency. Duration is how long sound continues; intensity is the loudness of a sound; and frequency is the number of repeated sequences of events or cycles per unit time that occur in a sound wave (CHS, 2005). The risk of developing a hearing loss from noise relies on these three characteristics of sound.

Hearing loss can be conductive, sensorineural, or mixed and can occur in one or both ears. Conductive hearing loss results from problems with or within the outer and middle ears and is reversible. Sensorineural hearing loss is irreversible resulting from problems in the inner ear and mixed hearing loss results when there are conductive and sensorineural problems (Berger et al., 2000).

Three common causes of sensorineural hearing loss are nosoacusis, presbycusis, and noise-induced hearing loss. Hearing loss caused by injury, infection, disease, harmful drugs or chemicals, or birth defects is classified as nosoacusis. Presbycusis is the term given to hearing loss due to age, and noise-induced hearing loss is the term that describes loss due to occupational and recreational noise. Hearing loss that occurs from recreational noise is called sociacusis, and occupational noise-induced hearing loss is the term used for hearing loss from one's occupation (Berger et al., 2000).

Occupational noise-induced hearing loss is the most common injury found in the workplace and is preventable in most cases. Workplace chemicals such as toluene as well as ototoxic (harmful to the ear) drugs have been shown to have a synergistic effect on hearing loss when combined with noise (NIOSH, 1998). Presently, an estimated one in four workers will develop a permanent hearing loss as a result of workplace hazards which include noise and chemical exposures. Government agencies such as the National Institute for Occupational Safety (NIOSH) and Health and the Occupational Safety and Health Administration (OSHA) serve to protect workers from workplace hazards such as noise by setting regulations that limit the time a worker can be exposed to certain noise levels and requires workers to be enrolled in a hearing conservation program if their noise exposure levels exceed certain levels (CDC, 1996).

Sound and Its Characteristics

Sound is a vibration that travels through the air in the form of a wave. A sound wave is a pattern of pressure fluctuations or change in air pressure over a specific time or distance. From the source of sound, sound waves travel outward in all directions and are distinguished by wavelength, frequency (perceived as pitch), pressure, power, and intensity (perceived as loudness or amplitude) (Sataloff & Sataloff, 1993).

The distance between two peaks of a sound wave is a called a wavelength (λ) as shown in Figure 1. Wavelengths can be described as the distance sound travels or the distance vibrations travel during one pressure cycle (Talty, 1988). A wavelength is defined by the following equation:

$$\lambda = c/f, \tag{1}$$

where c=velocity and f=frequency.

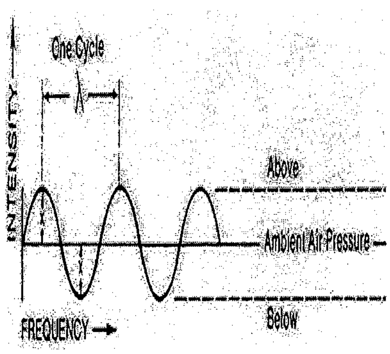

Figure 1. Wavelength.
From *Fundamentals of Industrial Hygiene* (p. 210), by Plog, B. and Quinlan, P. 2002, National Science Foundation. Reprinted with permission.

The number of times per second a cycle occurs in a sound wave is known as frequency. Frequency is measured in Hertz (Hz) or cycles per second. Lower frequencies correspond to longer wavelengths and higher frequencies correspond to shorter wavelengths. The human hearing frequency range is approximately between 20Hz and 20,000 Hz (20 kHz) (Gelfand, 1997). Though frequency is perceived as pitch, pitch is the property of a sound of definite vibration that is determined by the frequency of the sound wave producing it. Higher frequencies correspond to higher pitches (Sataloff & Sataloff, 1993).

Sound pressure is the difference between atmospheric pressure and pressure in the air during compression and decompression and is expressed as a force per unit area. The measurement unit of pressure is Pascals (Pa), which is the same as Newtons per square meter (N/m^2). Sound pressure is measured in decibels. A decibel (dB) is a dimensionless unit based on the logarithm of the ratio of a measured quantity to a reference quantity (Berger, et al., 2000). A decibel is defined by the following equation:

$$\mathrm{L} = 10 \log_{10}\left(\frac{A}{B}\right), \tag{2}$$

where L is the level in decibels, A and B are quantities having the same units (NIOSH, 1998).

Sound pressure is generated by a source and is determined by where the hearer is located in relation to the source of sound. Sound pressure level (L_p) is what is perceived by our ears. The range of sound pressure level audible to the human ear is 0-140 dB with a reference of 20 micropascals (μPa). Sound pressure level is measured using instruments called sound level meters which display readings measured in decibels. Sound pressure level is defined by the following equation:

$$L_p = \frac{20 \log p_1}{p_2} \mathrm{dB}, \tag{3}$$

where p_1 is the measured sound pressure and p_2 is the reference sound pressure (20μPa) (Sataloff & Sataloff, 1993).

Sound power (p) is produced by all sources of sound and is measured in watts (Talty, 1988). The sound power of a source is the total output of sound energy produced by that source in unit time. Regardless of a sound source's location in different environments, sound power, in most cases, is constant. Sound power level (L_P) is defined in equation 4, where w is measured sound power and w_o is reference sound power (Berger et al., 2000).

$$L_P = 10 \log \left(\frac{P}{P_o} \right) \tag{4}$$

As sound travels from its source, the amount of energy at any location is described by sound intensity, measured in joules per square meter per second. Sound intensity at a specific location is the average rate at which sound energy is carried through an area normal to the direction of the wave's movement. For a spherical or free field sound wave, intensity is described by the following equation:

$$I = \frac{p^2}{\rho c}, \tag{5}$$

where p is sound pressure, ρ is the density of the medium, and c is the speed of sound in the medium. Sound intensity units are expressed as decibels. Sound intensity level is defined as:

$$L_I = 10 \log \frac{I}{I_o} \text{dB}, \tag{6}$$

where I is measured intensity and I_o is reference intensity (10^{-12} watts/m^2) (NIOSH, 1973).

The relationship between sound pressure and sound power is a function of intensity and can be described by the following equations (NIOSH, 1973):

$$P = I_{ave} 4\pi r^2, \tag{7}$$

where $4\pi r^2$ = the surface area of a sphere.

From equations 5 and 7 the relationship between sound power, intensity, and pressure is:

$$P = I_{avg} 4\pi r^2 = \frac{p^2 avg 4\pi r^2}{\rho c}, \tag{8}$$

Re-arranging results in:

$$p_{avg} = \sqrt{\frac{P\rho c}{4\pi r^2}}, \tag{9}$$

Dose is a combination of noise intensity and duration that quantify the amount of noise one has been exposed to. Daily noise dose (D) is not to exceed 100% when there are periods of different stages of noise as calculated using the following equation (NIOSH, 1998):

$$D = [C_1/T_1 + C_2/T_2 + ... + C_n/T_n] \text{ x } 100, \tag{11}$$

where: C_n = total time of exposure at a specified noise level and T_n = total time of exposure permitted at that noise level.

Dose is integrated into noise exposure standards, which have criterion levels (85 dBA and 90 dBA two commonly accepted criterion levels used in the United States) equivalent to sound levels that make up 100% of an 8-hour average of various noise exposure levels or time-weighted average (TWA).

When assessing hearing impairment as a function of noise levels and duration, an exchange rate is used. An exchange rate is an increment of decibels that cuts exposure time in half as sound pressure level increases and doubles exposure time as sound pressure level is halved. OSHA recommends a 90 dBA criterion level for an 8-hour day with a 5dB exchange rate (the 5dB exchange rate is sometimes called the OSHA rule). The National Institute for Occupational Safety and Health (NIOSH), The American Conference of Governmental Industrial Hygienists (ACGIH), and the Department of Defense (DOD) recommend an 85 dBA criterion level for an 8-hour day with a 3 dB exchange rate (NIOSH, 1998). The 3-dB exchange rate is the most scientifically supported; it is stricter, aiming to prevent hearing loss whereas the 5-dB exchange rate aims to conserve hearing (Berger et al., 2000) (NIOSH, 1998).

The following formula is used when converting daily noise dose from 85 dB criterion and 3 dB exchange rate measurements to an 8-hr TWA (Berger et al., 2000):

$$TWA = 16.61 \times \log [(D/100) + 85], \tag{12}$$

The equation for converting daily noise dose from 90 dB criterion and 5 dB exchange rate measurements is (Berger et al., 2000):

$$TWA = 16.61 \times \log (D/100) + 90, \tag{13}$$

Tables 1 and 2 respectively illustrate NIOSH/ACGIH/DOD noise exposure limits and OSHA's Permissible Exposure Limits (NIOSH, 1998). Allowable occupational exposure duration in Table 1 is calculated using the following equation (NIOSH, 1998):

$$T\ (\text{minutes}) = \frac{480}{2^{(L-85)/3}}, \tag{14}$$

where L= sound pressure level. Allowable occupational exposure time in Table 2 is calculated using the following equation (NIOSH, 1998):

$$T \text{ (minutes)} = \frac{480}{2^{(L-90)/3}}, \qquad (15)$$

where L = sound pressure level.

Table 1

NIOSH/ACGIH/DOD Noise Threshold Limit Values (TLVs) [a]

	Duration/Day	Sound/Level dBA[b]
Hours	24	80
	16	82
	8	85
	4	91
	2	94
	1	
Minutes	30	97
	15	100
	7.50[c]	103
	3.75[c]	106
	1.88[c]	109
	0.94[c]	112
Seconds	28.12[c]	115
	14.06[c]	118
	7.03[c]	121
	3.52[c]	124
	1.76[c]	127
	0.88[c]	130
	0.44[c]	133
	0.22[c]	136
	0.11[c]	139

[a] No exposure to continuous, intermittent, or impact noise in excess of a peak C-weighted level of 140 dB.
[b] Sound level in decibels are measured on a sound level meter, conforming as a minimum to the requirements of the American Standards Institute Specifications for Sound Level Meters, S1.4 (1983), Type S2A, and set to use the A-weighted network with slow meter response.
[c] Limited by the noise source, not by administrative controls.
Note: Retrieved from Lawrence Livermore National Laboratory at the University of California Environmental and Safety Manual website November 15, 2005.
http://www.llnl.gov/es_and_h/hsm/doc_18.06/doc18-06.html
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Table 2

OSHA's Permissible Exposure Limits

Duration/day, hours	Sound Level dBA slow response
8	90
6	92
4	95
3	97
2	100
1 ½	102
1	105
½	110
¼ or less	115

Note. Retrieved from the Occupational Safety and Health Administration's website July 22, 2005.
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735
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Sound Measurement

As mentioned earlier, intensity is perceived as loudness. The perception of loudness is not the same for all sounds; the human ear does not recognize all sounds as being equally loud and for this reason, weighting curves or equal loudness contours were empirically derived. There are three standardized weighing curves aimed at estimating loudness equal to the response of human hearing at low, medium, and high sound pressure levels. The curves are plotted as a function of frequency, showing the sound pressure level required to produce the same loudness level at 1000 Hz (see Figure 2). Frequency weighting curves indicate the intensity and frequency of tones judged to be equal in loudness (loudness is measured in phons). Curve A is designated to be represented by 40 phons, curve B is represented by 70 phons and curve C is represented by 100 phons. At 1000 Hz 40 dB produces a loudness of 40 phons, while approximately 52 dB are required to produce the same loudness at 100 Hz (Berger et al., 2000).

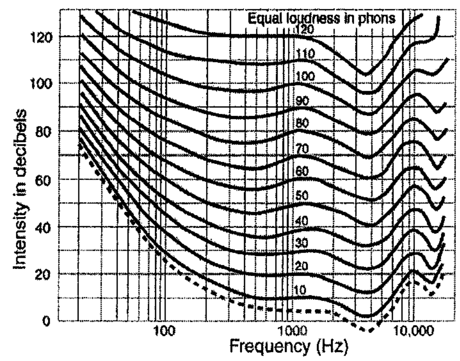

Figure 2. Equal loudness contours.
From Acoustical Surfaces retrieved November 15, 2005.
http://www.acousticalsurfaces.com/acoustic_IOI/101_3.htm.
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When weighting networks are used, sound level measurements are expressed as decibels of A, B-, and C- weighted levels written respectively as dBA, dBB, and dBC. The A-weighting network is used when the effects of lower frequencies are not desired; it tremendously de-emphasizes the lower frequencies and is most commonly used for noise measurement. Though not as much as the A-weighting network, the B-weighing network also de-emphasizes lower frequencies. The C-weighting network measures the overall level of sound pressure for all sounds (Gelfand, 2001).

Sound is measured using sound level meters (SLMs), octave band analyzers, and noise dosimeters. Sound level meters are instruments that pick up sound with a microphone and convert it into a signal to be analyzed by an electrical circuit. After analysis by the circuit, the level of sound, in dB, is shown on a meter (Gelfand, 2001).

The microphone on a sound level meter picks up many bandwidths (frequency ranges). The octave band is the most familiar bandwidth used for noise measurement. An octave band is a frequency range with an upper limit that is twice the frequency of its lower limit. An octave band consists of three 1/3 octave bands. Sound level meters use octave band analyzers to separate octave bands into 1/3 octave bands when more detailed characteristics of a noise are required. For example, if there are many noise sources in a specific area, a 1/3 octave band can be used to distinguish which source the noise is coming from (Berger et al., 2000). Figure 3 illustrates commonly used octave bands along with their center, lower, and upper frequencies.

Name of Octave Band (Center Frequency Hz)	Defining Frequencies (Hz)		A-Weighting of Octave Band (dB)	C-Weighting of Octave Band (dB)
	Lower	Upper		
31.5	22.4	45	-39.4	-3.0
63	45	90	-26.2	-0.8
125	90	180	-16.1	-0.2
250	180	355	-8.6	0.0
500	355	710	-3.2	0.0
1000	710	1400	0.0	0.0
2000	1400	2800	+1.2	-0.2

Figure 3. Commonly used octave bands.
From *The Occupational Environment, its evaluation and control* (p. 428), by DiNardi, S. 1997, Fairfax, VA: American Industrial Hygiene Association. Reprinted with permission.

The geometric mean of the lower and upper limits of an octave band is known as its center frequency and is represented by the following equation:

$$f_c\sqrt{f f_2 Hz}\,, \tag{10}$$

where f_1 and f_2 are respectively the upper and lower band limits in Hz. Most sound level meters (see Figure 4) come equipped with octave band analyzers that separate the total range of measured frequencies into smaller groups (Berger et al., 2000).

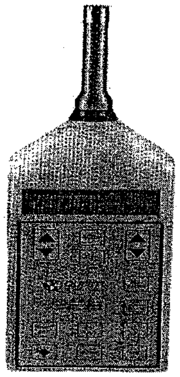

Figure 4. Sound level meter.
From *Essentials of Audiology* (p.32), by S.,Gelfand, 2001, New York, NY:Thieme. Reprinted with permission.

