

Worker Exposure to Noise During Computer Manufacturing: Measurement and Control

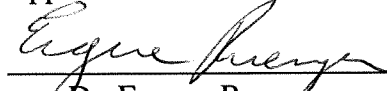
by

Jennifer Sheffer

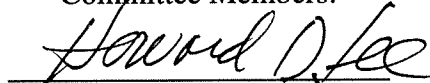
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ABSTRACT

The purpose of this study was to evaluate the effectiveness of fixed-point sound level monitors for controlling worker exposures to noise and to measure worker exposures to noise during the manufacture of supercomputers. Full-shift personal noise monitoring was conducted to measure the sound pressure levels experienced by the employees. The employees' exposures did not exceed the Occupational Health and Safety Administration permissible exposure limit for noise, 29 CFR 1910.95. There appeared to be little correlation between the sound pressure level measurements by dosimeters adjacent to the fixed-point sound level monitors and concurrent sound pressure level measurements by dosimeters on employees working in the bays where the fixed-point sound level monitors were located. There was no statistically significant difference between the time-weighted average sound pressure levels measured by the dosimeters adjacent to the fixed-point sound level monitors and the dosimeters on employees working in the bays where the fixed-point sound level monitors were located. The employees experienced numerous incidences of elevated sound pressure levels, >85 dBA, without the fixed-point sound level

monitors alarm lighting. The lack of alarm suggests that the fixed-point sound level monitors do not provide the level of protection desired by the company and may provide a false sense of security.

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TABLE OF CONTENTS

<u>Contents</u>	<u>Page</u>
Abstract.....	ii
Table of Contents.....	v
List of Tables	viii
List of Figures.....	ix
CHAPTER 1 INTRODUCTION	1
1.1 Introductory Remarks	1
1.2 Purpose of the Study	2
1.3 Research Objectives	2
1.4 Research Questions.....	3
1.5 Limitations.....	3
CHAPTER 2 LITERATURE REVIEW	4
2.1 Introduction	4
2.2 Properties of Sound	5
2.2.1 Physics of Sound	5
2.2.2 How Sound is Sensed	6
2.3 Occupational Noise Health Effects.....	7
2.3.1 Auditory Effects	7
2.3.1.1 Hearing Impairment.....	7
2.3.1.2 Noise Induced Hearing Loss.....	8
2.3.2 Non-auditory Effects	9
2.3.2.1 Cardiovascular Effects.....	9
2.3.2.1.1 Cardiovascular Effects in Animals	9
2.3.2.1.2 Cardiovascular Effects in Humans	10
2.3.2.2 Impaired Job Performance.....	11
2.4 Measurement of Noise	12
2.4.1 Decibels	12
2.4.2 Frequency Weighting Filters	12
2.4.3 Meters	13
2.4.3.1 Sound Level Meters.....	14
2.4.3.2 Noise Dosimeter	15

<u>Contents continued</u>	<u>Page</u>
2.5 Regulations and Recommended General Industry Standards.....	15
CHAPTER 3 METHODOLOGY	17
3.1 Subject Selection and Description.....	17
3.2 Noise Monitoring Procedures.....	18
3.2.1 Noise Measurement.....	19
3.2.2 Settings.....	19
3.2.2.1 Dosimeter.....	20
3.2.2.2 Fixed Point Sound Level Meter.....	20
3.3 Scope of Testing.....	21
CHAPTER 4 RESULTS AND DISCUSSION.....	22
4.1 Full Shift Personal Noise Exposures.....	22
4.2 A Comparison of Personal Exposures to Fixed Point Sound Pressure Level ...	24
Measurements	
4.2.1 A Comparison of Average Sound Pressure Levels.....	24
4.2.2 Evaluation of the Fixed Point Sound Level Meter to	26
85 dBA Warning Set Point	
4.2.3 Comparison of Personal Dosimeter to	27
Fixed Point Monitor Sound Pressure Level Measurements	
4.4 Estimation of Risk of Hearing Loss.....	28
CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS.....	30
5.1 Worker Exposures to Noise.....	30
5.2 Effectiveness of Fixed Point Sound Level Monitor	30
5.3 Opportunity for Research	31
BIBLIOGRAPHY	32
APPENDICES	42
Appendix A: Regulations, Guidelines, and Calculations.....	42
Appendix B: Correlation Graphs of Personal Dosimeters and	46
Fixed Point Area Monitors Dosimeters	
Appendix C: Comparison of Personal Dosimeter and.....	54
Fixed Point Area Monitor to 85 dBA Alarm Level	
Appendix D: Compared Sound Pressure Level Data.....	62

Contents continuedPage

Appendix E:	UW-Stout Protection of Human Subjects in Research Form	103
Appendix F:	American Industrial Hygiene Association Copyright Permission	104

LIST OF TABLES

<u>Table</u>		<u>Page</u>
Table 3.1	Identification of the dosimeters of the personnel who worked in the bays that have the fixed point area monitors	20
Table 4.1	Worker Full Shift Data Results	23
Table 4.2	Matched sets of average sound-pressure levels measured by personal dosimeters and fixed point monitors during the computer manufacturing	24
Table 4.3	Dosimeter mean paired students t-test results	25
Table 4.4	NIOSH Excess Risk of Developing Hearing Impairment	28
Table 4.5	Risk Assessment of worker personal dosimeter average SPL results	29

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
Figure 2.1 Cross-sectional view of the human ear	7
Figure 2.2 Fletcher Munson Equal Loudness Curve developed in 1933.....	13
Figure 3.1 Facility layout and noise monitoring locations	17
Figure 4.2 Exposure comparison with respect to programmed 85 dBA indication light	26
Figure 4.3 Correlation of personal dosimeter and fixed point sound level meter	27

Chapter 1

Introduction

1.1 Introductory Remarks

The loss of hearing can result in a reduced quality of life, impaired communication with others, a diminished ability to monitor the work environment, the loss of productivity and increased accidents resulting from impaired communication and isolation, and an increased expenditure related to worker's compensation claims (National Institute of Occupational Health [NIOSH], 1998). Occupational exposure to noise has been a major cause of hearing loss. In the United States, approximately 30 million workers are exposed to hazardous noise on the job.

Occupational Safety and Health Administration's (OSHA) general industry standard, 29 CFR 1910.95 (c)(2), requires the implementation of the Hearing Conservation Program when employee noise exposure exceeds an 8 hour time weighted average of 85 dBA and five dB exchange rate (U.S. DOL, 1983). Employees reduce their risk of hearing loss by decreasing exposure to noise through controls. The recommendation for engineering controls is to control the noise source, the noise transmission path, and noise at the worker level (Barrientos, Lendrum, & Steenland, 2004). Administrative controls provide reduced noise exposure by modifying worker behavior including time spent in noisy areas (Jensen, Jokel, & Miller, 1978).

The Midwest computer manufacturer participating in this study engineers custom computers for each client. In response to employee complaints about noise, the company installed area monitors to alert employees of high noise levels. The employees were required to wear personal hearing protection devices in areas when the fixed-point sound level monitor

indication light was illuminated. The effectiveness of the fixed-point sound level monitors to control worker noise exposure had not been evaluated.

Noise control options should be evaluated, at a minimum, based on their effectiveness (NIOSH, 1998). This study examined the effectiveness of the fixed-point sound level monitors for controlling high noise exposure incidences experienced by workers.

1.2 Purpose of the Study

The purpose of this study was to evaluate the effectiveness of fixed-point sound level monitors used to determine worker exposures to noise.

This study measured worker exposures to noise during the manufacture of supercomputers and evaluated the effectiveness of fixed-point sound level monitors for controlling worker exposures to noise.

1.3 Research Objectives

1. Determine the sound-pressure level exposures experienced by workers during the manufacture of supercomputers and
2. Compare the sound-pressure levels at the fixed-point sound level monitors to the employee exposures.

1.4 Research Questions

The questions to be answered by the research were:

1. Are workers manufacturing supercomputers exposed to noise levels that exceed current OSHA regulations?
2. Do the fixed-point sound level monitor alarms provide adequate warning of high noise level work activities?

1.5 Limitations

This study was limited to measurements during the first work shift at a single facility and meter placement as established by the company.

Chapter 2

Literature Review

2.1 Introduction

Hearing is important to the quality of one's life, particularly life as part of a community. Berger, Royster, LH, Royster, JD, Driscoll, and Layne (2003, Chapter 1) discussed how hearing is important for both social interactions and for worker performance. Ong (1982) compared primary oral cultures to cultures that include writing; he concluded that language is an oral phenomenon and that the ability to hear is important for full communication. Hearing is not simply a part of existence as the loss of hearing has been described as much worse than the loss of a leg.

The importance of hearing is often not recognized until it is lost. Gasaway (1985, Chapter 4), in a section on the under appreciation of hearing, presented an anecdote of parents who chose chemotherapy, with its side effect of hearing loss over amputation of a cancerous leg of their 9 year old daughter. One year later, the parents reported that they had made the incorrect choice. Helen Keller was often asked if it was worse to be blind or deaf. Her answer during an interview by Jean Christie (1955) was "after a lifetime in silence and darkness that to be deaf is a greater affliction than to be blind...Hearing is the soul of knowledge and information of a high order. To be cut off from hearing is to be isolated indeed" (p. 125).

NIOSH reported in 2001 that hearing loss was the second most self-reported occupational illness or injury. Since the beginning of the Industrial Revolution, there has been disagreement regarding compensation from hearing loss due to workplace exposure to noise (Driscoll, 1991). The first occupational hearing loss workers compensation claim record was in 1946 (Dembe,

1996). Nearly two decades later, during a span of 10 years in the late 1970's and early 1980's the reported occupational hearing loss worker compensation claims were an estimated \$835 million (Seidman, 1999). In industrialized countries, hearing loss from occupational noise is the biggest compensatable health hazard, costing an estimated two percent of gross domestic product (World Health Organization [WHO], 1997).

2.2 Properties of Sound

2.2.1 Physics of Sound

Sound is a form of mechanical energy and is a result of a vibration that creates a series of sound waves that travel outward in a medium (air, solid, or liquid) to a receiver (Johnson, Papadopoulos, Takala, Watfa, 2001; U.S. Department of Labor [DOL], 2008). The sound waves propagate longitudinally in all directions, in compressions and rarefactions through the medium causing pressure variations in the air, characterized by wavelength, frequency, and amplitude. Frequency and wavelength are inversely proportional linking the speed of sound with the direction and duration a sound wave travels (Berglund, Lindvall, Schuvela, 1999; Brownell, 1997; Cowan, 1994; Peterson, 1980, p. 14, 15; WHO, 1999).

A wavelength is the measure of the distance between two crests of the sound wave. The frequency, denoted by hertz, is the number of wave compression cycles in one second. The human ear has the ability to perceive frequencies between 20-20,000 hertz (Hz). The sensitivity of the human ear is greatest in frequencies associated with speech and communication, 50-5,000 Hz. (Berglund, Lindvall, Schuvela, 1999; Brownell, 1997; Malchaire, 2001; Peterson, 1980, p. 14, 15; WHO, 1999)

Amplitude is the degree of variation in the compression and rarefaction of pressure variations in the sound waves. The human ear is pressure sensitive, and perceives these pressure variations as loudness. The larger the sound wave, the greater the amplitude, and the louder the sound will be perceived. This is measured as sound pressure level (SPL) and expressed in decibels. (American Conference of Governmental Industrial Hygienists [ACGIH], 2006; Berglund, Lindvall, Schuvela, 1999; WHO, 2001; WHO, 1999)

The SPL is computed using the threshold of audibility at 1,000 Hz, 20 microPascals, as the reference pressure and is proportional to the square of the measured sound pressure (Berglund, Lindvall, Schuvela, 1999; WHO, 2001, WHO, 1999).