The current sound level meter standard is the American National Standards Institute (ANSI) S1.4-1983. Types 0, 1, and 2 are three commonly used types of sound level meters. Type 0 is the laboratory standard used in labs as a reference standard of high-precision. Type 1 is used for precision in labs as well as in the field and its error rate is not to exceed 1 dB. A Type 2 SLM is used for field general purposes and its error rate is not to exceed 2 dB. OSHA requires Type 2 sound level meters for noise exposure standards (Berger et al., 2000).

Sound level meters commonly used to measure workplace noise exposures are called noise dosimeters (see Figure 5). Noise dosimeters record the amount of sound produced in a workday and can be used for personal and area noise sampling. Noise dosimeters measure dose and equivalent time-weighted average (in dBA) for a workday (Gelfand, 2001).

Sound measurement devices help determine if there is a risk associated with noise and tell us how loud a noise is in a particular area. When assessing the risk noise has on hearing, the ratio of the population exposed to noise who are to be protected from material hearing impairment and the maximum acceptable hearing threshold level must be considered. The maximum acceptable hearing threshold level, also called the fence, is frequently defined as the average hearing threshold limit for two, three, or four audiometric frequencies. When a worker's average hearing threshold level, the decibel representation of a listener's threshold for a specified signal (for one ear or both ears) that exceeds the threshold level equivalent to a specified reference, exceeds 25 dB for both ears at 1000, 2000, 3000, and 4000 Hz, he or she is considered to have a material hearing impairment (NIOSH, 1998).

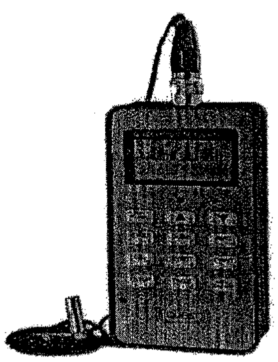

Figure 5. Noise dosimeter.
From *Essentials of Audiology* (p. 505), by S. Gelfand, 2001, New York, NY:Thieme. Reprinted with permission.

In 1972, NIOSH estimated excess risk (the percentage risk difference between the occupational noise-exposed-population and the non-exposed population exceeding the fence) of material hearing impairment for a 40-year lifetime workplace exposure to average daily noise levels at 80, 85, and 90 as being 3%, 16%, and 29% dB respectively. NIOSH has since reevaluated excess risk of material hearing impairment for a 40-year lifetime workplace exposure to average daily noise levels at 80, 85, and 90 as being 5%, 14%, and 32% dB respectively (NIOSH, 1998).

The Ear and the Process of Hearing

Hearing is the process, function, or ability to perceive or understand sound. In order for one to hear, a sensory organ capable of detecting vibrations must be involved; this sensory organ is the ear. The ear converts sound waves into electrical signals and transmits them to the brain where they are recognized and interpreted as sound (Talty, 1988).

The ear is composed of three major parts (as shown in Figure 6): the outer (external), middle, and inner ear. Sound enters through the outer ear and travels to the middle ear where it hits the eardrum causing it to vibrate. These vibrations produce a mechanical motion of the bones of the middle ear (the malleus, incus, and stapes) which in turn produces motion of the oval or round window of the cochlea which is contained in the inner ear. From the inner ear, nerve impulses are carried to the brain and interpreted as sound (Berger et al., 2000).

The outer ear, as shown in Figure 7, consists of the pinna (commonly referred to as the ear) and the ear canal (commonly referred to as the auditory canal). The pinna and the ear canal are both capable of adjusting aural airways allowing original sounds to be altered. Because of the ear's dimensions, sounds in the 3-kHz region can be greatly amplified (Berger et al., 2000). The middle-most part of the ear canal is a nearly circular opening in the skull bone and the outer part is cartilage. The ear canal is covered by skin and releases cerumen (wax); the buildup of cerumen in the ear canal to an extent that it becomes stopped up is a common cause of hearing loss (Moller, 2000).

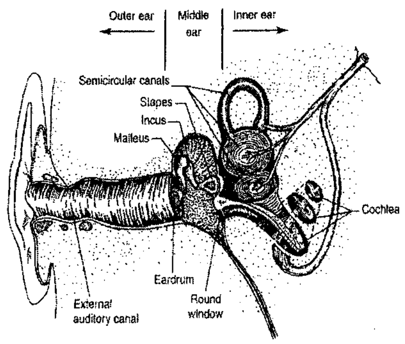

Figure 6. Cross-sectional view of the human ear.
From *The Noise Manual* (p. 102), by E. Berger, L. Royster, J. Royster, D. Driscoll, & M. Lane, 2000, Fairfax, VA: American Industrial Hygiene Association. Reprinted with permission.

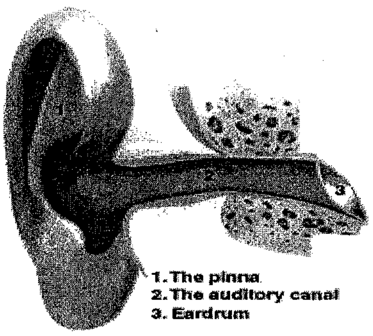

Figure 7. The outer ear.
Retrieved from the Hearing Institute's website on November 17, 2005.
http://www.hear-it.org/page.dsp?page=356
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The middle ear, shown in Figure 8, is air-filled and consists of the eardrum and three ossicles: the malleus, incus, and stapes (hammer, anvil, and stirrup respectively). The middle ear transforms acoustical energy from the outer ear into mechanical energy (Berger et al., 2000).

The eardrum is the slightly, round part of the middle ear that ends the ear canal and separates the outer from the middle ear. The eardrum also provides protection against foreign bodies that try to force their way into the middle and inner ears (Berger et al., 2000).

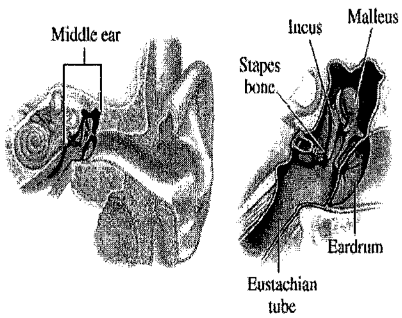

Figure 8. The middle ear.
Retrieved from Web MD's website November 15, 2005.
http://my.webmd.com/hw/healthz-guide_atoz/hw141827.asp?printing=true
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The inner ear is fluid-filled. It is filled with three fluids: perilymph, endolymph, and cortilymph. These fluids have four basic functions: supply nutrients to inner ear cells and remove waste; provide a chemical environment which is needed to transfer energy to a neural signal from a vibratory stimulus; serve as a medium to transfer vibratory stimulus' from the stapes to the sensory structure along the cochlear partition; and control the distribution of the pressure in the inner ear system (Gelfand, 1998).

The inner ear contains the vestibule, three semi-circular canals (posterior, superior, and horizontal), and the cochlea (see Figure 9). The utricle and the saccule are contained in the vestibule where they function as balance mechanisms. The semi-circular canals and the vestibule make up the balance system of the ear. The cochlea is the part of the inner ear responsible for hearing (Gelfand, 2001).

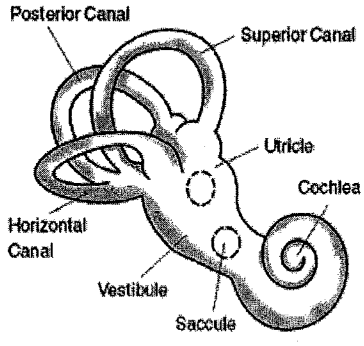

Figure 9. The inner ear.
Retrieved from National Institute on Deafness and Other Communication Disorders web-site November 15, 2005.
http://www.nidcd.nih.gov/health/balance/balance_disorders.asp.
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The cochlea is a snail-shaped coiled tube with three spiral turns that transforms mechanical vibrations, produced by hair cells, into electrical energy to form a nerve impulse (see Figure 10) (Berger et al., 2000). If the cochlea were flattened, three ducts would be visible (see Figure 11). The upper duct is called the scala vestibuli, the middle duct is called the scala media, and the lower duct is the scala tympani. The two outer ducts, (scala vestibuli and scala tympani) contain perilymph and assemble at an opening (called the helicotrema) at the far end of the tube. The middle duct, the scala media, is filled with endolymphatic fluid and is separated from the scala vestibuli via Reissner's membrane located above it and from the scala tympani by the basilar membrane located below it (Gelfand, 1997).

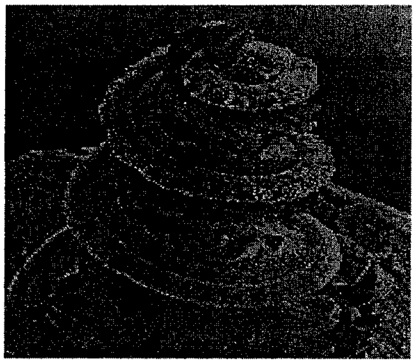

Figure 10. A microscopic view of the cochlea.
Retrieved from Rice University's website November 17, 2005.
http://www-ece.rice.edu/~dhj/cochlea.html
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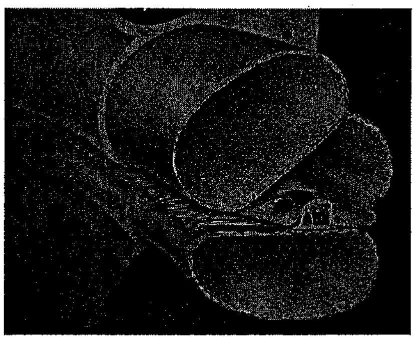

Figure 11. A cross-sectional view of the cochlea.
Retrieved from Rice University's website November 17, 2005.
http://www-ece.rice.edu/~dhj/cochlea.html
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The basilar membrane makes up the Organ of Corti and contains inner (approximately 3500) and outer hair cells (approximately 12,000). The hair cells (inner and outer) are separated by supporting and pillar cells. Inner hair cells are supported by phalangeal cells which act as a cup by holding the rounded base of flask-shaped inner hair cells. Outer hair cells are shaped like test tubes and are supported by Dieter's cells (Gelfand, 1997).

The hair cells that lie upon the basilar membrane and above the tectorial membrane (as seen in Figure 12) are the most important parts of the organ of Corti. They initiate changes that lead to the production of nerve impulses. Damage done to hair cells prevents the sending of signals to the hearing nerve (Berger et al., 2000).

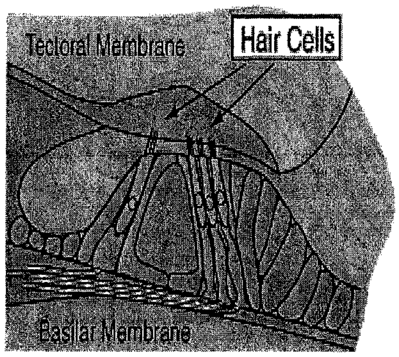

Figure12. The organ of Corti.
Retrieved from the Georgia State University's website November 15, 2005.
http://hyperphysics.phy-astr.gsu.edu/hbase/sound/corti.html
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Hair cells are composed of stereocilia which are sensory hair cells. Shorter stereocilia are adjusted mechanically to higher frequencies and longer stereocilia are mechanically adjusted to lower frequencies. When hair cells in the organ of Corti are damaged, sensorineural hearing loss results. An increase in damage to hair cells results in an increase of sensorineural hearing loss. Figures 13 and 14 respectively illustrate normal and damaged hair cells.

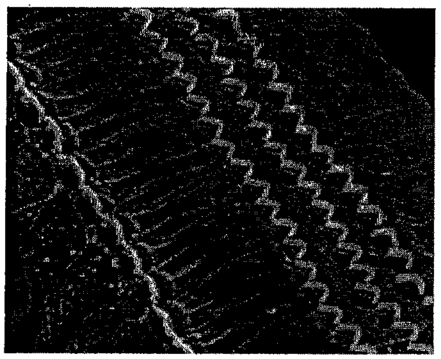

Figure 13. Normal inner ear hair cells.
Retrieved from House Ear Institute's website November 17, 2005.
http://www.hei.org/news/factshts/nihlfact.htm
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Figure 14. Damaged inner ear hair cells.
Retrieved from House Ear Institute's website November 17, 2005.
http://www.hei.org/news/factshts/nihlfact.htm
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Sensorineural hearing loss is irreversible; it can not be surgically or medically corrected. It is a hearing loss that results from damage to the inner ear and usually results in loss in the higher frequencies and affects the understanding or clarity of speech (Gelfand, 1997). Figure 15 shows an audiogram, a graphical representation, of sensorineural hearing loss.

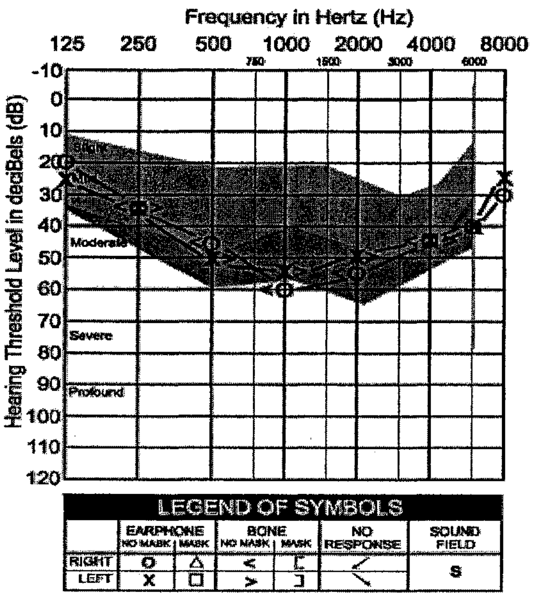

Figure 15. An audiogram depicting sensorineural hearing loss.
Retrieved from the Raising Deaf Kids' website November 15, 2005.
http://www.raisingdeafkids.org/hearingloss/testing/audiogram/cookiebite.jsp
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Sensorineural hearing loss has three common causes: presbycusis, nosoacusis, and noise-induced hearing loss (NIHL). Presbycusis is a bilateral, progressive hearing loss that occurs with age resulting in sensitivity to high frequencies and is commonly the main cause of sensorineural hearing loss. Presbycusis can be put into four categories: sensory, neural, strial, and cochlear conductive (Sataloff & Sataloff, 1993).

Sensory presbycusis is characterized by a symmetrical, bilateral loss with damage to the basal end of the cochlea. Neural presbycusis is characterized by loss of neurons in the cochlea. Strial presbycusis involves the deterioration of the strial vascularis which is a network of capillaries responsible for maintaining a chemical environment for hair cells. Cochlear conductive presbycusis is characterized with sloping, gradual loss in the high frequencies (Sataloff & Sataloff, 1993) (Gelfand, 2001).

Nosiacusis is hearing loss contributed to causes other than age. Head trauma, chronic ear infections, ototoxic medications and chemicals, and disease (see Table 3) can result in nosiacusis (Berger et al., 2000).

Table 3

Ototoxic Medications, Diseases, and Chemicals

Ototoxic Medicines	**Ototoxic Diseases**	**Ototoxic Chemicals and Solvents**
aspirin	Mumps	toluene
kanamycin	Lyme Disease	lead
gentamicin	AIDS	manganese
cisplastin	Meningitis	n-butyl alcohol
	Tuberculosis	arsenic
	Hypertension	mercury
	Syphillis	xylene
	Hypothyroidism	styrene
	Measles	trychloroethylene
	Flu	chlorobenzene
	Cancer	carbon disulfide
	Sarcoidosis	N-hezene
	Multiple Sclerosis	ethanol
	marfan's Disease	carbon monoxide

Note. From *Hearing Loss, third edition, revised and expanded* (p. 373), by J. Sataloff & R. Sataloff, 1993, New York, NY: Marcel Dekker.

Noise and Hearing Loss

Noise can be continuous, intermittent, or impulsive. Continuous noise has slight fluctuations within a certain period; intermittent noise is interrupted by periods of relative sound levels, and impulsive noise is distinguished by a sharp rise and quick delay in sound levels lasting less than 1 second (NIOSH, 1998).

Continuous and impulsive noises have both been shown to result in hearing loss. In an article by Luz and Hodge (1970), recovery from impulse noise-induced temporary threshold shift in rhesus monkeys and men was systematically traced. Four types of recoveries were seen: logarithmic, diphasic, plateau, and rebound. These recoveries were classified by using a descriptive model that proposed the existence of two types of temporary thresholds shifts: metabolic fatigue (process M) and structural fatigue (process S). These two temporary threshold shifts were seen after exposure to impulsive noise.

Ten monaural rhesus monkeys were tested for normal hearing. Nine of the ten monkeys were determined to have normal hearing. These nine were exposed to two different noise conditions: (1) Twelve minutes of 110-dB continuous noise recorded from an M60 tank and (2) two 168-dB impulses from a spark generator. Following exposure to the tank noise, a recovery of temporary threshold shift (TTS) as a function of log time was shown in almost all monkeys with one exception but a permanent threshold shift (PTS) was not evident in any of the monkeys. However; following exposure to impulse noise, a PTS was evident in some monkeys and all four types of recoveries were observed (Luz and Hodge, 1971).

Luz and Hodge (1971) also used thirty-nine Army enlisted men who had baseline (pre-exposure) hearing levels within 15 dB of the ANSI-1951 audiometric zero at 0.5-6 kHz as subjects in a human TTS recovery study. Subjects were trained to give reliable thresholds at 2, 4, and 6 Hz. Impulses were given in groups of 5 or more with 2 seconds between successive impulses in each group. Results showed that 60% of all recovery curves fell into the rebound category. As a whole, 84% of the curve resembled one of the non-logarithmic functions and the remaining 16% resembled recovery of M-type TTS.

In conclusion, the observed rebound effect was found mostly in men and in over one third of the monkeys, and resulted in the most permanent damage seen in monkeys.

In an article by Passchier-Vermeer (1971), the effects of steady-state versus continuous noise were compared to determine their effects on hearing. Data were gathered from 4500 individuals who were separated into twenty groups. All 4500 individuals were exposed to noise while in their workplace, but study participants had no previous history to noise exposure nor did they demonstrate prior congenital and/or continuous hearing damage.

Study participants in 12 of the 20 groups had a 10-20 year workplace related noise exposure. The remaining 8 groups had a 30-50 year exposure to workplace noise and were studied to examine changes in hearing levels over time. Data from all 20 groups were used to determine the effects of noise on hearing. According to this study's results, impact noise is more damaging than steady-state or continuous noise.

In an article by Clark, Bohne, & Boettcher (1987) results suggested continuous noise exposures were more likely to result in more permanent and temporary hearing loss than intermittent noise exposures at the same energy. It also suggested less cochlear damage from intermittent noise exposures as opposed to continuous exposures of the same energy.

In this study, two groups of chinchillas were exposed to noise at an octave band centered around 0.5 kHz, 95 dB. The two groups were placed on different exposure schedules. One group's schedule was 6 hours per day for 36 days and the other was 15 minutes per hour for 144 days. A one-forth octave band frequency measured in intervals of 0.125 and 16.0 Hz was used to behaviorally measure hearing sensitivity. Hearing sensitivity was measured 1 to 2 months post-exposure. After behavioral measurements were complete, anatomical data were recorded by removing and microscopically examining the chinchillas' cochleas. Upon examination, the loss of sensory cells was the determining factor of measuring the amount of damage done to the cochlea.

An initial 35-45 dB threshold shift was seen in both groups of chinchillas. Conversely, thresholds started to decrease and recover only after a few days of exposure. Thresholds recovered within 10-15 dB of baseline values despite the continuation of exposure. Recovery was measured after the end of exposure and signified only slight threshold shifts from animals in both groups.

The authors concluded the following: there was no production of asymptotic threshold shift resulting from interrupted noise schedules; the ear can recover as much as 30 dB of sensitivity from some periods of intermittent noise although exposure is continuous; lesions in the basal turn of the cochlea are sometimes seen and correlated with secondary losses of sensitivity for high frequency noise; and a smaller amount of hearing loss and cochlear damage is produced from exposure to octave band noise centered at 0.5 kHz, 95 dB SPL, 6h/day for 36 days or 15 min/h for 144 days than continuous noise of equal energy. The limitations of the study are as follows: the authors failed to define intermittent noise and suggested results and conclusions based on their specialization as opposed to the data.

Noise-induced hearing loss (NIHL) can result in a permanent or temporary threshold shift. A temporary threshold shift is a temporary change in hearing sensitivity due to exposure to high sound levels. The pre-exposure value prior to a temporary threshold shift ultimately returns; however, the pre-exposure value never returns if one experiences a permanent threshold shift. According to Berger, et al., noise above 80 dB can cause NIHL if the duration is long enough. Table 4 lists common noise sources that can cause a noise-induced hearing loss as well as other reference noise sources. NIHL can be divided into two subcategories: they are sociacusis and occupational noise-induced hearing loss. Occupational noise-induced hearing loss occurs from workplace noise. Some general estimates of workplace noise and their sources are illustrated in Figure 16 (Berger et al., 2000).

Table 4

Common Noise Sources

Common Sounds	Noise Levels (in dBA)
Rocket from launching pad	180
Airplane taking off	140
Nightclub	120
Football game (stadium)	117
Garbage truck	100
Farm tractor	98
Lawn mower	90
Many industrial workplaces	85
Average city traffic noise	80
Washing machine	78
Vacuum cleaner	70
Normal conversation	60
Quiet office	50
Refrigerator	40
Whisper	30
Normal breathing	10
Range of normal hearing	0-25

Note: Retrieved from the Canadian Hearing Society's website November 15, 2005.
http://www.chs.ca/info/noise/book1.html
Adapted with permission.

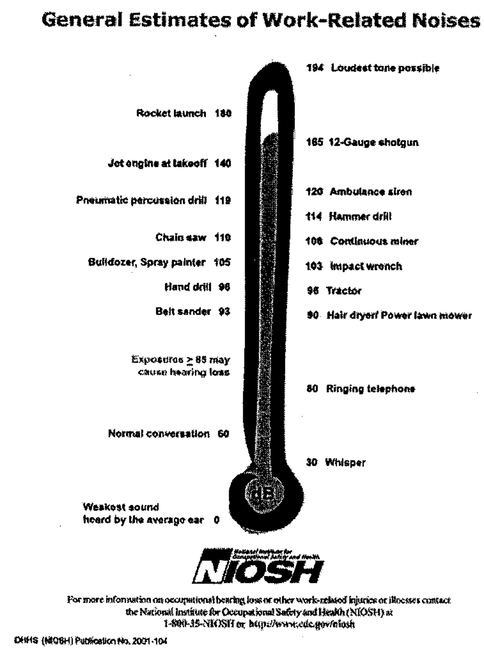

Figure 16. General estimates of work-related noises.
Retrieved from the Centers for Disease Control's website November 15, 2005.
http://www.cdc.gov/niosh/01-104.html
Adapted with permission.

According to The American College of Occupational Medicine Noise and Hearing Conservation Committee, occupational noise-induced hearing loss occurs over several years resulting from exposure to hazardous levels (levels greater than 85 dB) of continuous and intermittent noise. The following characteristics are definitive of occupational NIHL: always sensorineural; usually affects both ears; rarely results in profound hearing loss; once harmful exposure ceases, further development of hearing loss ceases as well; loss occurs in the high frequencies with most damage seen in the 4000 Hz frequency; and exposure to continuous noise is more harmful than intermittent noise (Sataloff & Sataloff, 1993).

Because of high noise exposure levels, certain occupations require workers to wear hearing protection devices (HPDs). However, when individuals are at home or away from work they are not required to protect themselves from harmful noise levels. The term given to noise-induced hearing loss from sources other than one's occupation is called sociacusis. Noise from recreational activities, activities that relate to amusement and/ or entertainment, can result in sociacusis (see Table 5 for recreational noise sources and levels) (Berger et al., 2000).

Table 5

Recreational Noise Sources

Noise Source	Sound Level (dBA)
Handgun	166
Rifle	163
Fireworks (at 1 m)	162
Balloon pop	157
Cap gun	156
Firecracker	150
Boom cars	145
Football game (stadium)	117
Rock music band or concert	110
Power saws, leaf blowers	110
Motorcycle	95
Jet boats/personal water craft	95

Note: Retrieved from the Canadian Hearing Society's website November 15, 2005.
http://www.chs.ca/info/noise/book1.html
Adapted with permission.

In 1991, Clark reviewed published studies regarding effects of noisy leisure activities. In his review Clark summarized articles from the following: the effects of noise from exposure to loud music, listening through personal cassette/stereo players, noise around the home, and hunting and target shooting (Clark, 1991).

In Clark's review he concluded individuals who attend noisy discotheques and rock concerts are exposed to sounds greater than 100 dBA; however, since they are only exposed for a few hours monthly or weekly, they are presented with little risk for noise-induced hearing loss. Attendees of classical music and jazz concerts were reported unlikely to experience any risk of noise-induced hearing loss since the average exposure was less than 90 dB.

Clark summarizes listening through personal cassette/stereo players only to result in noise-induced hearing loss if the listener prefers listening at maximum levels for extended periods of time. In Clark's summary regarding noise around the home, the gasoline-powered leaf blower, chainsaw operations, and the cordless telephone were associated with noise-induced hearing loss. With regard to Clark's summary of hunting and target shooting, it was concluded that large caliber rifles and shotguns produce exposure levels that are sufficient to cause acoustic trauma in some individuals and it is reasonably estimated that 50% of US industrial workers are exposed to gunfire from hunting and target shooting.

Hearing Loss

Hearing loss can be identified and diagnosed by a process called audiometry. Audiometry utilizes an instrument called an audiometer (see Figure 17) to measure thresholds. With the use of earphones, audiometers measure and evaluate hearing sensitivity to tones at 250, 500, 1000, 3000, 4000, 6,000, and 8000 Hz. An audiometer can produce sound pressure levels ranging from 0 dB to 110 dB. Audiometers are calibrated so that at certain frequencies, different reference sound levels are produced. The standardized reference level for hearing sensitivity is 0 but that does not mean that 0 dB of sound is being produced. When the dial that represents hearing level is set to zero, pre-calibrated reference sound levels are produced by the earphones (Berger et al., 2000).

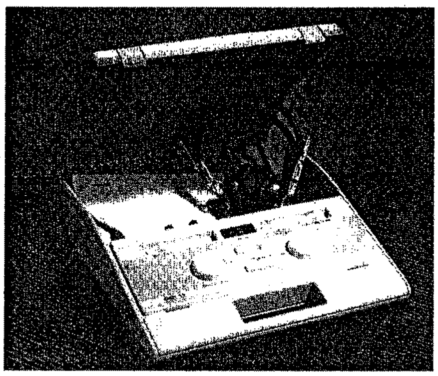

Figure 17. An audiometer.
From *Essentials of Audiology* (p. 119), by S. Gelfand, 2001, New York, NY:Thieme. Reprinted with permission.

Audiometers use reference sound levels recommended by The American Nation Standards Institute (ANSI). Reference hearing thresholds (shown in Table 6) are measured in decibels and were derived from data from a year long (1935-1936) national hearing survey that studied individuals with "normal" hearing (Sataloff & Sataloff, 1993).

The results from hearing tests given with audiometers are recorded on audiograms. Audiograms are graphical records relating hearing level to frequency and are made so that the 0 dB (hearing ability that matches the reference) is at the top of the audiogram with hearing level increasing toward the bottom. The level of the faintest audible sound for each frequency (500, 1000, 3000, 4000, and 6000 Hz) is recorded on an audiogram (Berger et al., 2000). Figure 18 illustrates an audiogram of normal hearing. The red marks in Figure 18 indicate the softest sounds that can be heard by the individual's right ear and the blue marks indicate the softest sound audible to the left ear.

Table 6

Reference Sound Levels

Frequency (Hz)	ANSI Reference Hearing Threshold in dB
125	45.5
250	24.5
500	11.0
1000	6.5
1500	6.5
2000	8.5
3000	7.5
4000	9.0
6000	8.0
8000	9.5

Note. From *Hearing Loss, third edition, revised and expanded* (p. 57), by J. Sataloff & R. Sataloff, 1993, New York, NY: Marcel Dekker. Adapted with permission.

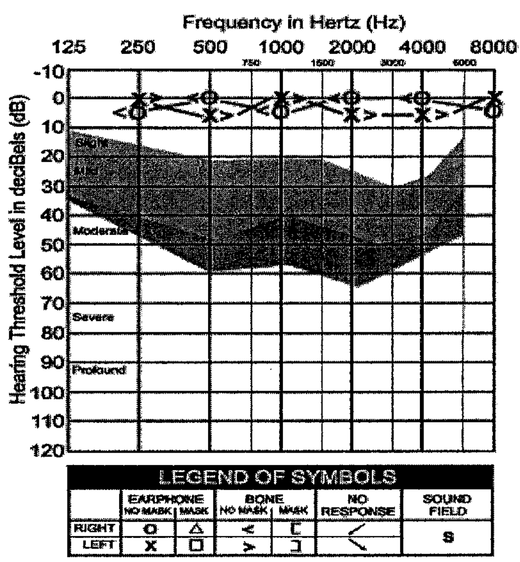

Figure 18. An audiogram depicting normal hearing.
Retrieved from the Raising Deaf Kids' website November 15, 2005.
http://www.raisingdeafkids.org/hearingloss/testing/audiogram/
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Hearing loss can occur in one (unilateral) or both (bilateral) ears and is put into three categories; conductive, sensorineural, and mixed hearing loss. Sensorineural hearing loss was discussed earlier and was noted as hearing loss that results from problems with the inner ear. Mixed hearing loss is loss due to both sensorineural and conductive problems (Gelfand, 2001).