2.2.2 How Sound is Sensed

Sound is sensed in the human ear, which acts as a transducer or microphone. Sound waves are transformed by the ear into nerve impulses. The brain interprets the nerve impulses as sound (Alberti, 2001). The person determines the difference between sound and noise, with unwanted sound being noise (Johnson, et al., 2001; WHO, 1999, chapter 2).

The ear has three sections: the outer, middle and inner ear. Sound is collected in the outer ear by the pinna, which has a canal like shape. Separating the pinna from the middle ear is the tympanic membrane (Figure 2.1). The sound waves cause the tympanic membrane to vibrate. The vibrations are transferred to the oval window at the entrance to the inner ear by three connected bones, the malleus, incus, and stapes. (Alberti, 2001) The vibrations of the oval window cause pressure waves in the tunnel of the Corti. In the tunnel of the Corti, the fluid bends cilia and nerve impulses are carried by the auditory nerve to the brain. (Brownell, 1997)

Consequently, the sensation of hearing occurs; the brain interprets the analysis of noise conducted by the ear (Alberti, 2001).

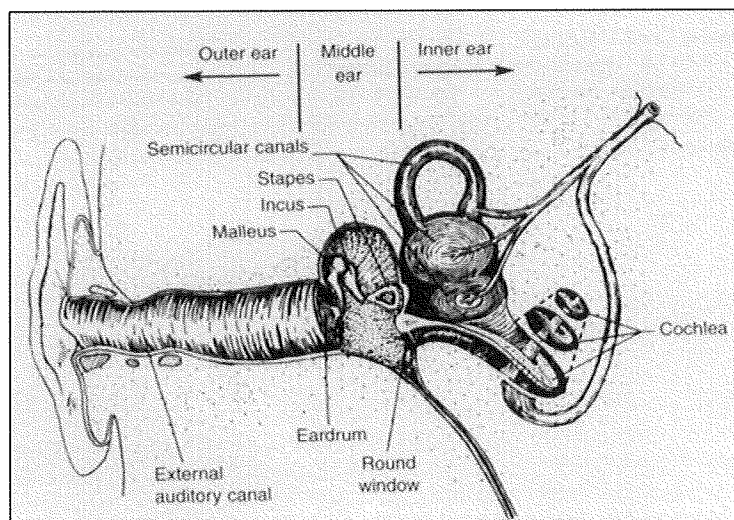


Figure 2.1. Cross-sectional view of the human ear. Adapted from *The Noise Manual* (p. 102), by LH Royster, JD Royster, Ward, 2003, Indiana: American Industrial Hygiene Association. Copyright 2008 by American Industrial Hygiene Association. Reprinted with permission.

2.3 Occupational Noise Health Effects

Exposure to noise can cause significant adverse health effects (WHO, 1997 and 2001).

Occupational exposure to can affect both auditory and non-auditory health effects (Barrientos, Lendrum, and Steenland, 2004; WHO, 2001).

2.3.1 Auditory Effects

2.3.1.1 Hearing Impairment

The World Health Organization (2005) estimated that 278 million people were hearing-impaired. Hearing impairment, the experience of partial or complete loss of hearing in one or both ears, may be attributed to exposure to chemicals that damage the organs of the ear,

(ACGIH, 2006), acquiring infectious diseases, sustaining head injury, age, or exposure to excessive noise (Fausti, Helt, Helt, Martin-Konrad, and Wilmington, 2005; WHO, 2006). Exposure to excessive noise coupled with other causes of hearing impairment can have a synergistic effect (Aguilar, Charlip, DeNino, Endicott, Hill, Mulrow, Rhodes, Tuley, Velez, 1990; Herbst, Humphrey, 1980; NIOSH, 1998; WHO, 2006). The World Health Organization (2006) groups hearing impairment in to either conductive or sensorineural hearing loss. Conductive hearing impairment is reversible, occurs in the outer and middle ear, whereas sensorineural hearing impairment is irreversible, and occurs in the inner ear. In the work place, workers exposed to noise exposures greater than 85 dBA have an eight percent risk of experiencing sensorineural hearing impairment. (NIOSH, 1998)

2.3.1.2 Noise Induced Hearing Loss

Noise Induced Hearing Loss (NIHL) is the most common form of hearing loss in industrialized countries (Rabinowitz, 2000; Seidmn, 1999 p.1). NIHL is a result of damage to the sensory hair cells in the cochlea (NIOSH, 1998, chap. 2, p. 11; National Institute on Deafness and Other Communication Disorders Fact Sheet Noise Induced Hearing Loss, 2007; Seidman, 1999). The likelihood of experiencing NIHL is affected by SPL, sound frequency, individual susceptibility, and duration (Johnson, et al., 2001).

An analogy used in the Australian government Occupational Noise Management publication by the Noise Management Committee of the Northern Territory (2003) describes similarity between carpet wear and damage to sensory hair cells in the cochlea. One may have noticed the manner in which new carpet springs back to the upright position when first walked upon and the difference following years of being walked upon in the same area resulting in loss

of spring. The carpet fibers are leveled and wear away. Similarly, when sound energy inflames the sensory hair cells, it is initially repaired. When the cell hairs are “leveled” due to an exposure to a loud noise for a short period, followed by a period of quiet time or rest, the hair cells “bounce back.” This describes a temporary shift in hearing. The repeated inflammation from exposure to excessive noise eventually damages and destroys the hair cells. When the hair cells do not recover, the result is a permanent threshold shift in hearing as quantified by a change in response to frequencies. Humans do not regenerate the hair cells, thus the damage is permanent. (Alberti, 2001; Lawrence, 1961)

2.3.2 Non-auditory Effects

The exposure to noise can lead to non-auditory effects. (Powazka, Pawlas, Zahorska-Markiewicz, Zejda, 2002). Among those non-auditory effects is cardiovascular and impaired job performance. There is inadequate data to establish risk criteria for non-auditory effects. (NIOSH, 1998)

2.3.2.1 Cardiovascular Effects

The effects of noise exposure on cardiovascular functions have been demonstrated experimentally in animals and epidemiologically in groups of workers.

2.3.2.1.1 Cardiovascular Effects in Animals

Exposure to noise increased blood pressure in rhesus monkeys by over 20 percent (Peterson, Augenstein, Janis, and Augenstein, 1983). The monkeys were exposed to six episodes of noise designed to mimic an industrial workday; 24-hour Leq exposures were 85 dBA with

peak sound pressure levels of 97 dBA each day for 9 months. The monkeys' blood pressures were highest during the daily noise exposure episodes. The blood pressures remained elevated during the balance of each day and during the entire 27-day non-exposure testing that followed the 9 months of exposure testing. The monkeys' auditory sensitivity as measured by click-evoked auditory brainstem responses was not affected by the 9 months of noise exposures.

Chen, Wu, and Yen (1992) exposed rats to noise greater than 100 dB to study its effects on blood pressure and vascular properties. Systolic blood pressure increased in rats periodically exposed to noise over a four-week period. The tissue lining the artery from the rats' exposure to the noise had enhanced vascular constriction and decreased vascular dilation caused by deterioration of the tissue's function.

2.3.2.1.2 Cardiovascular Effects in Humans

The cardiovascular effects of noise exposure in humans are generally evaluated through epidemiologic studies. Chan, Chang, Jain, Lin, and Su (2007) measured the arterial vascular properties of autoworkers during work and sleep periods. The workers with eight hour average noise exposure of 85 dBA had lower arterial elasticity and higher blood pressure than workers with workplace average noise exposure of 59 dBA.

Lusk, Hagerty, Gillespie, and Caruso (2002) conducted a retrospective study examining whether there was a correlation between workplace noise exposure and blood pressure for workers at an automobile plant. While there was no correlation between estimated noise exposure and blood pressure, workers using hearing protectors had significantly lower blood pressures than employees who had not worn hearing protection. This would suggest the area

noise measurements used to estimate exposures did not provide an accurate assessment of personal exposures.

The results of a cross-sectional study conducted by Powazka, Pawlas, Zahorska-Markiewicz, et al. (2002) had similar findings. Blood pressure, height, body weight, and hearing thresholds were measured in a group of workers, all under the age of 35, in a metallurgical plant. The researchers identified a positive association between noise exposure and blood pressure.

2.3.2.2 Impaired Job Performance

Work tasks exposing employees to high noise levels are generally different from work tasks with low noise exposures, which may make it difficult to compare accident frequency rates between the two exposure levels. Cohen (1973a) reported a 35 percent higher accident rate for workers exposed to greater than 95 dBA than a similar group, matched for age and work experience, exposed to less than 80 dBA. Van Charante and Mulder (1990) case-controlled study of 300 shipyard workers determined the risks attributable to noise exposure and hearing loss accounted to 43 percent of the injuries. Picard, et al. (2008) retrospective study of 52,982 workers exposed to noise levels greater than 80 dBA reported over 12 percent of the accidents were attributable to the combination of noise exposures greater than or equal to 90 dBA and noise-induced hearing loss.

Coehn (1973b) summarized experimental testing of the effects of noise on frequency of correct responses and changes in reaction times for performing a task. Coehn presented evidence that demonstrated noise exposure decreases the frequency of correct responses and increases the reaction time required for performing a task. Coehn also presented evidence indicating that

changes in noise level, both increases and decreases, increased the response time for performing a task.

2.4 Measurement of Noise

2.4.1 Decibels

Decibels, dB, are a dimensionless unit of measure of sound intensities that indicate loudness (Wolfe, 2005; Mosely and Stepkin, 1984; Rathy, 2006). Decibels are the logarithms of the ratio of the sound pressure to a reference pressure, 0.0002 mbar. Sound pressure level, SPL, is the decibel measurement used to evaluate exposure. $SPL = 20 \log (P/P_0)$ where P is the sound pressure in mbar and P_0 is the reference pressure, 0.0002 mbar.

Sound level meters and dosimeters assess sound intensity responding to sound pressure and measuring in decibels. Additionally, since the human ear does not respond equally to all frequencies, the meters use filters to approximate to the human ear response. (Malchaire, 2001; NIOSH, 1998)

2.4.2 Frequency Weighting Filters

Frequency weighted filters, A, B, C, or Z, combine the SPL of all sound frequencies into a single value. Filter scales compensate for frequency dependant variations in human ear sensitivity and increase or decrease each of the frequencies' measured sound pressure levels before combining them into a single value. (Hansen, 2001) The weighted scale representing frequency response to A, B, C, and Z weighting compares each in terms of frequency and relative response in decibels (Hansen, 2001; NIOSH, 1998).

The A weighted filter mimics the human ear response to sound waves of 40 phons equal perception (Figure 2.2) (U.S. DOL, 2009; WHO, 1999). The A weighted filter is used when determining worker exposure to noise as it better predicts the risk NIHL than the B, C, and Z scales (Earshen, 2003). The B weighted filter is used to approximate medium sound levels, 70 phons, and the C weighted filter is used to approximate the ear at high sound levels, 100 phons. The Z weighted filter adds all frequencies equally. (Earshen, 2003) The weighted filters used are expressed by dBA, dBB, dBC, or dBZ (Hansen, 2001). A meter's frequency weighting is generally set before conducting an exposure assessment (U.S DOL, 2009; Hansen, 2001).

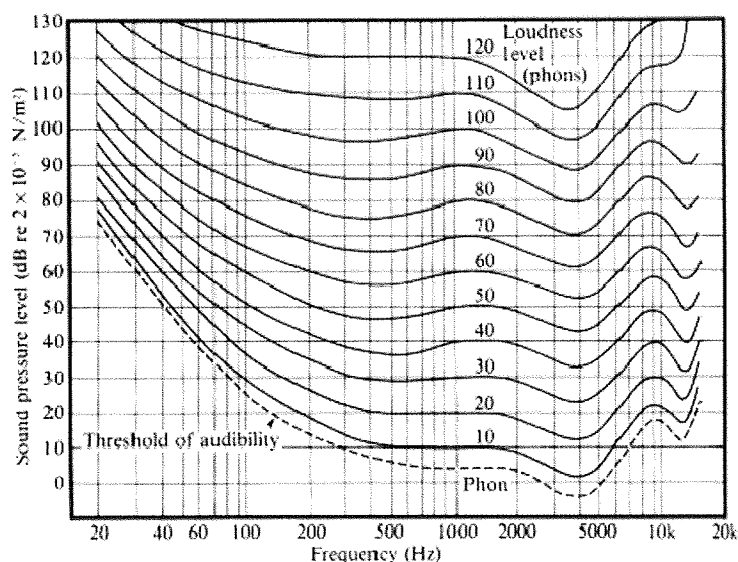


Figure 2.2. Fletcher Munson Equal Loudness Curve developed in 1933. The curve reflects the response of the human ear to sound comparing sound pressure levels to frequency. Adapted from “*Noise and Hearing Conservation, Appendix I:A. Physics of Sound,*” by Occupational Safety & Health Administration. (n.d.)
http://www.osha.gov/dts/osta/otm/noise/health_effects/physics.html

2.4.3 Meters

The type of meter and microphone used to measure sound is dependant on the purpose of the study, characteristics of sound, and other information requested (Arbey, Lester, Malchaire,

and Thiery, 2001; Malchaire, 2001). The objectives of the survey shall determine the type and strategy of the measurement (Arbey, et al., 2001).

2.4.3.1 Sound Level Meters

The Sound Level Meter (SLM) is direct reading instrument with a microphone, frequency selective amplifier and readout and is generally used to provide immediate readings of noise levels (Malchaire, 2001; NIOSH, 1998). SLMs are generally handheld or tripod mounted portable meters. They are used for area measurements, typically for the design of engineering controls. Current SLMs log the data as well as providing direct read out of SPL values. The range of frequencies measured and the precision of measurement distinguish the SLM type.

The International Electrotechnical Commission (IEC) 60651 delineates four types of SLM, 0, 1, 2, and 3. Type 0 SLM are generally used as a laboratory reference standards. They have precision requirements of less than 1 dB and after have microphones that measure into the ultrasonic range. Type 1 SLMs are used for research or precise field measurements. They have 1 dB precision requirements and use microphones that can measure high frequencies. Type 2 SLMs are for general field assessments. They have 2 dB precision requirements and have microphones that cut off at 10 kHz. Type 3 SLMs are for field noise survey assessments. (Malchaire, 2001; U.S. DOL, 2009) OSHA recommends, at a minimum, a Type 2 SLM for the purpose of identifying and evaluating individual noise sources, understanding feasibility for engineering controls, determining employee noise dose, and to spot-check noise dosimeter performance (U. S. DOL, 2009).

2.4.3.2 Noise Dosimeter

The noise dosimeter is the equipment preferred to measure worker exposure to noise (Malchaire, 2001; NIOSH, 1998). The noise dosimeter is generally worn on the belt of the participant with the attached microphone located on the employee's shoulder (NIOSH, 1998; U.S. DOL, 2009). The noise dosimeter measures and records the SPL values and automatically computes the employee's exposure dose for the criterion levels set in the meter (NIOSH, 1998). The noise dosimeter is essentially the equivalent of a Type 2 SLM with a DC output signal that allows for dose calculations dependent on the duration of measurement (Malchaire, 2001; NIOSH, 1998; U.S. DOL, 2009).

2.5 Regulations and Recommended General Industry Standards

The OSHA General Industry standard for occupational noise exposure, 29 CFR 1910.05 (1983), establishes an 8-hour TWA permissible exposure limit (PEL) of 90 dBA using a 5 dB exchange rate. Exposures at 90 dBA were estimated by Gilbert, Prince, Smith, and Stayner (1997) to provide a 25 percent increased risk for hearing loss of 25 dB at 1 Hz, 2 Hz, 3 Hz, and 4 Hz.

ACGIH and NOISH have recommended using an 8-hour TWA exposure limit of 85 dBA using a 3 dB exchange rate. Gilbert et al. (1997) estimated that using the 85 dBA would reduce the risk of NIHL to eight percent.

Petrack et al. (1996) compared employee exposure measurements using the OSHA criteria, 90 dBA 8-hour TWA, 5 dB exchange rate, and 80 dBA threshold, to the ACGIH recommended criteria, 85 dBA 8-hour TWA, 3 dB exchange rate, and 80 dBA threshold. The study measured the exposure of 50 workers in seven job categories. Two dosimeters were used

for each evaluation. Each employee had one dosimeter set with the OSHA criteria and a second dosimeter set with the ACGIH criteria.

The striking feature of the study was a demonstration of how the OSHA criteria algorithm used to calculate dose and TWA underestimates the actual exposure when there is variability in the noise level. The TWA calculated using the OSHA algorithm was from 0.2 dBA to 12.6 dBA less than the adjacent dosimeter's TWA calculated using the ACGIH criteria (ACGIH, 2006; NIOSH, 1998; U.S. DOL, 2009). This suggests that workers are exposed to higher noise levels than reported using the OSHA criteria and thus have higher risk of NIHL than would be predicted from the reported exposure levels.

Chapter 3

Methodology

3.1 Subject Selection and Description

This study measured full shift worker exposure to noise and evaluated the effectiveness of area monitors for controlling worker exposures during the manufacture of supercomputers. The subjects performed tasks in the bays in which the supercomputers are manufactured and the fixed-point sound level monitors were located. The bays are separate rooms with individual doors for entry in a common hall. The tasks included intermittent use of handheld power tools to assemble and repair computer parts as well as working the majority of the work shift at stationary desktop computers troubleshooting the custom made computers. Three workers were selected each day to participate in the study. Each wore a noise dosimeter for the duration of his/her work shift. The noise dosimeter microphones were affixed to the shoulder of each employee and the dosimeters were kept in their vest pockets.

The microphone of a noise dosimeter was placed next to the fixed-point sound level monitor microphone in Bay 3 and Bay 6 (Figure 3.1). The times the employees were working in the same area of the fixed-point sound level monitors were observed and recorded. More time working in Bay 3 in comparison to Bay 6 was observed due to the computer being in early production stages.

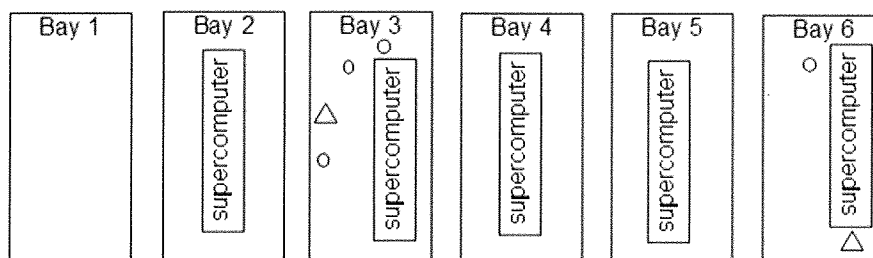


Figure 3.1. Facility layout and noise monitoring locations. The triangles represent the location of the fixed-point sound level monitors. The circles represent the location of the employee.

3.2 Noise Monitoring Procedures

The data collected was obtained June 13, 16, 18, and 19, 2008. The noise dosimeters measuring employee exposures and those positioned adjacent to the fixed-point sound level monitors measured and logged the one-minute average sound pressure levels. The noise was measured based on the OSHA Hearing Conservation criteria which uses a 5 dB exchange rate, a slow response, a 80 dBA threshold and criterion level of 90 dBA (29 CFR 1910.95). The noise dosimeters were calibrated before and after each use to ensure their accuracy. Noise dosimeters are calibrated by inserting their microphone into a precision sound level calibrator. Prior to sampling the noise dosimeter was adjusted to match the sound pressure level output of the calibrator. After each use measuring and recording the output of the calibrator verified the accuracy of each noise dosimeter. All post sample calibration values were within one decibel of the calibrator's output value.

3.2.1 Noise Measurement

The noise dosimeters were worn each work shift by the employees. The noise dosimeters placed on the fixed-point sound level meters remained stationary for the duration of the work shift. At the completion of the work shift the noise dosimeters were collected, post calibrated, and the data recorded.

3.2.2 Settings

Measurements were made using the OSHA criteria, A-scale, 90 dBA criterion, 80 dBA threshold, and 5 dB exchange rate.

Dose: The amount of actual exposure relative to the amount of allowable exposure, and for which 100 percent and above represents exposures that are hazardous. The noise dose is calculated according to the following formula:

$$D = [C_1/T_1 + C_2/T_2 + \dots + C_n/T_n] \times 100 (\%)$$

Where:

C_n = total time of exposure at a specified noise sound pressure level

T_n = exposure time at which noise for this SPL becomes hazardous

Exchange rate: An increment of decibels that requires the halving of exposure time, T_n , or a decrement of decibels that requires the doubling of exposure time. The OSHA criterion has an allowed exposure time of 8-hours at 90 dBA. OSHA uses a 5-dB exchange rate so the allowed exposure time at 95 dBA is 4 hours and at 85 dBA it is 16 hours. The exchange rate affects the dose, average SPL values, and TWA

3.2.2.1 Dosimeter

The Larson Davis Model 703 noise dosimeter and Larson Davis Model 706 noise dosimeter were used in the measurement of noise exposure. The Larson Davis Model 706 has the ability to be programmed without a computer, and the Larson Davis Model 703 does not have this function. Both the Larson Davis Model 703 and Larson Davis Model 706 have the capability to measure and record average SPL at specified time intervals and calculate dose and time-weighted average. (<http://www.larsondavis.com/Dosimeters.htm>)

3.2.2.2 Fixed-point Sound Level Meter

The fixed-point sound level meters are Extech SL130s. The SL130 meters are programmed to alert employees via a flashing red light whenever the sound exceeds 85 dBA. The alarm light is designed to be visible up to 30 feet away.

3.3 Scope of Testing

Seven full-shift sets of noise exposure data were collected see Table 3.1. The three employees participating in this study performed different tasks in different bays. Portions of the employees' workdays were spent in the rooms outfitted with fixed-point sound level meters.

Table 3.1

Identification of the dosimeters of the personnel who worked in the bays that have the fixed-point area monitors

Date	Fixed Point Area Monitor Dosimeter Number	Personal Dosimeter Number
June 13, 2008	21209	21207, 21210
June 16, 2008	21208	21207, 21209, 21210
June 18, 2008	17623	21208
June 19, 2008	21210	21208

Chapter 4

Results and Discussion

4.1 Full Shift Personal Noise Exposures

Data was collected on June 13, 16, 18, and 19, 2008 during the first work shifts at Company XYZ using Larson Davis dosimeters Models 703 and 706. The data collected represent the exposure to noise experienced by the worker wearing the personal noise dosimeter and the exposure to noise experienced by the fixed-point sound level meter in the same work bay.