Conductive hearing loss occurs when sound is not conducted efficiently through the outer and middle ears. The absence or malformation of the pinna, ear canal, or ossicles can result in conductive hearing loss. The presence of a foreign body; impacted ear wax; fluid in the ear associated with colds, allergies, ear infections (otitis media); or a poorly functioning Eustachian tube (allows for the equilibrium of air pressure in the middle ear and provides for its aeration and drainage) are also causes of conductive hearing loss. Conductive hearing loss usually involves a reduction in sound level, or the ability to hear faint sounds but can often be corrected through medicine or surgery (reversible) (Gelfand, 1997). If there is a conductive hearing loss, it usually results in hearing loss in the lower frequencies (Berger et al., 2000). Figure 19 illustrates an audiogram of conductive hearing loss.

Hearing Protection Devices

Hearing protection devices (HPDs) are personal safety products worn to decrease noise. There are three types of HPDs: earplugs, earmuffs, and helmets. Earmuffs cover the ears and form a seal against the head, earplugs form a seal and block sound by fitting into or against the entrance of the ear canal, and helmets surround most of the head and are mainly intended for impact protection (Berger et al., 2000).

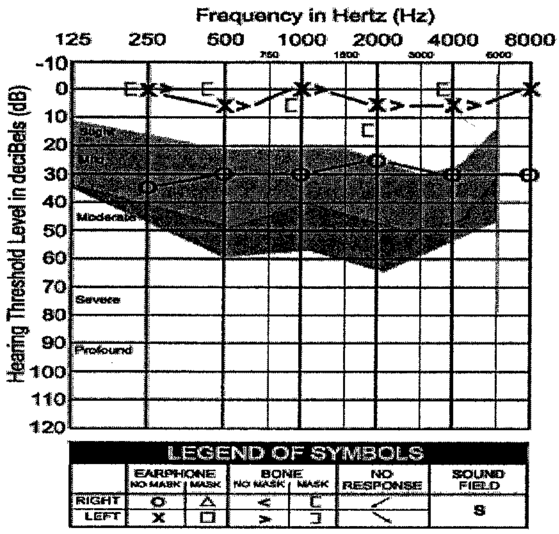

Figure 19. An audiogram depicting conductive hearing loss.
Retrieved from the Raising Deaf Kids' website November 15, 2005.
http://www.raisingdeafkids.org/hearingloss/testing/audiogram/ome.jsp
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There are various types of earplugs made from various types of materials. Formable, pre-molded, foam, semi-insert, and custom-molded are types of earplugs made from material such as vinyl, foam, silicone, fiberglass, elastomer formulation, and wax/cotton formulations (Berger et al., 2000).

Formable earplugs (see Figure 20) are not prevalent in the occupational setting. They are made from materials such as silicone putty, spun fiberglass, and cotton/wax combinations. Unlike foam earplugs, formable earplugs do not stretch in place and instead tightly fit into the ear's canal entrance in order to form a seal. The packing of the formable earplug into the entrance of the canal allows the seal to be loosened by jaw and neck motion. When the seal is loosened, the plugs must be reset and resetting may become a nuisance if done repeatedly. Formable earplugs are more popular in the consumer market where they are used to prevent water from entering the ear canal while bathing or swimming (Berger et al., 2000).

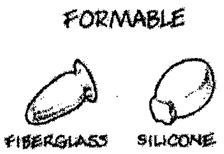

Figure 20. Formable earplugs.
From *The Noise Manual* (p. 385), by E. Berger, L. Royster, J. Royster, D. Driscoll, & M. Lane, 2000, Fairfax, VA: American Industrial Hygiene Association.
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Pre-molded earplugs are available in different sizes and are made from materials such as foam which can be molded into bulbous or conical shapes (see Figure 21). Pre-molded earplugs are pushed into ear canals where they form a seal against the walls of the ear canal and usually have a stem at the end used for handling. Pre-molded earplugs have sealing rings and up to five projections or flanges that are used to provide a better fit for the wearer. Though they are made in various sizes, ear plugs are not made to fit all ears. Existing sizes must be made available to fit each individual (Berger et al., 2000).

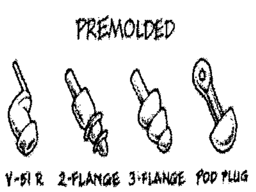

Figure 21. Pre-molded earplugs.
From *The Noise Manual* (p. 385), by E. Berger, L. Royster, J. Royster, D. Driscoll, & M. Lane, 2000, Fairfax, VA: American Industrial Hygiene Association.
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"Roll down" foam earplugs are so named because they must be rolled and compressed before insertion (see Figure 22). They are made from polyurethane or slow –recovery polyvinyl chloride material. Both polyvinyl chloride and polyurethane provide similar amounts of decibel reductions in sound levels; however, polyvinyl chloride based plugs are suggested for optimal insertion and comfort. As a result of high comfort levels and decibel sound reduction, foam plugs have become the most utilized type of HPDs since their introduction in 1972. They can be used more than once and reports show that even after their use of a week or longer, foam plugs give no problems to wearers (Berger et al., 2000).

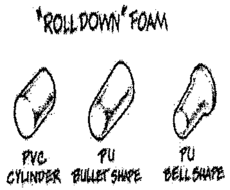

Figure 22. Foam earplugs.
From *The Noise Manual* (p. 385), by E. Berger, L. Royster, J. Royster, D. Driscoll, & M. Lane, 2000, Fairfax, VA: American Industrial Hygiene Association.
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Semi-insert earplugs, also referred to as semi-aural devices (see Figure 23), are made up of soft tips or pods which are held in place by a spring-loaded lightweight band. The band is required to hold the tips or pods in place inside of the ear canal. The tips can be made from polyurethane foam, silicone, vinyl, or composites. Semi-inserts are not intended for continuous use (Berger et al., 2000).

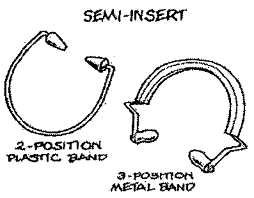

Figure 23. Semi-aural hearing protectors.
From *The Noise Manual* (p. 385), by E. Berger, L. Royster, J. Royster, D. Driscoll, & M. Lane, 2000, Fairfax, VA: American Industrial Hygiene Association.
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Custom-molded ear plugs are made by taking individual impressions of the wearer's ear canal (see Figure 24) and can be made from vinyl or acrylic but most are made from silicone. The impression made of the ear canal can be used as the plug. It is unlikely that custom-molded plugs will loosen with time but use over time may result in cracking or shrinking. Molded ear plugs are small and are therefore sometimes lost or misplaced. The loss of the small plugs can become expensive and since they take a certain amount of time to be made, losing them could cause problems in worker performance (Berger et al., 2000).

Like semi-insert earplugs, earmuffs (as seen in Figure 25) are held in position by a band. The spring-loaded headband has a plastic molded ear cup on each end. The cups form a seal around the ear. Cushions usually foam or fluid-filled along with a foam layer, form the seal. The ear cups are made of material made to absorb high frequency energy. Plastic or fabric straps made to fit over the head and under the chin make it possible to maintain proper protection. Earmuffs are made to fit almost everyone. In the United States, 85% of employees who utilize HPDs on a regular basis would rather wear earplugs rather than earmuffs (Berger et al., 2000).

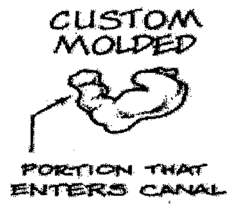

Figure 24. Custom-molded earplugs.
From *The Noise Manual* (p. 385), by E. Berger, L. Royster, J. Royster, D. Driscoll, & M. Lane, 2000, Fairfax, VA: American Industrial Hygiene Association.
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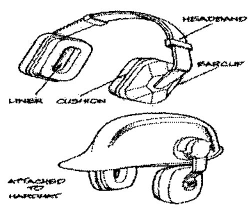

Figure 25. Earmuffs.
From *The Noise Manual* (p. 385), by E. Berger, L. Royster, J., Royster, D. Driscoll, & M. Lane, 2000, Fairfax, VA: American Industrial Hygiene Association.
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Helmets (see Figure 26) are not commonly used in the workplace but are commonly worn by motorcyclists and military personnel. Some helmets, such as military helmets contain material that allows the user to be protected from noise beyond normal limits (Berger et al., 2000).

The amount of attenuation or how much noise reduction a hearing protection device provides determines how effective the HPD will be. HPDs, according to the EPA, should be labeled in accordance to the attenuation they provide. Three ways attenuation can be measured are by (1) real ear attenuation at threshold (REAT), (2) the behavioral method, and (3) microphone in real ear (MIRE), the physical measurement (Gelfand, 2001). The

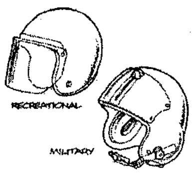

Figure 26. Helmets.
From *The Noise Manual* (p. 385), by E. Berger, L. Royster, J. Royster, D. Driscoll, & M. Lane, 2000, Fairfax, VA: American Industrial Hygiene Association.
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REAT method is the most effective attenuation test; data from REAT measurements is considered the gold standard in comparison with all other types of attenuation measurements (Berger et al., 2000).

Two American National Standards Institute methods (ANSI Z 24.22-1957 and ANSI S3.19-1974) were developed to perform REAT measurements of HPDs. Both standards required the following: a minimum of ten subjects, the measuring of subjects' hearing thresholds while the ear was open and occluded, and thresholds were to be repeated three times each. The attenuation provided by HPDs is measured by taking the difference between the two thresholds (open and occluded) (Gelfand, 2001).

Before the new standard was developed, (ANSI S3.19-1974), the original standard (ANSI Z 24.22-1957) required subjects to sit in a sound field that was directional and used pure tones as test sounds. The new standard for performing REAT specifies the use of a diffuse sound field using 1/3 octave bands of noise. Both methods, original and new are used in Figures 27 and 28 which respectively illustrate attenuation curves for earmuffs and earplugs. In comparison to the new standard, the original standard indicates smaller standard deviations (NIOSH, 1991).

The attenuation of octave bands is combined into a single number called a noise reduction rating which is the difference between the overall noise level measured in dBA under a HPD (the "protected exposure") and the level of "unprotected exposure" measured in dBC. This measurement allows for a 3dB adjustment and is expressed as follows (Gelfand, 2001):

$$NRR = dBC_{unprotected} - dBA_{protected} - 3dB. \tag{16}$$

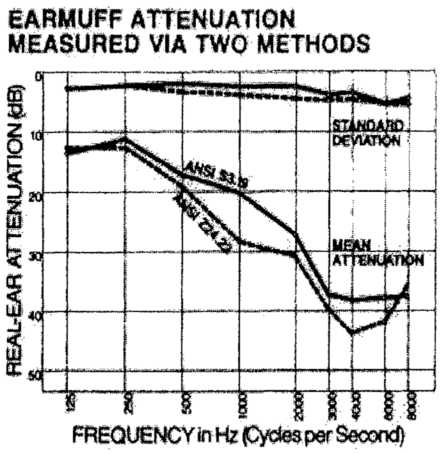

Figure 27. Earmuff attenuation curves.
From the *National Institute for Occupational Safety and Health Publications on Noise and Hearing*, 1991, Cincinnati, OH. Reprinted with permission.

When dBC levels are not known, the effectiveness of HPDS are to be based on unprotected noise levels measured in dBA but the NRR is reduced by 7dB as opposed to 3dB and is expressed as follows (Gelfand, 2001):

$$dBA_{protected} = dBA_{unprotected} - [NRR - 7]. \tag{17}$$

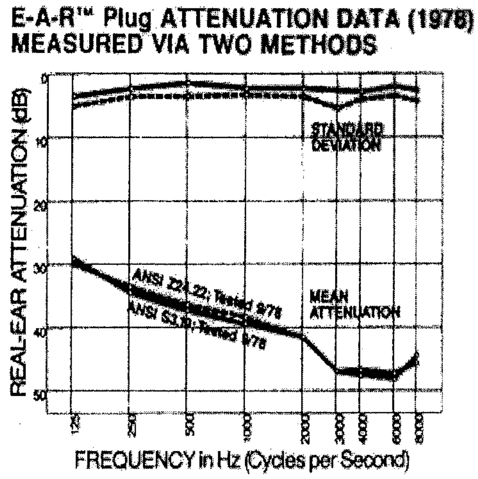

Figure 28. Earplug attenuation curves.
From the *National Institute for Occupational Safety and Health Publications on Noise and Hearing*, 1991, Cincinnati, OH. Reprinted with permission.

There are various steps involved in combining octave bands into single number ratings. First, octave band sound pressure levels are combined into an overall sound pressure level using the following formula (Gelfand, 2001):

$$L = 10\log\sum_{i=1}^{n} 10^{L_i/10}, \tag{18}$$

L= overall (combined) level in dB sound pressure level

n= # of bands being combined

i= i^{th} band

L_i= octave band level of the i^{th} band

Octave band frequencies 125, 250, 500, 1,000, 2000, 4000, and 8,000 are included in the calculation of a noise reduction rating. Second, C-frequency weighting values for relative response (American National Standards Institute S1.4-1983 R 1997) that correspond to each test frequency are subtracted from the octave-band levels. Third, a logarithmic sum of the given band levels is calculated to obtain the overall dBC value.

Fourth, steps 1 and 2 are repeated using the A-frequency weighting values for relative response. Fifth, for each A-weighted octave band sound pressure level, earplug attenuation is subtracted and two standard deviations are added to the resulting number yielding the estimated protected A-weighted octave band sound levels. Sixth, a logarithmic sum of the estimated protected A-weighted octave band levels is calculated to obtain the overall A-weighted protected value. Seventh, the equivalent dBA value is subtracted from the overall dBC value and a safety factor of 3 is subtracted to yield the noise reduction rating (see Figure 29 for calculation of NRR) (Royster & Royster, 2002).

The MIRE method utilizes a tiny probe microphone which is placed inside the ear behind the HPD along with another tiny microphone placed outside the hearing protector. The strategic placement of the microphone allows test sounds to be measured on each side of the HPD. Attenuation is calculated by taking the difference between the sound levels detected inside and outside of the HPD. When based on MIRE versus REAT measurements, attenuation appears to be slightly higher (Gelfand, 2001).

Because HPDs often do not provide the amount of rated attenuation, they are often derated. Their rated capability is lowered because of improper use, inadequacy, and deterioration. OSHA utilizes a 50% derating for all HPDs. NIOSH suggests a 25% derating for earmuffs, 50% for formable earplugs, and 70% for other types of ear plugs (Gelfand, 2001).

In an article by Hempstock and Hill (1990), attenuations of some hearing protectors as they were used in the workplace were examined. Forty-two subjects from eight industrial worksites were tested in mobile trailer. The trailer contained a booth that used a sound field set up according to ISO 4869 (1981) requirements. The test frequencies used 1/3

Octave band center Frequency, Hz	125	250	500	1000	2000	4000	8000	Log Sum
1. Assumed pink noise (dB)	100	100	100	100	100	100	100	
2. C weighting corrections (dB)	-0.2	0	0	0	-0.2	-0.8	-3	
3. Unprotected ear C-weighted level (Log Sum)	99.8	100	100	100	99.8	99.2	97	**107.9**
4. A weighting corrections (dB)	-16.1	-8.6	-3.2	0	1.2	1.0	-1.1	
5. Unprotected ear A-weighted level	83.9	91.4	96.8	100	101.2	101	98.9	
6. Average attenuation at each frequency (example)	21	22	23	29	41	47	36	
	21	22	23	29	41	45*	38.5*	
7. Std. deviation in dB at each frequency (example)	3.7	3.3	3.8	4.7	3.3	3.4	6.5	
	x2	x2	x2	x2	x2			
8. Two standard deviations	7.4	6.6	7.6	9.4	6.6	6.7**	12.6**	
9. Complete APV-98 in dB at each frequency. (Line 6 - line 8) (APV = Average Protection Value)	13.6	15.4	15.4	19.6	34.4	38.3	25.9	
10. Protected ear A-weighted level, (average attenuation minus two std. deviations develops the A-weighted levels (line 5 - line 9)) (Log Sum)	70.3	76.0	81.4	80.4	66.8	62.7	73.0	**85.1**
11. **NRR** is unprotected ear "C" level (line 3) minus protected ear "A" level (line 10) **minus 3 dB**								**19.8**

Figure 29. Calculation of a noise reduction rating.
From *Compendium of hearing protection devices, sound and vibration*, 18 (5) 26-39 by B. Leupert, 1984, Reprinted with permission.
* Average attenuation at 3000 and 4000 Hz and at 6000 and 8000 Hz.
** Summed standard deviation for 3000 and 4000 Hz and 6000 and 8000 Hz.

octave bands centered around 125 Hz and above. Approximately 350 hearing protectors, including ear muffs, earplugs, and helmet-mounted muffs were used during the study. The subjects in this study were not influenced to wear a particular type of hearing protection device. Instead, they were tested using the same type of hearing protection used at their place of employment.

Results found that manufacturer predicted attenuations were less when workers used them in the "real world." The study found that the hearing protectors (ear muffs, earplugs, and helmet-mounted muffs) did not provide as much attenuation as printed by the manufacturer and the standard deviations were higher. Attitudes and education of the workforce, the wearing of eyeglasses, and headband tension were factors discussed to have affected measured performance of the hearing protectors.

The limitations of this study are as follows: the sample size was not large enough and data were insufficient for testing if other factors such as beards and long hair affected measured outcomes.

The utilization of hearing protection devices is one of the effective ways to reduce hearing loss from harmful noise exposures. Employees must be trained to wear HPDs. One-on-one interaction or separation into small groups (about 5 people per group) is the best approach to issue HPDS. Approximately 7-10 minutes should be allotted for the proper fitting of a HPD. Training can be done in large groups, but should not be done in place of one-on-one or small group training. Large group training can be done to serve as a review or additional training. Furthermore, workers should be fitted in environments that are more noisy than quiet. Noisy environments provide the wearer with a better sense of their HPD's effectiveness. If in a noisy environment, when the HPD is inserted or worn, its effectiveness is immediately illustrated. If a noisy environment is not provided, the fitter should check with the wearer in their normal work environment to ensure a proper fit and effectiveness (Berger et al., 2000).

Hearing Conservation Programs

An occupational hearing conservation program (HCP) is vitally important in the preservation of employee hearing. An effective HCP is made up of five basic parts. They are as follows: noise surveys and data analysis, education and motivation, noise control, hearing protection devices, and audiometric monitoring (Berger et al., 2000).

The noise survey and data analysis part of an HCP measures noise levels in the workplace and monitors the worker's exposure levels. Monitoring noise levels allows for the identification of possible noise-hazardous areas and overexposures. The OSHA Hearing Conservation Amendment requires monitoring to be done when workers are suspected to be exposed to noise levels greater than or equal to 85 dBA TWA, the action level. Noise between 80 and 130 dB, intermittent, impulsive, and continuous, are included in the exposure measurements. If noise levels are found to be greater than or equal to 85 dBA TWA, all exposed employees must be notified. Additional monitoring is required if it is thought that more employees are exposed to noise at or above the action level or if the hearing protection provided is thought to be providing inadequate attenuation (Gelfand, 2001). Workers with a standard threshold shift, an increase of 10 dB or more in the average of test frequencies at 2000, 3000, and 4000 Hz in either ear in comparison to the initial or baseline audiogram, are required to wear hearing protection if exposed to noise exceeding 85 dB (Berger et al., 2000).

The education and motivation component of the HCP informs all employees (including management) of hazardous noise in the workplace. They are educated about the hazard and made aware of how a HCP can prevent NIHL. This component of the program also encourages those exposed to comply with the activities and requirement of the HCP (Berger et al., 2001).

In order to decrease or eradicate the harmful effects of noise in the workplace, the amount of noise must be controlled; this is done by the implementation of administrative and engineering controls. Administrative controls include any decision made by management that positively effects an employee's exposure to noise (Berger et al., 2000). Administrative controls include but are not limited to change in policies in order to decrease an employees' exposure to noise levels that meet or exceed the action level and prohibiting the purchase of noise sources that exceed action levels. They involve the cooperation of administrators such as managers and supervisors. Engineering controls are dependent on the noise source. Sources such as machines can be replaced or enclosed in order to decrease the level of noise they produce (Gelfand, 2001, Berger et al., 2000).

The fitting and issuing of HPDs is considered to be the most vital part of a HCP. The selection and fit of a HPD is dependent on the employee. The fitter is responsible for providing the most suitable type of HPD (Berger et al., 2000). Before HPDs are issued, the fitter should examine the external ear. It should be examined for medical conditions such as sores or discharge and the structural makeup of the ear such as surgical malformations or birth defects. If any problems with the external ear are discovered, consultation with a professional and/or treatment must be done before the employer can be issued hearing protection. When examining the employee, the fitter should have the following available: an earlight, otoscope, or penlight for HPD insertion determination, tweezers for earplug removal, and a tool used to size the ear canal for assistance with sized earplugs (Berger et al., 2000).

HPDs should be cleaned on a regular basis, normally with water and soap, according to instructions of the manufacturer. Earplugs should be washed all over and completely dried. Earmuff cushion liners should be washed clean or wiped. Cushions of earmuffs and earplugs should be discarded when they can no longer be cleaned or have the ability to maintain their original shape or qualities, they should be thrown away (Berger et al., 2000).

The Hearing Conservation Amendment requires that a variety of HPDs be provided free of charge. It also requires the following: HPDs be worn by employees who are exposed to noise levels that exceed 90 dBA TWA PEL, employees who are exposed to noise levels that meet or exceed the action level who wait more than 6 months to receive baseline audiogram "under the exceptions of mobile test vans," and finally employees who meet or exceed the action level who have had a "standard threshold shift" (Gelfand, 2001).

Audiometric testing is the final component of an effective HCP. An audiometer is used to test each ear at 500, 1000, 2000, 3000, 4000, and 6000 Hz. Baseline audiograms, annual audiograms, retests and referrals are all a part of audiometric testing. Baseline and annual audiogram testing is required for employees who meet or exceed exposure to noise levels at or above the action level of 85 dBA TWA.

A baseline audiogram is required within the first six months of exposure to noise levels greater than or equal to 85 dB TWA. It serves as a comparison audiogram for detection of degeneration of hearing that may have developed from occupational exposure (Gelfand, 2001). If there is an increase of 10 dB or more at 2,000, 3,000, and 4,000Hz in either ear when compared to the baseline audiogram, a standard threshold shift has occurred (Berger et al., 2000)

Hearing conservation programs serve to protect an employee's hearing. However; for some employees HCPs are not an option. Some employees have and will suffer from an occupational hearing loss. These employees may be eligible to receive money for their loss. Workers' compensation programs allow and determine the eligibility of compensation to those who suffer from occupational hearing loss. Details concerning compensation vary by state (Gelfand, 2001).

Non-Occupational Noise Exposure

A cross-sectional, population-based cohort study by Nondahl et al. (2000) evaluated hearing loss as a result of recreational firearm use. Three thousand seven hundred and fifty three men from Beaver Dam, Wisconsin ages 48 to 92 completed a questionnaire which included questions about medical and family history, hearing handicaps, and leisure and occupational noise exposures. The section on the questionnaire regarding hunting and target shooting was completed by interview and focused on hearing protection use, type of firearm used most often, and shooting history.

Results from the study revealed an association in high-frequency hearing loss and the use of recreational firearms in 1538 men. Two-hundred forty six of the 1538 participants had participated in target shooting in their lifetime. Of the 246, 77 had been target shooting within a year of the study. Of the 77 who were target shooters within a year of the study, 38% reported never wearing hearing protection.

The results of this study found that men who participated in regular target shooting or who had done so within the year prior to the study were more likely to have experienced a high-frequency hearing loss than those who had not. For every five years the men had hunted, their risk of having a marked high-frequency hearing loss increased by 7%.

The limitations of this study include recall bias, response, and interviewer bias. As a result of the method used to collect data, recall, interviewer, and response may be prevalent. Questions from the questionnaire required participants to remember things from their past, therefore recall bias may be prevalent. Some participants may have under-reported while others may have over-reported because they did not really remember what happened in their past resulting in response bias (Stevens, 1986). Data for each participant's shooting history was gathered by an interviewer; therefore interviewer bias may have existed. Interviewers may have unintentionally guided participants to answer a certain way and participants may have intentionally given incorrect answers because they felt questions were too personal or because they feared their answers would affect their employment (Stevens, 1986).

In a study by Clark and Bohl (Axellson, 1996), hearing levels of US industrial workers employed in low noise environments were evaluated and the effectiveness of industrial hearing conservation programs was tested.

Hearing level data for 15, 297 industrial workers were obtained from 22 companies (22 data sets) in the United States and Canada. Workers were included in the analysis based on the following: individuals had a time-weighted average noise level at or below 85 dBA, individuals had at least four available audiograms, data was from a US company, and individuals had an audiometric test done within 24 months of employment.

One-thousand one hundred and one males and 515 females were included in the analysis. Results of the study indicated hearing of industrial workers, male and female, to be worse than hearing observed in a random US population. Young male individuals (less than 30 years old) had similar hearing ability in spite of race. However, hearing levels for white males were worse than hearing levels for black as age increased. White male workers hearing was poorer than Blacks by 4 dB at 30 years of age, 10 dB at 40 years of age, and 18 dB at 50 years of age. In addition, the study revealed that white males at 3000, 4000, and 6000 Hz lose more hearing as they age than black males.

The hearing level comparison for Black and White females for all ages shows little to no difference at all frequencies. Results showed black and white females had better hearing sensitivity than males.

It is noted that the difference in hearing level among Black and White males in the study is attributable to different exposure histories among the two races. Fifty to 70% of the white males in the study reported enjoying hunting and target shooting, whereas few black males and women reported enjoying the same. A large portion of the data for this study was obtained from companies from the South and Southeastern parts of the United States which may be why 50-70% of the white males in the study reported enjoying hunting and target shooting.

Results from a review done by Clark (1991) support the following: large caliber rifles and shotguns produce exposure levels that are sufficient to cause acoustic trauma in some individuals and it is reasonably estimated that 50% of US industrial workers are exposed to gunfire from hunting and target shooting.

Study Problem

In 1987, workers employed at the Anniston Alabama Army Depot (ANAD) were enrolled in a hearing conservation program based on an 85 dBA criterion level for an 8-hour day with a 5 dB exchange rate. Under this criterion level, 500-700 employees were removed from the program because they worked in areas where noise levels were less than 85 dBA. In 2001, the employees removed from the hearing conservation program were re-enrolled, this time under a criterion level of 85 dBA for an 8-hour day with a 3 dB exchange rate. During the removal period, workers were not exposed to hazardous occupational noise but according to Norman (2005), workers still experienced significant changes in hearing sensitivity.

The purpose of Norman's study was to evaluate changes in hearing threshold levels of the workers who were removed from the HCP in 1987 and re-enrolled in 2001. In Norman's study, a total of 675 workers from the ANAD participated in informational sessions held at the ANAD. During the sessions, the purpose of her study and the importance of employee participation were explained followed by a question-and- answer session. Employees who agreed to participate in the study did so by signing an informed consent form. A total of 231 employees signed consent forms but 187 were excluded based on the following: they were female (16); insufficient audiogram data (70); incomplete work histories (81); and participation withdrawal (20). Of the 44 remaining subjects, an additional 13 were excluded because of the following: medical history and non-occupational exposure were indicated as a cause of hearing loss, audiograms showed unaccountable threshold shifts, and there were unreliable audiometric test results. After exclusions were made, there were a total of 31 study participants whose ages ranged from 24 to 44 in 1987 and 38 to 58 by 2001 (Norman, 2005).

Job-exposure matrices were developed for the 31 remaining study participants based on employment records and noise exposure data. From the matrices, it was determined that participants were exposed to 71 to 87 A-weighted dB of noise individually and 65 to 89 A-weighted dB collectively (Norman, 2005).

Norman defined hearing impairment as a loss of 25 dB for both ears at 1000, 2000, and 3000 Hz. Hearing threshold levels were compared to hearing threshold levels associated with age (HTLA) according to ANSI S3.44-1996. The differences were found to be statistically insignificant (see Figures 30 and 31) (Norman, 2005).

Noise-induced permanent threshold shifts were also calculated to determine hearing loss. A mean of 80 dBA for noise-induced permanent threshold shifts was found, indicating noise to be highly unlikely in producing a hearing threshold shift. Norman's results indicated that factors other than occupational noise exposure were responsible for the observed change in hearing sensitivity over the study period. The results of this study indicated that the OSHA-rule (a criterion level of 85 dBA for an 8-hour day with a 5 dB exchange rate) is sufficient to prevent occupational hearing loss. One limitation of Norman's study is that the study population was small, resulting in low power. The low power of this study decreased the chances of detecting a relationship between occupational noise and hearing loss among the study population (Norman, 2005).

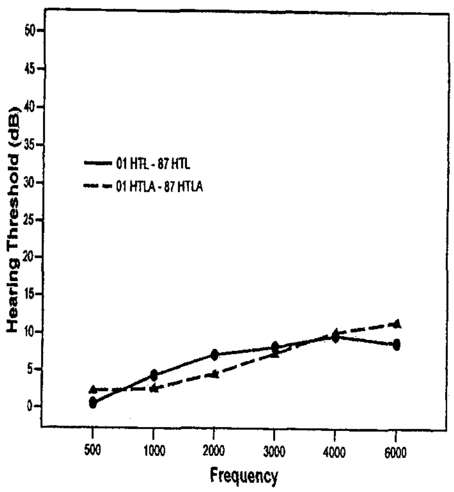

Figure 30. Shift in HTL and HTLA between 1987 and 2001
From Norman 2005, Reprinted with permission.