The first work shift at the company historically has the greatest number of workers and work tasks performed. The fixed-point sound level meters were located in bays 3 and 6 during the time of the study. Hearing protection, anti-static shoes, and anti-static smocks were worn by all employees monitored.

Full shift personal sound-pressure level exposures were logged each day in one-minute intervals see Appendix D. None of the employees' exposures exceeded the acceptable dose permissible exposure limit (PEL) for OSHA's (1983) Hearing Conservation Criterion, dose ≥ 0.5 , or Engineering Criteria, dose ≥ 1.0 see Table 4.1.

Table 4.1

Worker Full Shift Data Results

Date	Dosimeter Number	Time (minutes)	Hearing Conservation TWA	Hearing Conservation Dose ¹	Engineering Dose ²
6-13-08	21207	562	79	0.24	-
6-16-08	21207	541	80	0.28	0.002
6-18-08	21207	554	81	0.34	0.05
6-19-08	21207	563	82	0.37	0.05
6-18-08	21208	550	78	0.22	-
6-19-08	21208	563	78	0.22	0.01
6-16-08	21209	543	82	0.38	0.08
6-18-08	21209	539	78	0.20	-
6-13-08	21210	552	83	0.44	0.07
6-16-08	21210	543	80	0.28	0.02

1. OSHA Hearing Conservation Permissible Exposure Limit, Dose > 0.5 , calculated using 80 dBA threshold, 5 dB exchange rate, 90 dBA shown criterion SPL values

2. OSHA Engineering Permissible Exposure Limits, Dose > 1.0 , calculated using 90 dBA threshold, 5 dB exchange rate, 90 dBA shown criterion SPL values

4.2 A Comparison of Personal Exposures to Fixed- Point Sound Pressure Level Measurements

4.2.1 A Comparison of Average Sound Pressure Levels

The paired students t-Test was used to compare the SPL measurements at the fixed-point noise monitors to the personal exposures. The paired students t-Test is appropriate to use when assessing whether the means of two related groups are statistically different from each other. The match sets of SPL measurements include only the times when employees were working in areas with the fixed-point monitors. (Table 4.2) The duration of time spent in the same work area was determined through observations and worker interviews.

Table 4.2

Matched sets of average sound-pressure levels measured by personal dosimeters and fixed-point monitors during the computer manufacturing

Date	Fixed-Point Dosimeter Number	Fixed-Point SPL Average (dBA)	Personal Dosimeter Number	Personal SPL Average (dBA)	Duration in the Same Work Area
June 13, 2008	21209	86	21207	79	249 min
	21209	86	21210	79	202 min
June 16, 2008	21208	80	21207	81	107 min
	21208	80	21209	85	76 min
	21208	80	21210	82	61 min
June 18, 2008	17623	82	21208	79	62 min
June 19, 2008	21210	77	21208	77	121 min

A comparison of the average sound pressure levels measured by noise dosimeters adjacent to fixed point sound level meters to the average sound pressure levels measured by personal noise dosimeters (Table 4.2) did not demonstrate a statistically significant difference, $p \geq 0.05$ see Table 4.3.

Table 4.3

Dosimeter mean paired students t-test results

	Personal Dosimeter Results	Fixed Point Dosimeter Results
Count	7	7
Mean	80.396	81.867
Variance	6.149	10.981
Standard Deviation	2.480	3.314
Standard Error	0.937	1.252
Mean Difference		-1.471
Degrees of Freedom		6
t Value		-0.882
t Probability		0.412
Correlation		-0.143
Correlation Probability		0.759

4.2.2 Evaluation of the Fixed-Point Sound Level Meter to 85 dBA Warning Set Point

One of the functions of the fixed-point noise monitors is to alert the employees of high noise levels. The monitor was set to a flash red light whenever the SPL exceeded 85 dBA. The seven sets of matched SPL were evaluated to determine if employees experienced SPL greater than 85 dBA without a concurrent alarm by the fixed-point monitor. (Appendix B) Four of the seven data sets had times when the employees were exposed to noise greater than 85 dBA, while the warning light was off. (Figure 4.2)

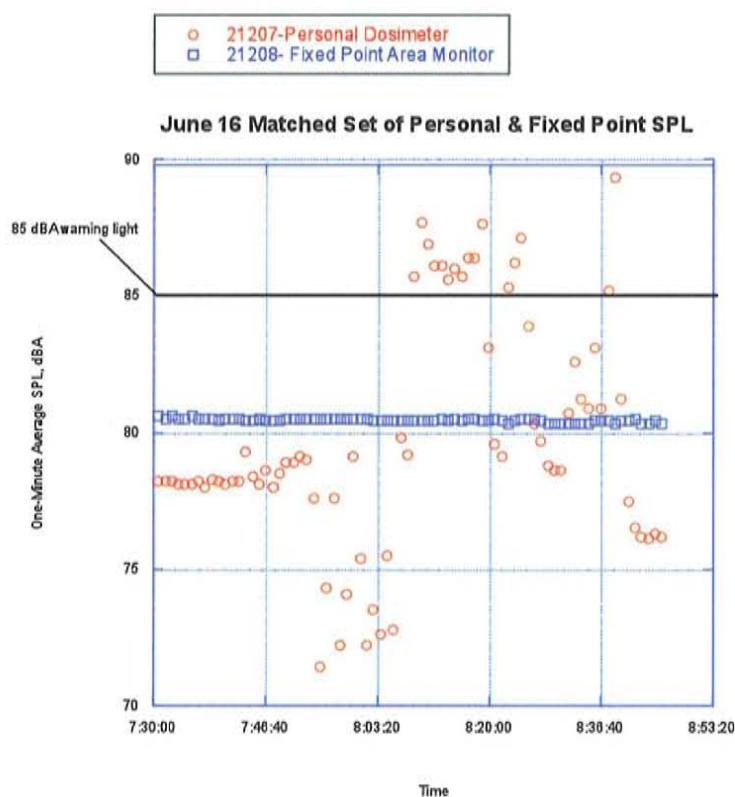


Figure 4.2. Exposure comparison with respect to programmed 85 dBA indication light

4.2.3 Comparison of Personal Dosimeter to Fixed-Point Monitor SPL Measurements

There appears to be little correlation (strong correlation meaning an R value closest to one) between the SPL measurements by the personal dosimeters and the fixed point SPL measurements (Appendix C). The SPL values for the fixed- point monitors were quite consistent during five of the seven periodic, 80 dBA, plus or minus 5 dB, while personal exposures varied. (Figure 4.3)

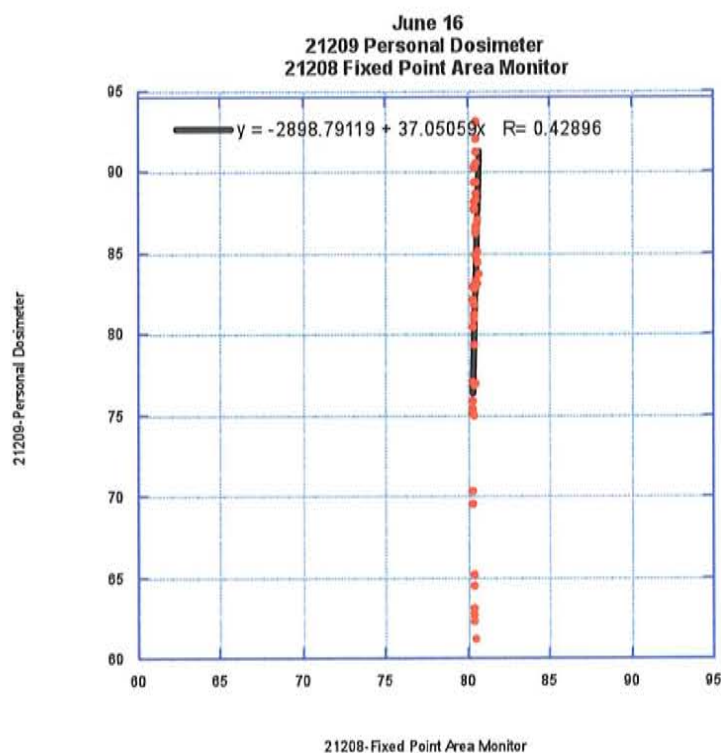


Figure 4.3. Correlation of personal dosimeter and fixed-point sound level meter

4.4 Estimation of Risk of Hearing Loss

Gilbert et al. (1997) presented an update of a model for estimating risk of developing hearing impairment due to workplace noise exposure. The model estimates that daily exposure to 85 dBA would cause additional eight percent of the workers to develop a material hearing loss (Table 4.4). Based on that model, the risks for material hearing loss for the exposures measured in this study (Table 4.5) would be expected to be substantially less than eight percent.

Table 4.4

NIOSH Excess Risk of Developing Hearing Impairment

Average daily noise exposure (dBA)	percent excess risk
90	25
85	8
80	1

Table 4.5

Risk assessment of worker personal dosimeter average SPL results

Date	Dosimeter Number	Time (minutes)	Hearing Conservation TWA
6-13-09	21207	562	79
6-16-09	21207	541	80
6-18-09	21207	554	81
6-19-09	21207	563	82
6-18-09	21208	550	78
6-19-09	21208	563	78
6-16-09	21209	543	82
6-18-09	21209	539	78
6-13-09	21210	552	83
6-16-09	21210	543	80

Chapter 5

Conclusions and Recommendations

This study measured worker exposures to noise during the manufacture of supercomputers and evaluated the effectiveness of fixed-point sound level monitors for controlling worker exposures to noise.

5.1 Worker Exposures to Noise

All of the worker noise exposures were less than regulatory limits (29 CFR 1910.95). The noise exposures measured in this study indicated risk for material hearing loss was less than eight percent.

5.2 Effectiveness of Fixed-point Sound Level Meters

There was not a statistically significant difference between the average sound pressure levels measured by dosimeters adjacent to the fixed-point sound level meters and the average sound pressure levels measured by dosimeters on the workers.

Four of the seven data sets had times when employees were exposed to noise greater than 85 dBA while the warning light remained off. There were no times when the warning lights were on while employees had no exposure to high noise levels.

Hazard alerting systems monitor conditions and issue warnings to employees when unsafe conditions occur. The Company relied on the fixed-point sound level meters to alert workers of noise levels that could cause hearing loss. This study demonstrated that the fixed-point system did not provide an effective warning for high noise exposure incidences

experienced by workers. Their use presents a false sense of security of protection from exposures to high noise levels.

Alarm systems must be functional when installed and used in accordance to the manufacturer's directions. Alerting systems that do not account for sources, layouts, and operators are unlikely to provide reliable warnings.

Use of the system tested would need testing under a wide variety of conditions to determine its reliability. This research demonstrated the fixed-point sound level meter failed to provide warning during several conditions. Discontinuation of its use is recommended.

5.3 Opportunity for Research

- A. Workplace exposures generally have lognormal distributions (Buringh and Lanting, 1991). Measure the exposure of employees during 2nd and 3rd work shifts to determine the shift-to-shift variance at this workplace.
- B. Evaluate the degree of compliance with the company policy that requires employees wear hearing protection when the fixed-point monitor alarms.
- C. Measure the sound pressure levels of the third-octave frequency bands and assist in the design of noise reduction systems.