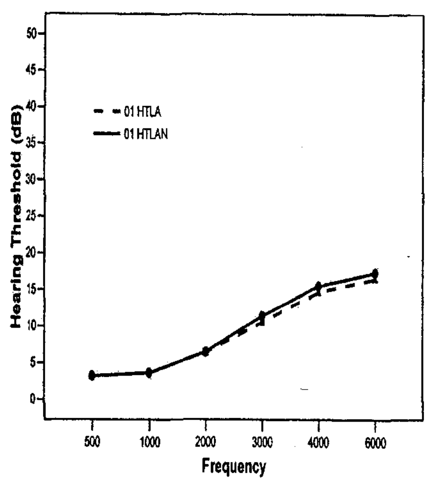

Figure 31. 2001 HTLA and HTLAN
From Norman 2005, Reprinted with permission.

Study Purpose

It has been determined that workers at the ANAD who were removed from the hearing conservation program in 1987 and re-enrolled in 2001 did not experience significant changes in hearing sensitivity due occupational noise, nevertheless there were significant changes. The purpose of this study was to determine what factors (non-occupational noise exposure factors and/or/both non-noise occupational exposure factors) were associated with measured hearing levels in 2001 (See Table 7).

Table 7.

List of Non-Occupational Noise Exposures and Non-Noise Occupational Exposures.

Non-Occupational Noise Exposures	**Non-Noise Occupational Exposure**
Military Service	ANAD Serious Illness
Military Weapons Fire	ANAD Heavy Metals
HP While Exposed to Weapons Fire	ANAD Solvents
Other Loud Noises While in the Military	ANAD Carbon Monoxide
HP While Exposed to Loud Noise	*Medical Conditions*
Home and Recreational Noise Exposures	Immediate Family HL
Watercraft	Surgery on Either Ear
Race Cars	Traumatic Injury to Either Ear
Motorcycles	Hospitalized for Head Injury
Heavy Machinery	Diagnosed with High Blood Pressure
Yard Equipment	Diabetes
Carpentry Tools	
Recreational Hunting	
Loud Music	

Hypothesis 1

H_0: Hearing threshold levels among Anniston Army Depot workers in 2001 were not associated with non-occupational noise exposure factors.

Alternative Hypothesis 1

H_A: Hearing threshold levels among Anniston Army Depot workers in 2001 were associated with non-occupational noise exposure factors.

Hypothesis 2

H_0: Hearing threshold levels among Anniston Army Depot workers in 2001 were not associated with non-noise occupational exposure factors.

Alternative Hypothesis 2

H_A: Hearing threshold levels among Anniston Army Depot workers in 2001 were associated with non-noise occupational exposure factors.

CHAPTER 2

METHODS

Step 1: Criteria for the Study Population

The study population was defined by the following:

1. The worker was employed by the ANAD from January 1987 until January 2001.
2. The worker was removed from the hearing conservation program in 1987 and re-enrolled in the hearing conservation program in 2001.
3. The worker had an audiogram ± 1 year of January 1, 2001.
4. The worker signed an informed consent form and completed a hearing sensitivity questionnaire.

Step 2: Identification of Study Population

The study population was asked to attend informational sessions held at the ANAD. The sessions explained the purpose of the study and the importance of employee participation. During the sessions, time was allotted for questions and answers. Those who agreed to participate in the study signed informed consent forms (Appendices A and B) and those who did not were asked to return to work. Of the 675 attendees, only 500 were eligible and of those 500, 231 agreed to participate (34%).

Step 3: Employee Interview

During the Spring of 2002, appointments were scheduled to conduct employee interviews for participants who completed informed consent forms. Each interview involved a one-on-one question and answer session between a UAB research assistant and the employee. The research assistant read questions from a questionnaire and completed the questionnaire according to the employee's response. Please see Appendix C for a copy of the questionnaire.

Step 4: Questionnaires

Questionnaires contained questions regarding the following topics: demographics, military history, medical history, chemical exposure history, occupational noise exposure history, and non-occupational noise exposure history. Twenty of the 231 who agreed to participate did not complete questionnaires; therefore, questionnaire data was available for 211 participants. Each participant was assigned a subject number to protect their identity and the questionnaire data was numerically coded. Please see Appendix D for the code sheet. The coded data was entered into a Microsoft Excel ® spreadsheet.

Step 5: Audiometric Evaluation and Measuring Hearing Sensitivity

Audiograms from ± 1 year of January 2001 were used to calculate average hearing threshold levels at 500, 1000, 2000, 3000, and 4000 Hz. Of the 211 participants, 96 had an audiogram available for 2001 (± 1 year). The average hearing threshold level for both ears at 500, 1000, 2000, 3000, and 4000 Hz was calculated for each ear for each of the 96 participants.

The normal range of hearing is between zero and 25 decibels. The ability to understand everyday speech is noticeably affected in persons having a hearing threshold level greater than 25 dB (Berger, 2000). In this study, if the average HTL for either ear was less than 25 dB, the participant was excluded as a subject. If the average HTL for both ears exceeded 25 dB, the average hearing threshold level for ear with the greater HTL was used in the analysis. Of the 96 participants, 53 were excluded from the study because of HTLS greater than 25 dB, leaving 43 subjects in the study.

The dependent variable in this study was average hearing threshold level for the worse ear at 500, 1000, 2000, 3000, and 4000 Hz and was coded as a continuous variable and measured on an interval scale. There were 26 independent variables (see Table 8) placed in five categories: demographics, military history, medical history, chemical exposure history, and non-occupational noise exposure history.

Step 6: Analyzing the Data

Questionnaire data was entered into an Excel workbook and imported into an SPSS® data file and analyzed using a linear regression analysis. The data were also imported into a SAS® data file and analyzed using a principal component analysis.

A linear regression analysis was performed for each independent variable to determine if there was a relationship between the independent variables and the dependent variable. Linear regression is a statistical method used to determine the extent of the relationship between the independent variable and the dependent variable. This relationship is described as the coefficient variation (R^2). Linear regression assumes the data are linear and finds the slope and intercept that make a straight line that fits the data best (Daniel, 2005).

Table 8

Independent Variables

Demographics
Age
Gender
Race

Military History
Military Service
Military Weapons Fire Exposure
HP While Exposed to Weapons Fire
Other Loud Noises While in the Military
HP While Exposed to Loud Noise

Medical History
Immediate Family HL
Surgery on Either Ear
Traumatic Injury to Either Ear
Hospitalized for Head Injury
Diagnosed with High Blood Pressure
Diabetes

Chemical Exposure History
ANAD Serious Illness
ANAD Heavy Metals
ANAD Solvents
ANAD Carbon Monoxide

Non-Occupational Exposure History
Watercraft
Race Cars
Motorcycles
Heavy Machinery
Yard Equipment
Carpentry Tools
Recreational Hunting
Loud Music

Although it is assumed that variables are normally distributed, that assumption could be false. If the dependent variable is not normally distributed for the independent variable, the relationship between the dependent variable and the independent variable may be underestimated. These assumptions were tested by using residual plots, normal quantile plots, and a robust test of normality. Results from these tests indicated the data were normally distributed.

Following the linear regression analysis of the separate independent variables, a principal component analysis was performed, using SAS®, to determine if there was a pattern in the data set and to identify significant relationships (Stevens, 1986).

A principal component analysis is a method used to simplify a multidimensional data set by reducing the dimensions for analysis. A principal component analysis transforms original variables into principal components (the set of new linear combinations after transformation). The variance in the data set is explained by the principal components.

The use of five components or less will account for most (75% or more) of the variance in the data set. The first principal is responsible for the greatest amount of variance in the data set. The second principal component is not correlated with the first principal component but is responsible for the second largest amount of variance in the data set; the third component is responsible for the third largest amount of variance but is not correlated to the first or second component (Stevens, 1986).

The independent variables in this study were divided into five groups for the principal component analysis: Group 1 - demographics; Group 2 – weapons fire noise exposure; Group 3 – clinical history; Group 4 – recreational noise exposure; Group 5 – chemical exposures at ANAD.

CHAPTER 3

RESULTS

Of the 43 participants included in this study there were 2 white females, 37 white males, and 4 black males. The mean age was 53, the median was 52, and the range was 40. The 43 participants were grouped by age into following categories: 1 (30-39); 14 (40-49); 18 (50-59); 9 (60-69); and 1 (> 69).

The answers to the questionnaire data for the 43 participants were grouped by response (see Table 9). The HTL for both ears for each of the 43 participants was calculated for 500, 1000, 2000, 3000, and 4000 Hz. The average HTL for the left ear ranged from 14.07 dB to 54.77 dB. The average HTL for the left ear ranged from 17.67 dB to 50 dB (see Table 10 and Figure 32).

Table 9

Subject Responses to Each Question

	No	Yes
Military History		
Military Service	18	25
Military Weapons Fire Exposure	24	19
HP While Exposed to Weapons Fire	34	9
Other Loud Noises While in the Military	27	16
HP While Exposed to Loud Noise	30	13
Medical History		
Immediate Family HL	32	11
Surgery on Either Ear	40	3
Traumatic Injury to Either Ear	39	4
Hospitalized for Head Injury	40	3
Diagnosed with High Blood Pressure	27	16
Diabetes	36	7
Chemical Exposure History		
ANAD Serious Illness	34	9
ANAD Heavy Metals	21	22
ANAD Solvents	12	31
ANAD Carbon Monoxide	31	12
Non-Occupational Exposure History		
Watercraft	31	12
Race Cars	40	3
Motorcycles	35	8
Heavy Machinery	22	21
Yard Equipment	6	37
Carpentry Tools	10	33
Recreational Hunting	26	17
Loud Music	32	11

Table 10

Average Hearing Threshold Level Values (dB)

Frequency (Hz)	Left HTL Average	Right HTL Average
500	14.07	17.67
1000	15.93	16.51
2000	28.26	28.72
3000	47.33	39.07
4000	54.77	50

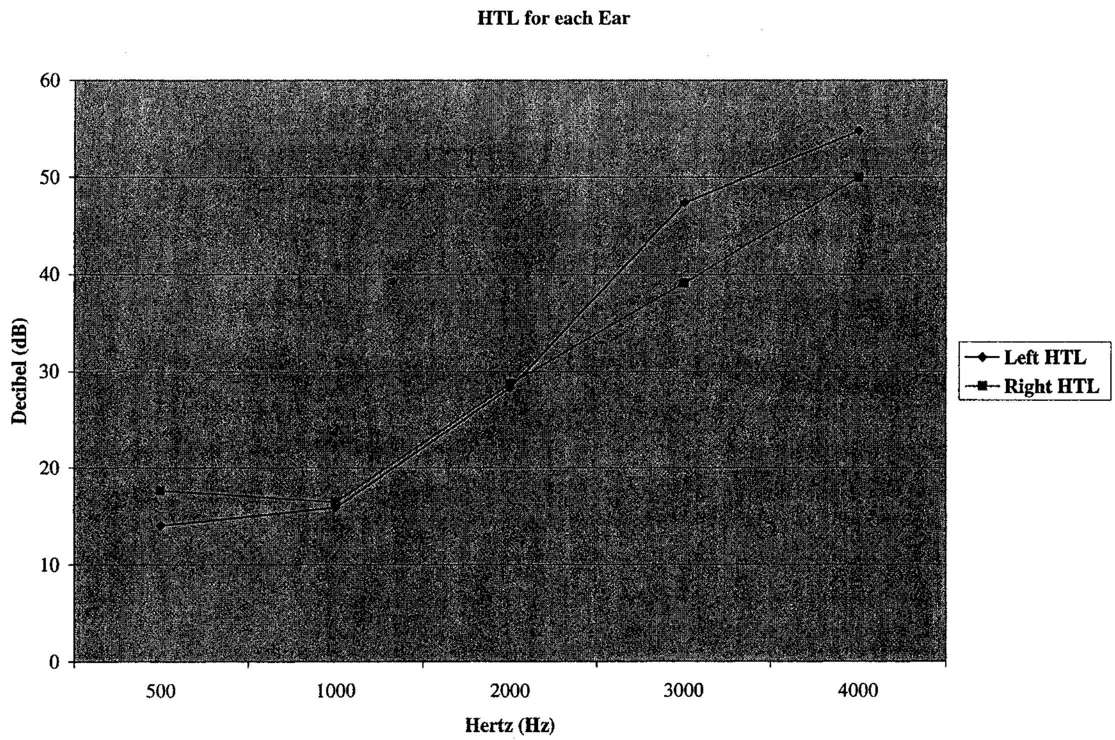

Figure 32. Left and Right HTLs

Results from the linear regression model indicated that there was a linear relationship between the average hearing threshold level and two of the independent variables (see Table 11). The R^2 values also seen in Table 11 indicated there to be little to no variation in the data set which indicated the linear regression analysis did not provide any predict-

Table 11

Linear Regression Model Results (R Square, Beta, and p-value)

Independent Variable	**R Square**	**Beta**	**p-value**
Age	0.11	0.33	0.03
Gender	0.00	0.00	0.98
Race	0.02	0.13	0.40
Military Service	0.05	0.22	0.15
Military Weapons Fire Exposure	0.11	0.33	0.03
HP While Exposed to Weapons Fire	0.00	0.08	0.60
Other Loud Noises While in the Military	0.03	0.18	0.25
HP While Exposed to Loud Noise	0.03	0.17	0.29
Immediate Family HL	0.00	0.00	0.95
Surgery on Either Ear	0.01	0.10	0.51
Traumatic Injury to Either Ear	0.02	0.16	0.32
Hospitalized for Head Injury	0.00	0.03	0.84
Diagnosed with High Blood Pressure	0.00	0.05	0.73
Diabetes	0.05	0.23	0.14
ANAD Serious Illness	0.03	0.16	0.30
ANAD Heavy Metals	0.04	0.20	0.19
ANAD Solvents	0.00	0.05	0.74
ANAD Carbon Monoxide	0.03	0.17	0.28
Watercraft	0.00	0.04	0.80
Race Cars	0.06	0.24	0.13
Motorcycles	0.01	0.08	0.63
Heavy Machinery	0.03	0.10	0.51
Yard Equipment	0.03	0.17	0.29
Carpentry Tools	0.02	0.14	0.37
Recreational Hunting	0.04	0.21	0.19
Loud Music	0.06	0.24	0.12

tion of a relationship between the independent variables and the dependent variable. The R^2 value explains how much variation in the dependent variable can be explained by the independent variables. The closer the R^2 value is to 1, the better prediction of a relationship between the dependent and independent variables (Stevens, 1986). Age and military weapons had p-values <0.05; however, since the R^2 value for both variables was 0.11, this indicated a very poor relationship between the independent variables and the dependent variable.