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Appendix A: Regulations, Guidelines and Calculations

Table A-1: OSHA PELs for Noise

Table A-2: OSHA Allowable Exposure Times

Table A-3: Noise Dosimeter Parameters using OSHA Guidelines

Table A-1 OSHA PELs for noise (U.S. DOL, 2009)

Duration in hours per day	Sound level in dBA slow response
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

Table A-2 OSHA allowable exposure times (U.S. DOL, 2007)

A-weighted Sound Pressure Level	Reference Duration
80	32
81	27.9
82	24.3
83	21.1
84	18.4
85	16
86	13.9
87	12.1
88	10.6
89	9.2
90	8
91	7
92	6.1
93	5.3
94	4.6
95	4

Table A-3 Noise dosimeter parameters using OSHA guidelines (U.S. DOL, 2008)

Category	Setting
Response	Slow
Frequency Weighting	A
Threshold	80 dB
Exchange Rate	5 dB
Criterion Level	90 dBA

Appendix B: Correlation Graphs of Personal Dosimeters and Fixed-Point Area Monitor

Dosimeters

Figure B-1: Correlation of 21207 and 21209, June 13, 2008	47
Figure B-1: Correlation of 21210 and 21209, June 13, 2008	48
Figure B-3: Correlation of 21210 and 21208, June 16, 2008	49
Figure B-4: Correlation of 21207 and 21208, June 16, 2008	50
Figure B-5: Correlation of 21209 and 21208, June 16, 2008	51
Figure B-6: Correlation of 21208 and 17623, June 18, 2008	52
Figure B-7: Correlation of 21208 and 21210, June 19, 2008	53

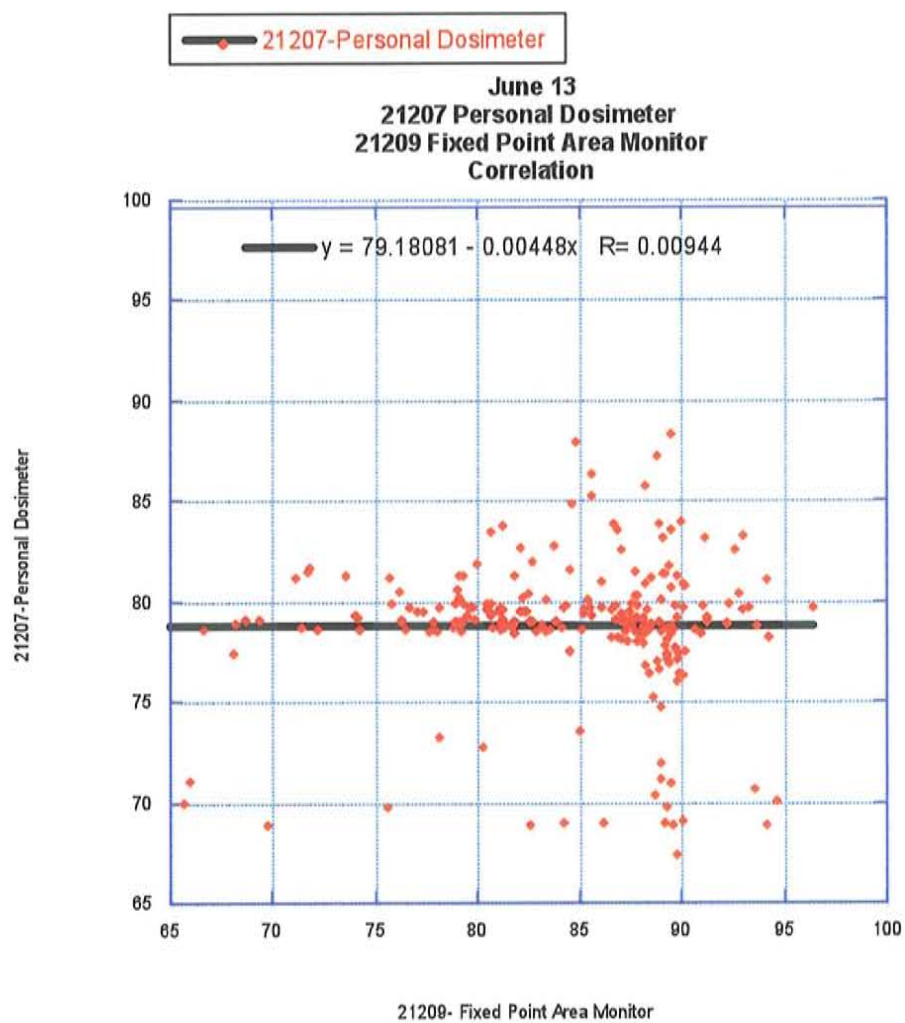


Figure B-1 Correlation of 21207 and 21209, June 13, 2008

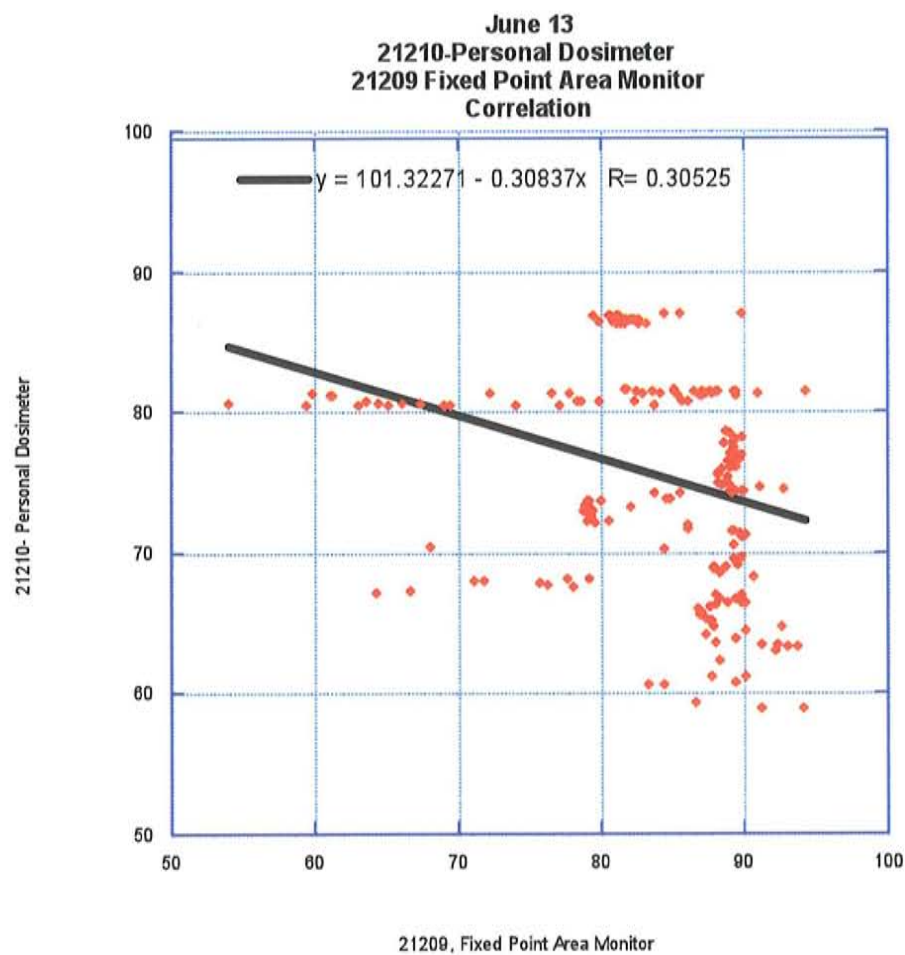


Figure B-2 Correlation of 21210 and 21209, June 13, 2008

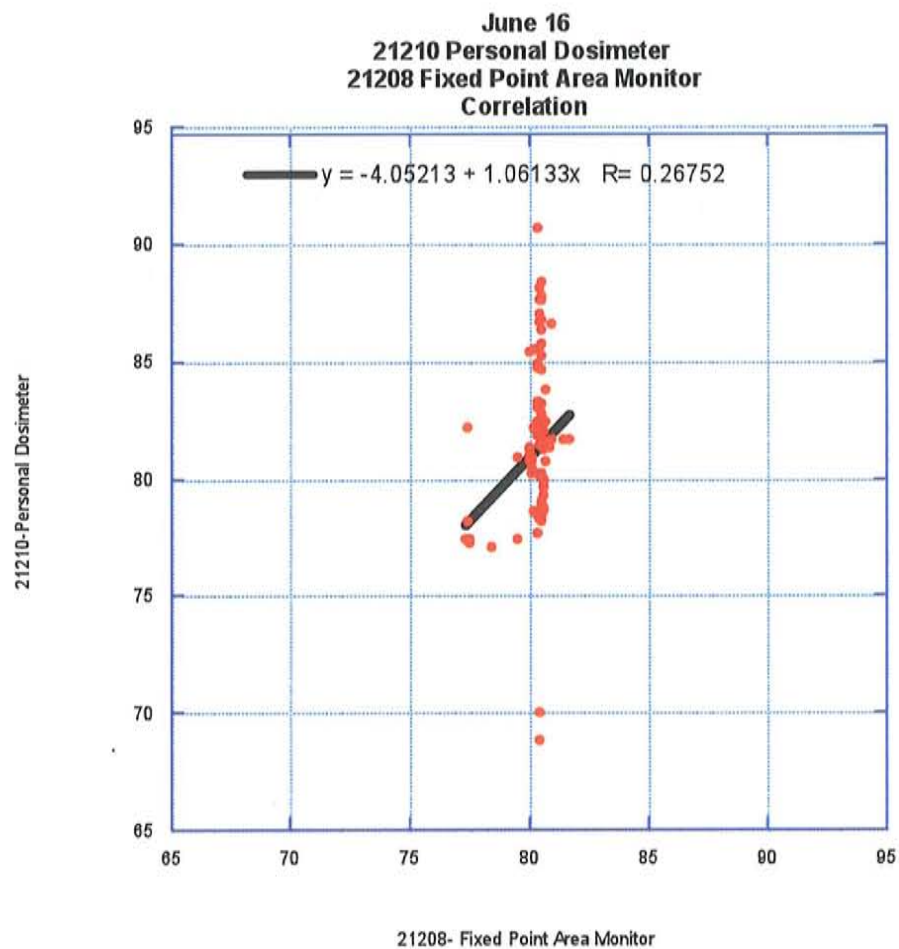


Figure B-3 Correlation of 21210 and 21208, June 16, 2008

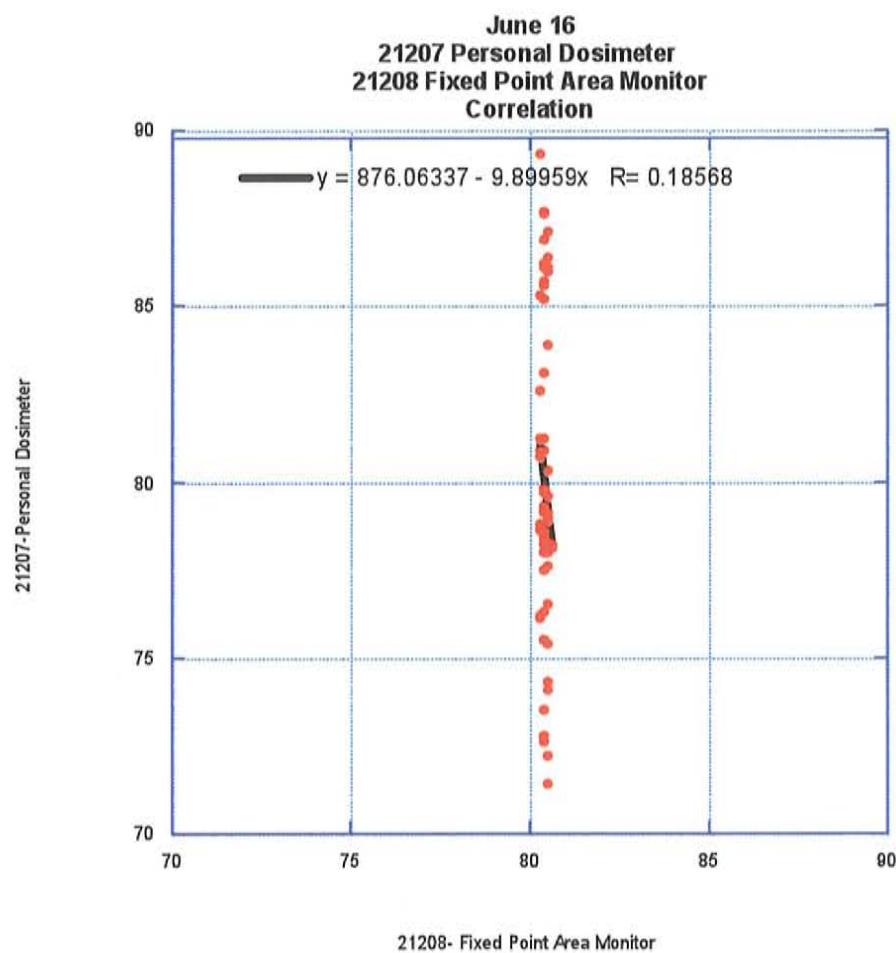


Figure B-4 Correlation of 21207 and 21208, June 16, 2008

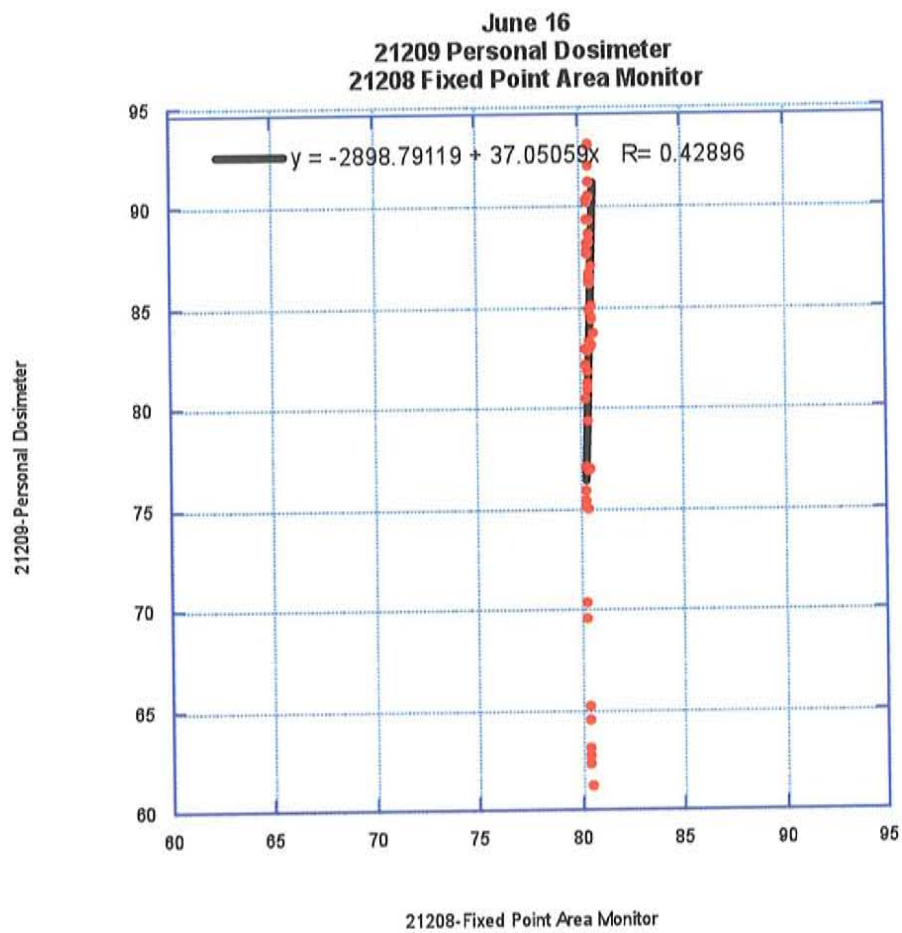
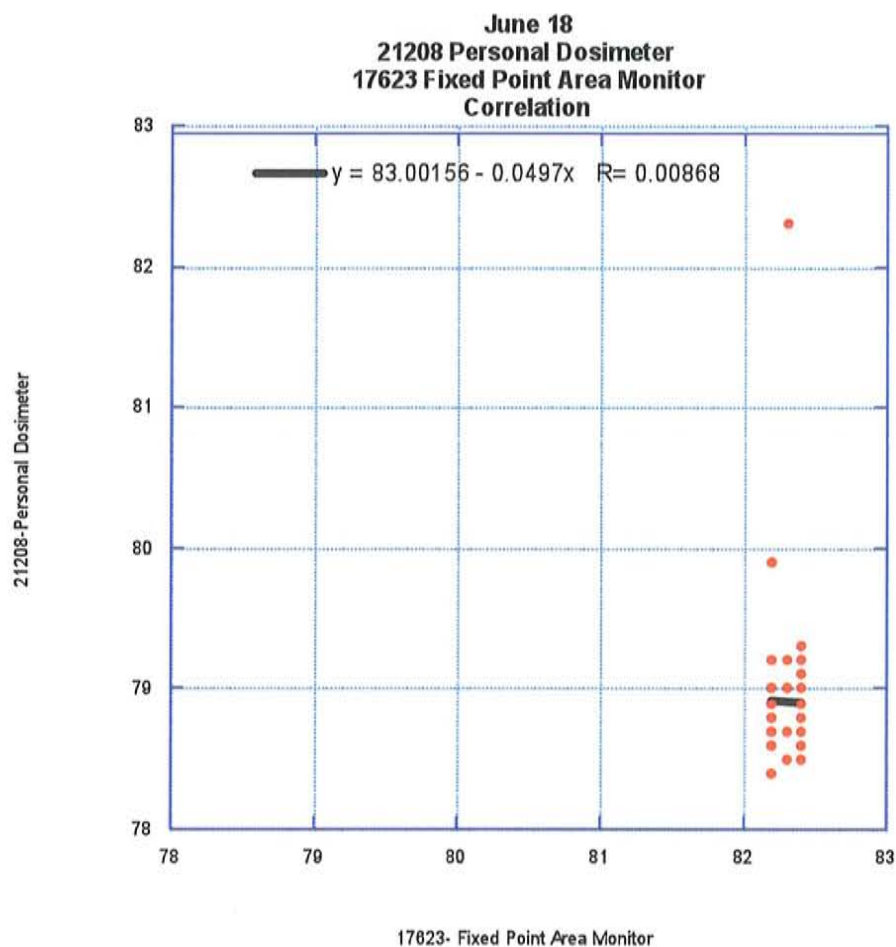


Figure B-5 Correlation of 21209 and 21208, June 16, 2008



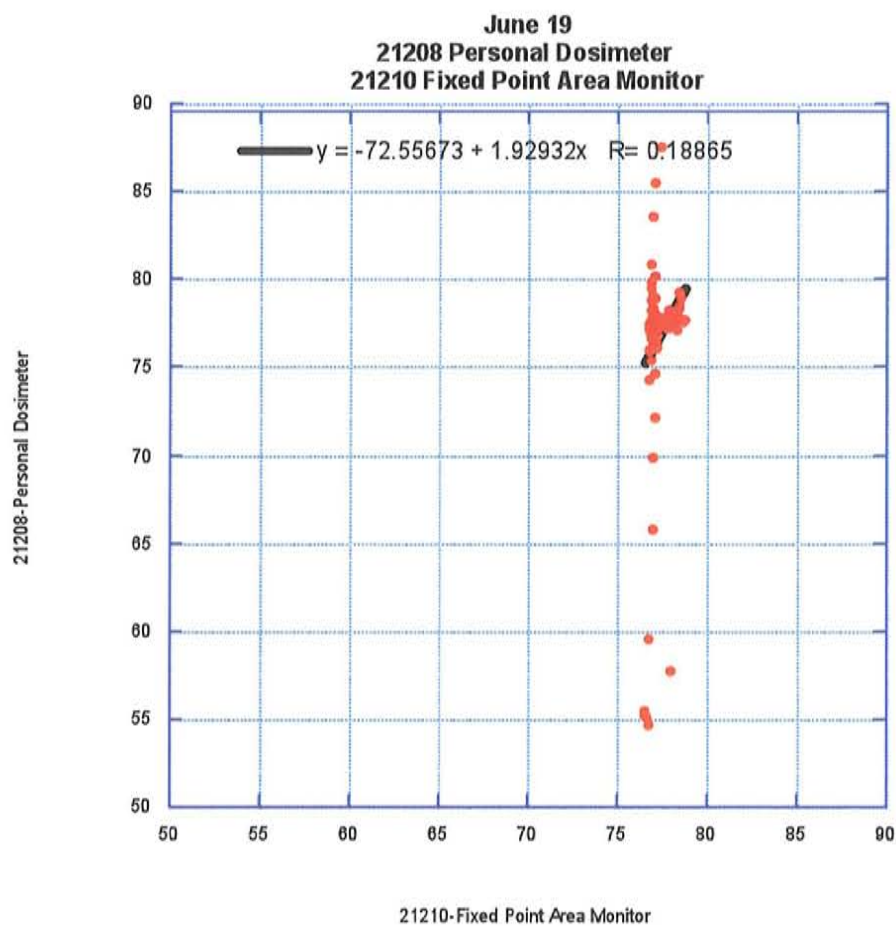


Figure B-7 Correlation of 21208 and 21210, June 19, 2008

Appendix C: Comparison of Personal Dosimeter and Fixed Point Area Monitor to 85 dBA alarm
level

Figure C-1: Comparison of 21207, 21209 on June 13, 2008	55
Figure C-2: Comparison of 21210, 21209 on June 16, 2008	56
Figure C-3: Comparison of 21210, 21208 on June 16, 2008	57
Figure C-4: Comparison of 21207, 21208 on June 16, 2008	58
Figure C-5: Comparison of 21209, 21208 on June 16, 2008	59
Figure C-6: Comparison of 21208, 17623 on June 18, 2008	60
Figure C-7: Comparison of 21208, 21210 on June 19, 2008	61