Table 12 shows linear functions of the variables that make up the principal components; these linear functions are known as eigenvectors. Principal components one and two from each category were included in a general linear model which indicated a linear relationship ($p < 0.05$) between the average hearing threshold level and two independent variables, recreational hunting (p-value = .05) and military weapons fire exposure (p-value = .00) (see Table 13).

Table 12

Principal Component Eigenvectors

	Prin 1	Prin 2	Prin 3
Demographics			
Age	0.68	0.02	0.74
Gender	0.51	0.74	0.44
Race	0.54	0.67	0.51
Noise History			
Military Service	0.48	0.21	0.50
Military Weapons Fire Exposure	0.41	0.66	0.13
HP while exposed to weapons fire	0.41	0.20	0.83
HP while exposed to loud noise	0.45	0.55	0.11
Other loud noises while in military	0.48	0.43	0.21
Clinical History			
Immediate Family HL	0.27	0.48	0.06
Surgery on either ear	0.20	0.58	0.54
Traumatic injury to either ear	0.46	0.23	0.49
Hospitalized for head injury	0.49	0.00	0.33
diagnosed with high blood pressure	0.44	0.56	0.02
Diabetes	0.49	0.25	0.60
Recreational Noise Exposure			
Watercraft	0.24	0.50	0.35
Race Cars	0.22	0.32	0.81
Motorcycles	0.42	0.25	0.38
Yard equipment	0.44	0.39	0.11
Carpentry Tools	0.50	0.10	0.16
Recreational Hunting	0.26	0.66	0.08
Loud Music	0.47	0.01	0.20

Table 13

Major Component Factor (p-value)

Parameter	Variable	p-value
PRIN1_DEM	Age	0.25
PRIN2_DEM	Gender	0.17
PRIN1_NOISE	Military Service	0.60
PRIN2_NOISE	Military Weapons Fire Exposure	0.00
PRIN1_CLIN	Diabetes	0.63
PRIN2_CLIN	Surgery on Either Ear	0.90
PRIN1_RECR	Carpentry Tools	0.58
PRIN2_RECR	Recreational Hunting	0.05

CHAPTER 4

CONCLUSION

Results from the linear regression analysis of the separate independent variables indicated that there was a significant statistical relationship between the average HTL and age ($p< 0.05$), and military weapons fire exposure ($p< 0.05$). However, the R^2 values were so low that the linear regression analyses provided almost no relationship between the independent variables and the dependent variable.

The general linear model that resulted from the principal component analysis indicated a linear relationship between the average HTL and two dependent variables, recreational hunting ($p = 0.05$) and weapons fire exposure ($p < 0.001$). No significant associations for medical conditions and non-noise occupational exposures were found by either statistical method. Therefore, it is concluded that hearing threshold levels among this group of Anniston Army Depot workers in 2001 were associated with non-occupational noise exposure factors but were not associated with medical conditions or non-noise occupational exposure factors.

The limitations of the analyses include small sample size, recall bias, interviewer bias, response bias, and selection bias. As a result of the method used to collect data, recall, interviewer, and response bias must be taken into consideration (Stevens, 1986). Questions from the questionnaire required participants to remember things from their past, therefore recall bias may be prevalent (Stevens, 1986). Some participants may have under-reported while others may have over-reported because they did not really remember what happened in their past. They may have also intentionally given incorrect answers for fear of losing pending worker's compensation claims for hearing loss. Recall bias can be evaluated by having participants complete the same questionnaire twice. However, in this study, the participants were only asked to complete the questionnaire once. Participants in this study were given a choice to be included or excluded. The participants' decision to participate in the study may have been correlated with traits that affect the study therefore making the participants a non-representative sample (Stevens, 1986).

Because the data collection method used interviewers, interviewer and response bias may also be present. Interviewers may have unintentionally persuaded participants to answer a certain way and participants may have intentionally given incorrect answers because they felt questions were too personal or because they feared their answers would affect their employment (Stevens, 1986).

The findings that from this study were consistent with results from studies conducted by Nondahl et al. (2000), Clark and Bohl (1996), and Clark (1991). The results from Nondahl et al. indicated men who participated in regular target shooting or who had done so within the year prior to the study were more likely to have experienced a high-frequency hearing loss than those who had not. For every five years the men had hunted, their risk of having a marked high-frequency hearing loss increased by 7%.

Findings from a 1991 Clark review, which summarized study findings regarding effects of noisy leisure activities, concluded that large caliber rifles and shotguns produce exposure levels that are sufficient to cause acoustic trauma in some individuals and it is reasonably estimated that 50% of US industrial workers are exposed to gunfire from hunting and target shooting.

Results of the study done by Clark and Bohl indicated hearing of industrial workers', male and female, to be worse than hearing observed in a random US population. Young male individuals (< than 30 years old) had similar hearing ability in spite of race. However, hearing levels for white males were worse than hearing levels for black as age increased. White male workers hearing was poorer than Blacks by 4 dB at 30 years of age 10 dB at 40 years of age, and 18 dB at 50 years of age. In addition, the study revealed that white males at 3000, 4000, and 6000 Hz lose more hearing as they age than black males. It is noted that the difference in hearing level among Black and White males in the study is attributable to different exposure histories among the two races. Fifty to 70% of the white males in the study reported enjoying hunting and target shooting, whereas few black males and women reported enjoying the same. A large portion of the data for that study was obtained from companies from the South and Southeastern parts of the United States where many white males enjoying hunting and target shooting, whereas few black males and females do so. The subjects in this study were predominantly white males (86%). Although the linear regression analysis found a statistically significant relationship between HTL and military weapons fire and recreational shooting in this group, the R^2s were so low that the associations were of no practical significance.

These results concur with those of Clark (1991), Clark and Bohl (1996) and Nondahl et al. (2000), and strengthen the assertion that the use of firearms without wearing hearing protection can cause significant hearing loss. This effect seems to be especially predominant among white southern males whom Clark and Bohl imply as enjoying hunting and recreational shooting more than other racial and gender segments of the population. Further research should be conducted to confirm this relationship, and to better define extent of hearing loss associated with hearing loss among southern white males.

Although employers can effectively prevent hearing loss from occupational noise exposures by implementing and maintaining Effective hearing conservation programs (HCP), employees may still develop hearing loss due to the use of firearms. Therefore, it would be beneficial to the employer and employees if HCP administrators included information on non-occupational noise exposures, especially the use of firearms, in their HCP training programs. The benefit to employees is obvious: prevention of hearing loss from non-occupational exposures, The benefit to employers would be to prevent hearing loss from occupational and non-occupational exposures; thus reducing the likelihood that employees would file future workers' compensation claims for hearing loss regardless of it's cause.

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APPENDIX A

GOVERNMENT CONSENT FORM

VOLUNTEER AGREEMENT AFFADAVIT

For use of this form, see AR 70-25 or 40-38; the proponent agency is OTSG

PRIVACY ACT OF 1974

Authority: 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087

Principal Purpose: To document voluntary participation in the Clinical Investigation and Research Program. SSN and hone address will be used for identification and locating purposes.

Routine Uses: The SSN and home address will be used for identification and locating purposes. Information derived from the study will be used to document the study; implementation of medical programs; adjudication of claims, and for mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State, and local agencies.

Disclosure: The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you in future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this investigational study.

PART A (1) VOLUNTEER AFFADAVIT

Volunteer Subjects in Approved Department of the Army Research Studies

---

Volunteers under the provisions of the AR 40-38 and AR 70-25 are authorized all necessary medical care for injury or disease which is the proximate result of their participation in such studies.

I, ______________________________________SSN________________ having full capacity to consent and having attained my _____ birthday, do hereby volunteer/give consent as legal representative for ____________________________ to participate in ____________________________ under the direction of __________________ And/or members of the Service ________________________ conducted; and the inconveniences and hazards that may reasonably by expected have been explained to me by **Mr. Charles L. Pederson of the ANAD Occupational Health Clinic, Dr. Oestenstad of UAB, or members of the UAB research team.**

DA FORM 5303-R, May 89 Previous Editions are Obsolete

I have been given the opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights/the rights of the person I represent on study-related injury I may contact the **Center Judge Advocate, EAMC, Fort Gordon, GA 30905-5650, tele (706) 787-6197**.

DA FORM 3503-R May 89 Previous Editions are Obsolete

VOLUNTEER AGREEMENT AFFIDAVIT (con't)

I understand that I may at any time during the course of this study revoke my consent and withdraw/have the person I represent withdrawn from the study without further penalty or loss of benefit; however, I/the person I represent may be required [military volunteer] or required [civilian volunteer] to undergo certain examination if, in the opinion of the attending physician, such examinations are necessary for my/the person I am represent's health and well-being. My/the person I represent's refusal to participate will involve no penalty or loss of benefits to which I am/the person I represent is otherwise entitled.

PART A (2) – ASSENT VOLUNTEER AFFIDAVIT (MINOR CHILD)

I, ______________________________________SSN_________________ having full capacity to consent and having attained my _____ birthday, do hereby volunteer/give consent as legal representative for ___________________________ to participate in _____________________________ under the direction of ___________________ conducted at ____.

The implications of my voluntary participation, duration and propose of the research study, the methods and the means by which it is to be conducted, and the inconveniences and hazards that may be reasonable expected have been explained to me by_____________________________.

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights I may contact ______________________ at ________________________________.

I understand that I may at any tine during the course of this study revoke my consent and withdraw/have the person I represent withdrawn from the study without further penalty or loss of benefit; however, I/the person I represent may be required [military volunteer] or required [civilian volunteer] to undergo certain examination if, in the opinion of the attending physician, such examinations are necessary for my/the person I am represent's health and well-being. My/the person I represent's refusal to participate will involve no penalty or loss of benefits to which I am/the person I represent is otherwise entitled.

DA FORM 3503-R May 89 Previous Editions are Obsolete

PART B- TO BE COMPLETED BY INVESTIGATOR

INSTRUCTIONS FOR ELEMENTS OF INFORMED CONSENT: (Provide a detailed explanation in accordance with Appendix C, AR 40-38 or AR 70-25).

DESCRIPTION OF STUDY: You are being asked to participate in a research project being conducted by the University of Alabama at Birmingham to asses the hearing sensitivity of about 500-7—Anniston Army Dept (ANAD) employees who were removed from the ANAD hearing conservation program in 195 and re-assigned in 2002. The assessment will determine if the employees were exposed to hazardous occupational and/or non-occupational noise during this time interval using the method outlined in ANSI S3.44. – *Determination of Noise Exposure and Estimation of Noise-Induced Hearing Impairment.* Information used in this study will include your prior audiograms and noise exposure data collected by the ANAD occupational health clinic, employee records indicating work area assignments during the study period, and completed by participants. The questionnaire is designed to provide information on employee noise history, medical history that is relevant to hearing sensitivity, and history of exposures to chemicals and the use of over-the-counter or prescription drugs that may affects hearing sensitivity and will require less than 30 minutes to complete. Questionnaire information will be used to determine if there may be other factors besides noise exposure that may have affected your hearing sensitivity.

ALTERNATE TREATMENT: There will be no treatment in this study. The only information provided by the participants will be from the employee hearing sensitivity questionnaire.

BENEFITS AND RISKS: There are no risks or discomforts associated with completing the questionnaire. This research will not involve any direct benefits to the participants. However, the results of this research may provide a better understanding between hearing loss and noise exposure on and off the job, and lead to more effective ways in which to develop and administer hearing conservation programs.

RIGHT TO ASK QUESTIONS AND/OR WITHDRAW FROM STUDY:
You may withdraw from this research at any time without prejudice by UAB or the ANAD. If you have any questions concerning this research, please contact the principal investigator, Dr. R. Kent Oestenstad, Department of Environmental Health Sciences, University of Alabama at Birmingham School of Public Health (205) 934-6208 or at oestek@uab.edu. If you wish to know more about your rights in regards to participation in this research, please contact Ms. Shelia Moore at (205) 934-3789 or 1-800822-8816 (press option #1 and ask for extension (4-3789) weekdays from 8:00 AM to 5:00 PM,

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Central Time. Should you have any questions you would like to discuss with someone other than the UAB research team or ANAD personnel, you may contact the Clinical Investigation Protocol Coordinator at (706) 787-4273. Your questions will be answered or you will be referred to an appropriate person.

STUDY RESULTS AND CONFIDENTIALITY:
The information collected during this study will be kept confidential to the extent permitted bylaw. Participants will be identified by a subject number; there will be no personal identifiers on any data form. However, the investigators and the UAB Institutional Review Board (IRB) will have access to the recorded information. By signing this document, you consent to such reviews. The information obtained may be published in scientific journals and presented at scientific meetings; however, your identity will not be revealed.

COMPENSATION FOR INJURY:
In the event of physical injury resulting from the investigational procedures, essential medical treatment (including hospitalization) is available. The extent of medical care provided should it become necessary, is limited and will be within the scope authorized for DOD health care beneficiaries. Necessary medical care does not include domiciliary care (home or nursing home).

PATIENT'S CONSENT
* IF THERE IS ANY PORTION OF THIS EXPLANATION THAT YOU DO NOT UNDERSTAND, ASK THE INVESTIGATOR BEFORE SIGNING.*

You are deciding whether or not to take part in this study. If you sign this form, it means you have decided to volunteer after reading and understanding all the information on the form.

I do____ do not_____ (check one and initial) consent to the inclusion of this form in my outpatient medical treatment record.

SIGNATURE OF VOLUNTEER DATE SIGNATURE OF LEGAL GUARDIAN (if you volunteer as a minor)

Permanent Address of Volunteer TYPED NAME OF WITNESS

TYPED NAME OF WITNESS DATE

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APPENDIX B

UAB CONSENT FORM

TITLE OF RESEARCH: Hearing sensitivity Among Anniston Army Depot Workers

INVESTIGATOR: R. Kent Oestenstad, PhD

SPONSOR: Anniston Army Depot

Explanation of Procedures

You are being asked to participate in a research project being conducted by the University of Alabama at Birmingham to asses the hearing sensitivity of about 500-700 Anniston Army Depot (ANAD) employees who were removed from the ANAD hearing conservation program in 1987 and reassigned to the program in 2001. The assessment will determine if these employees were exposed to hazardous occupational and/or occupational noise during this time interval. Information used in this study will include prior audiograms and noise exposure data collected by the ANAD health clinic, and employee records indicating work area assignments during the study period. As a participant you will be asked to complete a questionnaire designed to provide information on your noise exposure history, medical history that is relevant to hearing sensitivity, and a history of exposures to chemicals and the use of over-the-counter or prescription drugs that may affect hearing sensitivity. This information will be used to determine if there may be other factors besides noise exposure that may have affected your hearing sensitivity.

Risks and Discomforts

There are no risks or discomforts associated with completing the questionnaire used in this study.

Benefits

You may not personally benefit from participating in this research; however, the results of this research may provide a better understanding of the relationship between hearing loss and noise exposure on and off the job, and lead to more effective ways in which to develop and administer hearing conservation programs.

Participant Initials _____

Confidentiality

The information collected during this study will be kept confidential to the extent permitted by law. However, the investigators and the UAB Institutional Review Board (IRB) will have access to the recorded information. The results of this study may be published in the scientific literature, but your identity will not be revealed.

Withdraw Without Prejudice

You are free to withdraw consent and to discontinue participation in this project at any time without prejudice by UAB or ANAD.

Significant Findings

Any new findings that develop during this study which may affect your willingness to continue in the research will be discussed with you by Dr. Oestenstad.

Cost of Participation

There will be no cost to you to participate in this research.

Payment for Participation in the Research

No payment is offered for participation in this research.

Payment for Research Related Injuries

UAB has made no provision for monetary compensation in the event of injury resulting from your participation in the research.

Participant Initials _____

Questions

If you have any questions concerning this research please contact the principal investigator, Dr. R. Kent Oestenstad, Department of Environmental Health Sciences, University of Alabama at Birmingham School of Public Health (205) 934-6208. If you wish to know more about your rights in regards to participation in this research, please contact Ms. Shelia Moore, Director of the Institutional review Board. You may reach Ms. Moore at (205) 934-3789 or 1-800822-8816 (press option #1 and ask for extension (4-3789) weekdays from 8:00 AM to 5:00 PM, Central Time.

Legal Rights

You are not waiving your legal rights by signing this consent form.

Signatures

Your signature below indicates that you aggree to participate in this study. You will receive a copy of this informed consent form.

____

Signature of Participant or Legally Authorized Representative — Date

____

Signature of Investigator — Date

____

Signature of Witness — Date

____

Signature of person obtaining consent (if other than the investigator) — Date

Participant Initials _____

APPENDIX C

ANAD HEARING SENSITIVITY QUESTIONNAIRE

ANAD Hearing Sensitivity Questionnaire

Subject # _____

Military History

Circle yes or no to answer the following questions. If you answer yes to question, please briefly explain.

Have you served in the Military? Yes No If yes, how many years________

Were you exposed to weapons fire? Yes No If yes, briefly describe

____

____

Did you wear hearing protection while exposed to weapons fire? Please circle the most appropriate answer.

Never	Sometimes	Most of The time	Almost All of the Time	All of the Time

Were you exposed to other kinds of loud noise while in the military service? Yes No
If yes, please briefly explain____

____

Did you wear hearing protection while exposed to loud noises? Please circle the most appropriate answer.

Never	Sometimes	Most of The time	Almost All of the Time	All of the Time

Medical History

Circle yes or no to answer the following questions. If you answer yes to question, please briefly explain.

Does anyone in your immediate family (including yourself) have a hearing loss that they experienced in childhood or middle age? Yes No If yes, list all _________________

____

Have you ever had a surgical operation on either of your ears? Yes No If yes, what was (were) the operation(s) and when were they performed? ____________________

____

____

Medical History (Continued)

Have you ever experienced a traumatic injury to either one of your ears? Yes No If yes, explain: ____

____

Have you ever been hospitalized for a head injury? Yes No If yes, explain________

____

____

Have you ever been diagnosed with high blood pressure? Yes No If yes, when, and how long for?

____

Do you have diabetes? Yes No If yes, when were you diagnosed? _________________

Chemical Exposure History

During the time you worked at the Anniston Army Depot (ANAD), did you ever have a serious illness, which required powerful antibiotic or other medicine? Yes No If yes explain: ____

____

During the time you worked at the Anniston Army Depot (ANAD), did you ever receive treatment for cancer? Yes No If yes explain: ___________________________________

____

During the time you worked at the Anniston Army Depot (ANAD), did you work near, or were you ever around heavy metals (such as lead, arsenic, or mercury)? Yes No If yes explain: ____

____

____

During the time you worked at the Anniston Army Depot (ANAD), did you did you work near, or were you ever around solvents such as Toluene, Xylene, Styrene, Trichloroethylene, carbon disulfide, N-hexane, or ethanol? Yes No If yes, explain:

____

____

____

To your knowledge, during the time you worked at the Anniston Army Depot (ANAD), were you ever exposed to carbon monoxide? Yes No If yes explain: _______________

____

____

<u>Noise Exposure History</u>

While you have been employed at ANAD, have you ever been assigned to a work area that was classified as a high noise area? Yes No If yes, what area, and how long were you assigned there? ______________________________

If you worked in a high noise area, did you wear hearing protection? Yes No If yes, what type of hearing protection did you wear and about what percent of the time did you wear it? ______________________________

____

For each of the following questions, please circle the number which best describes the answer.

During the time you worked at the Anniston Army Depot (ANAD), did you ever drive or ride in powerboats, jet skis, loud watercraft or otherwise experience close-proximity exposure to noise from watercraft with powerful motors?

0	1	2	3	4	5
Never	Rarely 4-5 Times Year	Sometimes Once a Month	Regularly 2-3 Times a Month	Frequently 1-2 Times a Week	Almost Every Day

During the time you worked at the ANAD, did you drive racing cars or otherwise experience close proximity exposure to race car noise?

0	1	2	3	4	5
Never	Rarely 4-5 Times Year	Sometimes Once a Month	Regularly 2-3 Times a Month	Frequently 1-2 Times a Week	Almost Every Day

During the time you worked at the ANAD, did you ever drive, ride, ride on, or work close to motorcycles?

0	1	2	3	4	5
Never	Rarely 4-5 Times Year	Sometimes Once a Month	Regularly 2-3 Times a Month	Frequently 1-2 Times a Week	Almost Every Day

During the time you worked at the ANAD, did you ever drive or work with or close to heavy machinery such as tractors or heavy trucks?

0	1	2	3	4	5
Never	Rarely 4-5 Times Year	Sometimes Once a Month	Regularly 2-3 Times a Month	Frequently 1-2 Times a Week	Almost Every Day

During the time you worked at the ANAD, did you ever use or work close to yard maintenance equipment, such as lawnmowers, leaf blowers, grass trimmers, chain saws, or other devices?

0	1	2	3	4	5
Never	Rarely 4-5 Times Year	Sometimes Once a Month	Regularly 2-3 Times a Month	Frequently 1-2 Times a Week	Almost Every Day

During the time you worked at the ANAD, did you ever use or work close to carpentry tools or woodworking equipment such as hammers, saws, sanders, grinders, or other equipment?

0	1	2	3	4	5
Never	Rarely 4-5 Times Year	Sometimes Once a Month	Regularly 2-3 Times a Month	Frequently 1-2 Times a Week	Almost Every Day

During the time you worked at the ANAD, did you ever use or otherwise experience firearm use (such as hunting, competitive shooting, or target shooting)?

0	1	2	3	4	5
Never	Rarely 4-5 Times Year	Sometimes Once a Month	Regularly 2-3 Times a Month	Frequently 1-2 Times a Week	Almost Every Day

During the time you worked at the ANAD, did you ever use or otherwise experience loud music from a personal stereo listening device (such as a Walkman, boombox or car stereo)?

0	1	2	3	4	5
Never	Rarely 4-5 Times Year	Sometimes Once a Month	Regularly 2-3 Times a Month	Frequently 1-2 Times a Week	Almost Every Day

APPENDIX D

CODE SHEETS FOR ANAD HEARING SENSITIVITY QUESTIONNAIRE

Codes for Numeric Cells

Demographic Codes

Age=number

Gender:
1=male
2=female

Race:
1=White
2=Black
3=Other

Military History

1.1. Have you served in the military?
0=No
1=Yes

1.3. Were you exposed to weapons fire?
0=No
1=Yes

1.5. Did you wear hearing protection while exposed to weapons fire?
0=Never
1=Sometimes
2=Most of the time
3=Almost all the time
4=All the time

1.6. Were you exposed to other kinds of loud noise while in the military?
0=No
1=Yes

1.8. Did you wear hearing protection while exposed to loud noise?
0=Never
1=Sometimes
2=Most of the time
3=Almost all the time
4=All the time

Medical History

2.1. Does anyone in your immediate family (including yourself) have a hearing loss that they experienced in childhood or middle age?
0=No
1=Yes

2.3. Have you ever had a surgical operation on either of your ears?
0=No
1=Yes

2.5. Have you ever experienced a traumatic injury to either of your ears?
0=No
1=Yes

2.7. Have you ever been hospitalized for a head injury?
0=No
1=Yes

2.9 Have you ever been diagnosed with high blood pressure?
0=No
1=Yes

2.11. Do you have diabetes?
0=No
1=Yes

Chemical Exposure History

3.1. During the time you worked at the Anniston Army Depot (ANAD), did you ever have a serious illness, which required powerful antibiotics or other medications?
0=No
1=Yes

3.3. During the time you worked at the ANAD, did you receive treatment for cancer?
0=No
1=Yes

3.5. During the time you worked at the ANAD, did you work near, or were you ever around heavy metal (such as lead, arsenic, or mercury)?
0=No
1=Yes

3.7. During the time you worked at the ANAD, did you work near, or were you ever around solvents, such as Toluene, Xylene, Styrene, Trichloroethylene, Chlorobenzene, carbon disulfide, N-hexane, or Ethanol?

0=No
1=Yes

3.9. To your knowledge, during the time you worked at the ANAD, were you ever exposed to carbon monoxide?

0=No
1=Yes

Noise Exposure History

4.1. While you have been employed at the ANAD, have you ever been assigned to a work area that was classified as a high noise area?

0=No
1=Yes

4.3. If you worked in a high noise area, did you wear hearing protection?

0=No
1=Yes

4.5. What percentage of the time did you wear hearing protection?

0=Never
1=Sometimes
2=Most of the time
3=Almost all the time
4=All the time

Codes for Text Cells

Military History

1.2. Number of years in the military?

1.4. A brief description of the exposed weapons fire.

1.7. A brief description of exposure to other loud noise while in the military service.

Medical History

2.2. A list of immediate family (including yourself) who have a hearing loss that they experienced in childhood or middle age.

2.4. A brief description of the surgical operation (s) on either one of your ears and when it was performed.

2.6. Explanation of a traumatic injury to either one of your ears.

2.8. Explanation of any hospitalization for a head injury.

2.10. When and how long have you been diagnosed with high blood pressure?

2.12. When and how long have you been diagnosed with diabetes?

Chemical Exposure History

3.2. Explanation of a serious illness which required powerful antibiotics or other medicine while employed at ANAD.

3.4. Explanation of treatment of cancer while working at ANAD.

3.6. Explanation of ANAD work history near or around any heavy metals (lead, arsenic, mercury, or cadmium).

3.8. Explanation of ANAD work history near or around solvents, such as Toluene, Xylene, Styrene, Trichloroethylene, Chlorobenzene, carbon disulfide, N-hexane, or Ethanol?

3.10. Explanation of ANAD work history exposure to carbon monoxide.

Noise Exposure History

4.2. In what area and how long did you work in an area classified as high noise?

4.4 List the type of hearing protection devices used while in classified high noise area?

Codes for Questions

Other Questions

5. During the time you worked at the Anniston Army Depot (ANAD), did you ever drive or ride in powerboats, jet skis, loud watercraft or otherwise experience close-proximity exposure to noise from watercraft with powerful motors?

0=Never
1=Rarely 4-5 times a year
2=Sometimes once a month
3=Regularly 2-3 times a month
4=Frequently 1-2 times a week
5=Almost every day

6. During the time you worked at the ANAD, did you drive racing cars or otherwise experience close proximity exposure to race car noise?

0=Never
1=Rarely 4-5 times a year
2=Sometimes once a month
3=Regularly 2-3 times a month
4=Frequently 1-2 times a week
5=Almost every day

7. During the time you worked at the ANAD, did you ever drive, ride, ride on, or work close to motorcycles?

0=Never
1=Rarely 4-5 times a year
2=Sometimes once a month
3=Regularly 2-3 times a month
4=Frequently 1-2 times a week
5=Almost every day

8. During the time you worked at the ANAD, did you ever drive or work with or close to heavy machinery such as tractors or heavy trucks?

0=Never
1=Rarely 4-5 times a year
2=Sometimes once a month
3=Regularly 2-3 times a month
4=Frequently 1-2 times a week
5=Almost every day

9. During the time you worked at the ANAD, did you ever use or work close to yard maintenance equipment, such as lawnmowers, leaf blowers, grass trimmers, chain saws, or other devices?

0=Never
1=Rarely 4-5 times a year
2=Sometimes once a month
3=Regularly 2-3 times a month
4=Frequently 1-2 times a week
5=Almost every day

10. During the time you worked at the ANAD, did you ever use or work close to carpentry tools or woodworking equipment such as hammers, saws, sanders, grinders, or other equipment?

0=Never
1=Rarely 4-5 times a year
2=Sometimes once a month
3=Regularly 2-3 times a month
4=Frequently 1-2 times a week
5=Almost every day

11. During the time you worked at the ANAD, did you ever use or otherwise experience firearm use (such as hunting, competitive shooting, or target shooting)?

0=Never
1=Rarely 4-5 times a year
2=Sometimes once a month
3=Regularly 2-3 times a month
4=Frequently 1-2 times a week
5=Almost every day

12. During the time you worked at the ANAD, did you ever use or otherwise experience loud music from a personal stereo listening device (such as a Walkman, boombox or car stereo)?

0=Never
1=Rarely 4-5 times a year
2=Sometimes once a month
3=Regularly 2-3 times a month
4=Frequently 1-2 times a week
5=Almost every day

APPENDIX E

INSTITUTIONAL REVIEW BOARD FOR HUMAN USE APPROVAL FORM

12/20/'05

THE UNIVERSITY OF
ALABAMA AT BIRMINGHAM

Institutional Review Board for Human Use

Form 4: IRB Approval Form
Identification and Certification of Research
Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federalwide Assurance with the Office for Human Research Protections (OHRP). The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56 and ICH GCP Guidelines. The Assurance became effective on November 24, 2003 and expires on October 7, 2008. The Assurance number is FWA00005960.

Principal Investigator:	WRIGHT, KATRINA L
Co-Investigator(s):	
Protocol Number:	**X051216006**
Protocol Title:	*Contribution of Non-Occupational Exposure Factors and Non-Noise Occupational Exposure to Loss of Hearing Sensitivity Among Anniston Army Depot Workers*

The IRB reviewed and approved the above named project on 12-20-05. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.

IRB Approval Date: 12/20/05

Date IRB Approval Issued: 12-20-05

Marilyn Doss

Marilyn Doss, M.A.
Vice Chair of the Institutional Review
Board for Human Use (IRB)

Investigators please note:

The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.

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