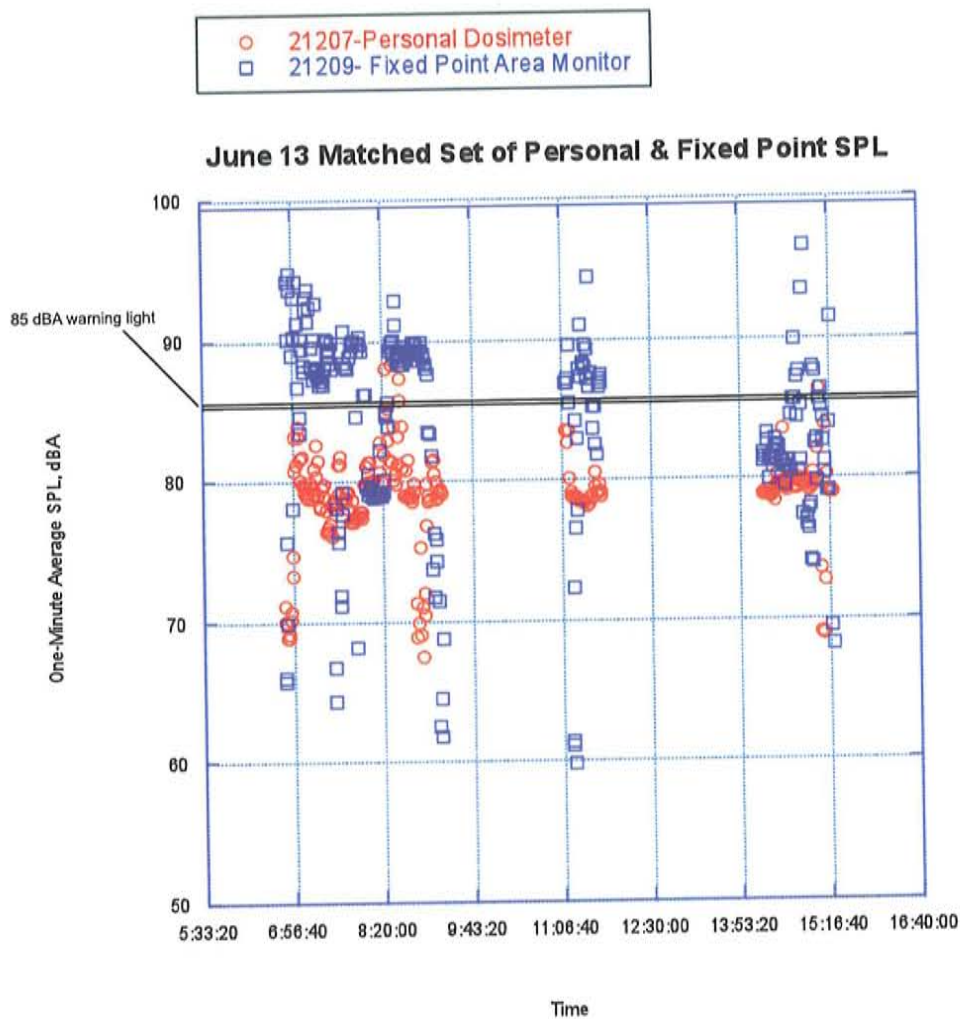


Figure C-1 Comparison of 21207, 21209 on June 13, 2009

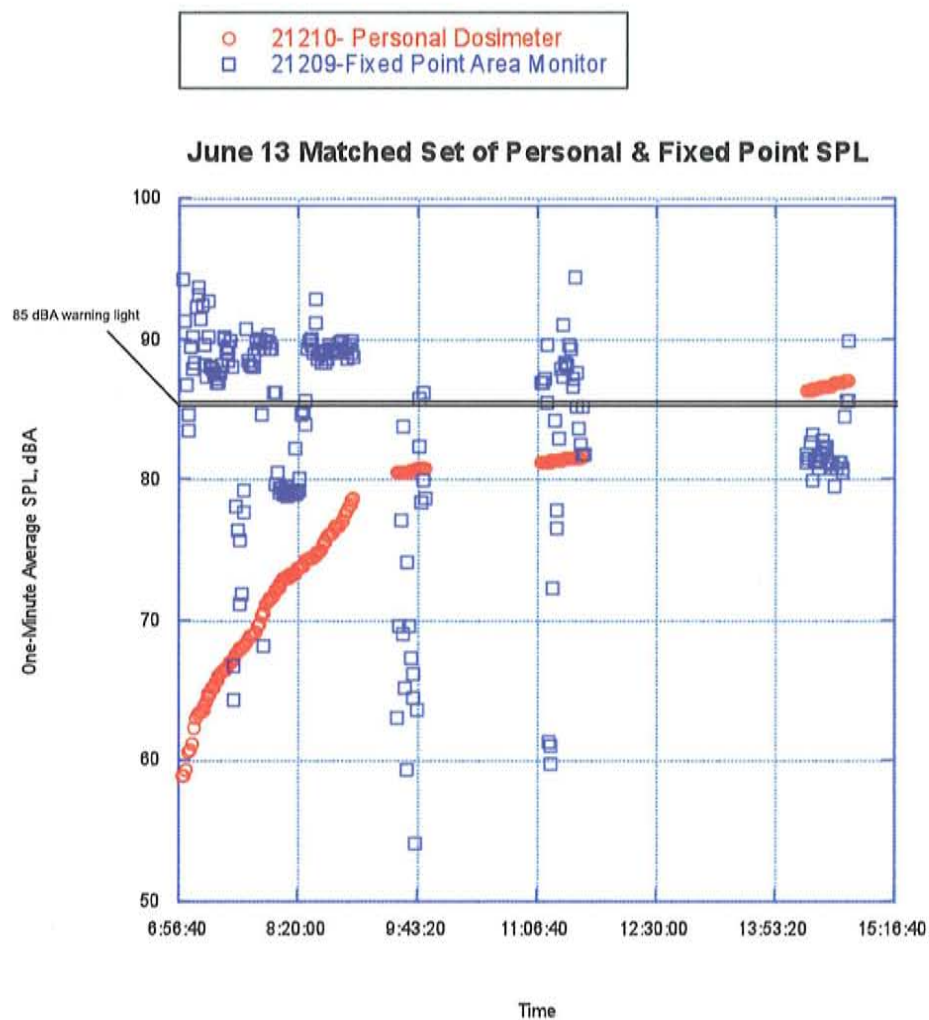


Figure C-2 Comparison of 21210, 21209 on June 13, 2009

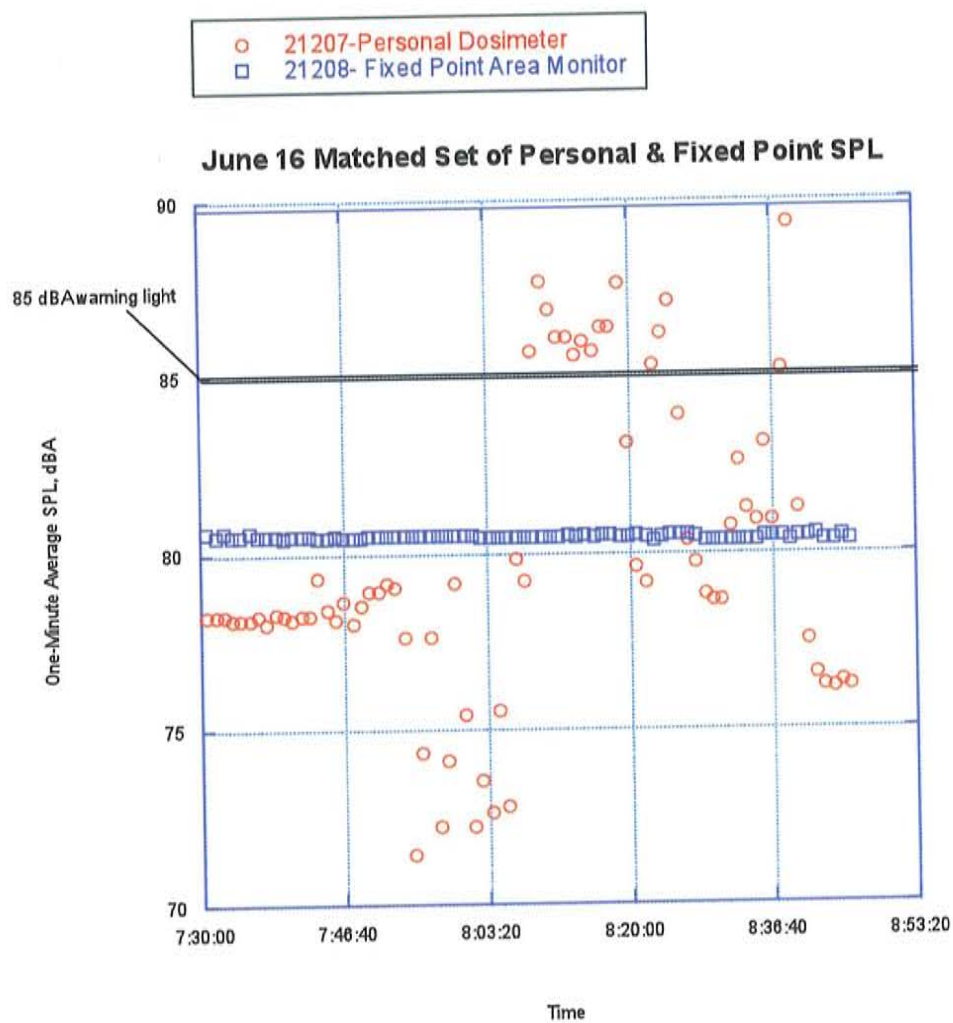


Figure C-3 Comparison of 21207, 21208 on June 16, 2008

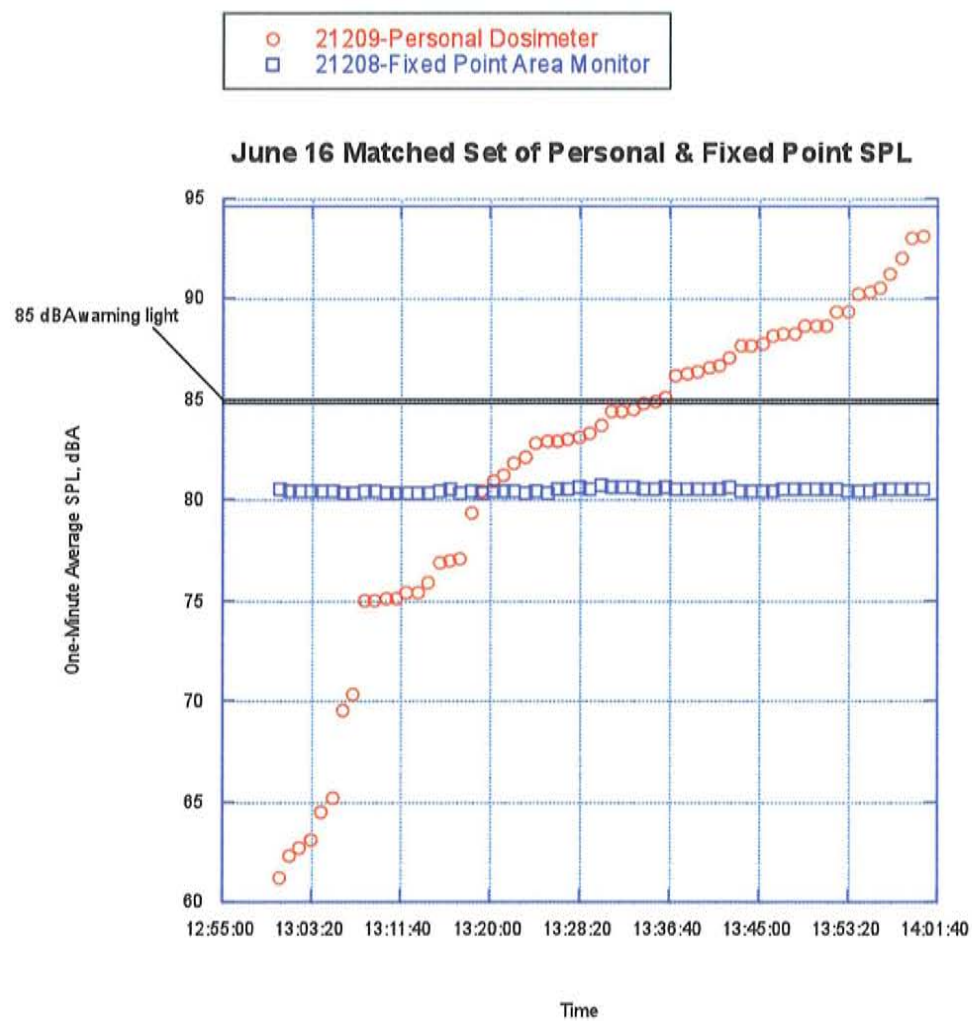


Figure C-4 Comparison of 21209, 21208 on June 16, 2008

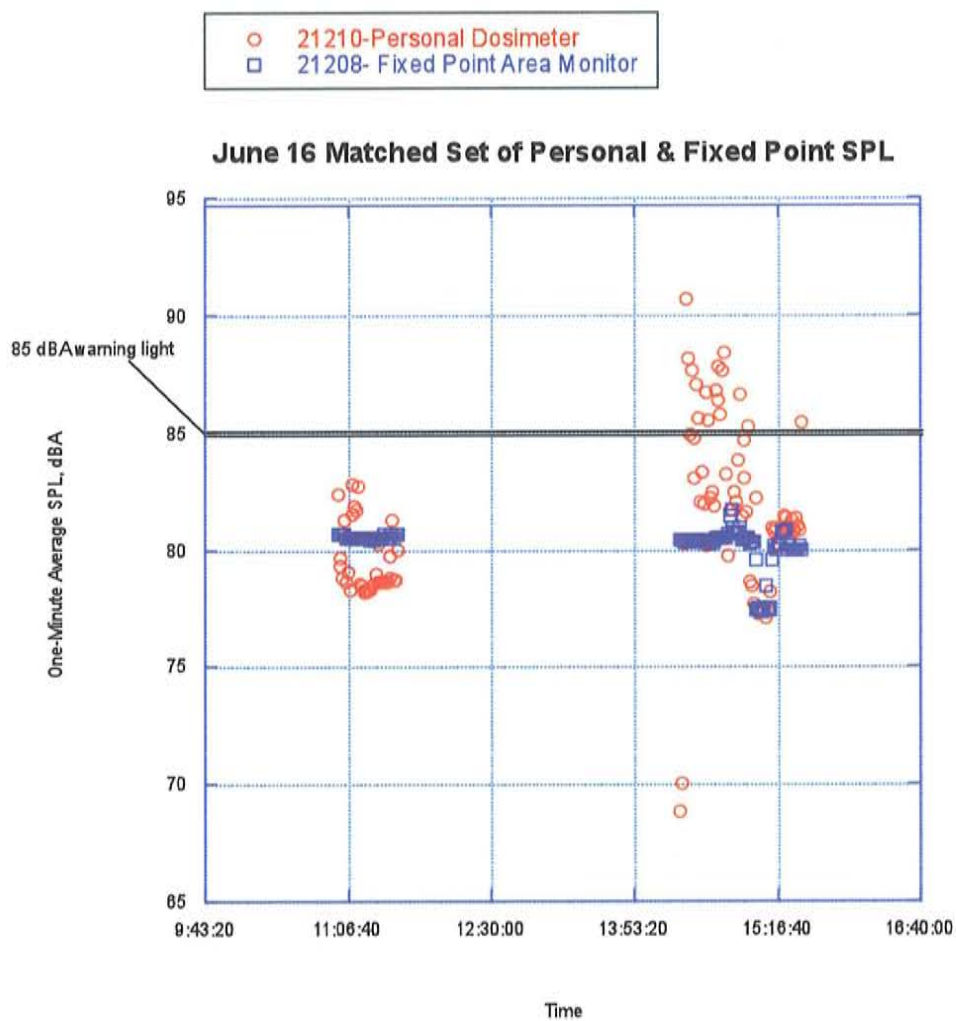


Figure C-5 Comparison of 21210, 21208 on June 16, 2008

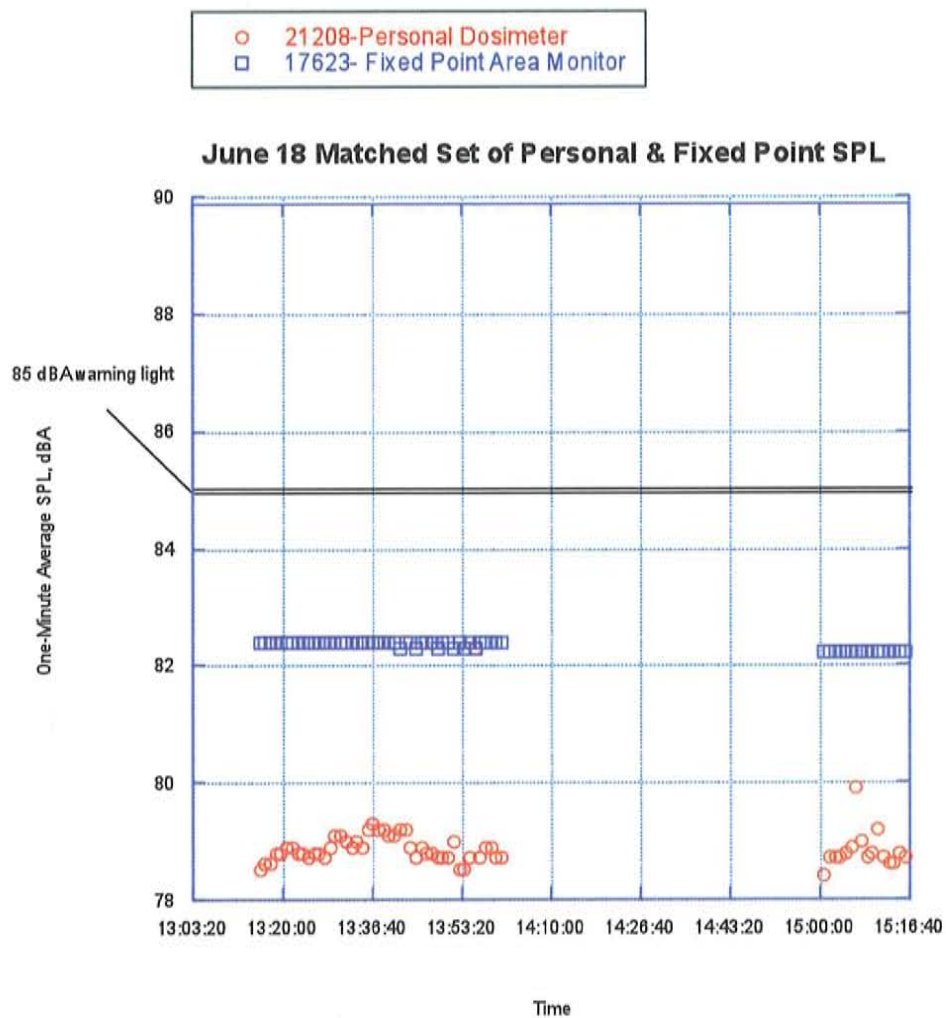


Figure C-6 Comparison of 21208, 17623 on June 18, 2009

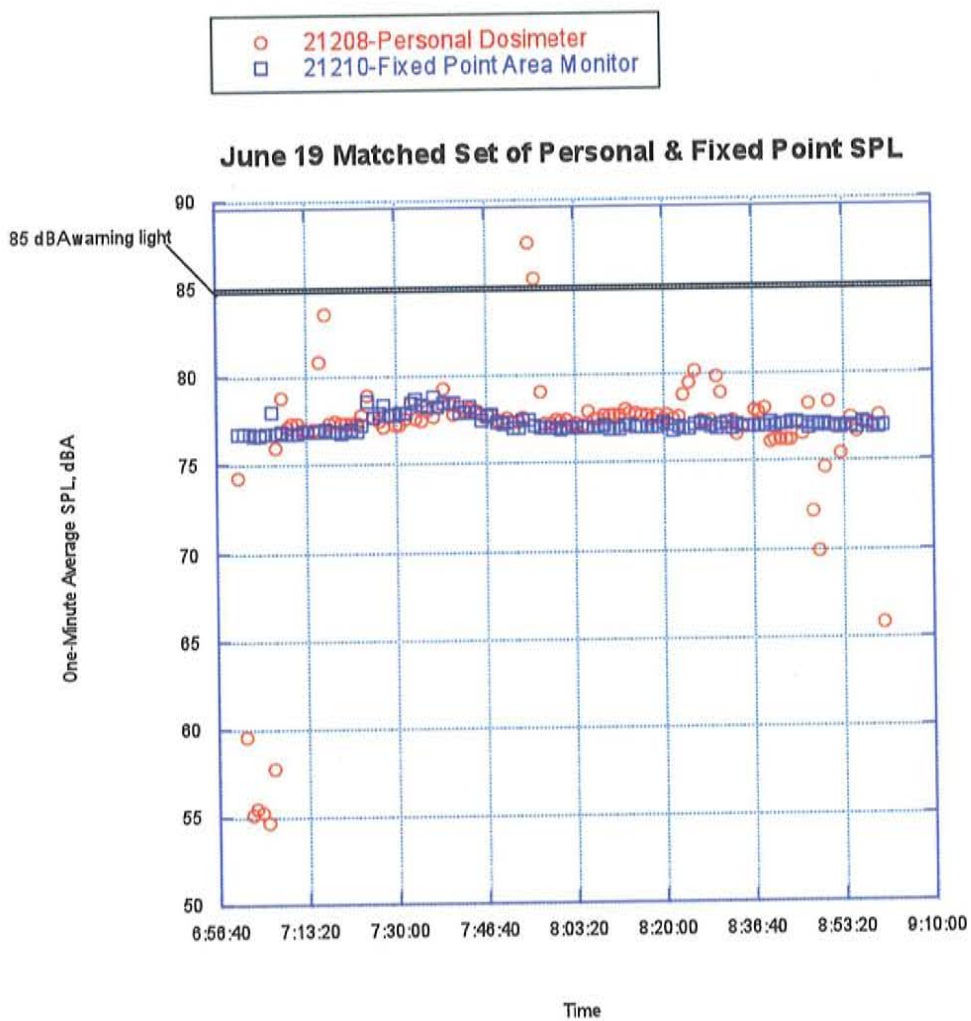


Figure C-7 Comparison of 21208, 21210 on June 19, 2009

Appendix D: Compared SPL data

 June 13, 2008

Worker		Fixed Point Sound Level Meter	
21207 Time	21207 SPL	21209 Time	21209 SPL
6:48:28	70	6:48:37	65.7
6:49:28	71.1	6:49:37	66
6:50:28	69.8	6:50:37	75.6
6:51:28	68.9	6:51:37	69.8
6:52:28	69.1	6:52:37	90.1
6:53:28	68.9	6:53:37	94.2
6:54:28	70.1	6:54:37	94.7
6:55:28	70.7	6:55:37	93.6
6:56:28	74.7	6:56:37	89
6:57:28	73.2	6:57:37	78.1
6:58:28	80.8	6:58:37	90.2
6:59:28	83.2	6:59:37	93
7:00:28	81.1	7:00:37	94.2
7:01:28	83.1	7:01:37	91.2
7:02:28	83.8	7:02:37	86.7
7:03:28	80.1	7:03:37	83.4
7:04:28	81.6	7:04:37	84.5
7:05:28	81.8	7:05:37	89.4
7:06:28	79.7	7:06:37	90.1
7:07:28	79.2	7:07:37	87.8

7:08:28	79.6	7:08:37	88.3
7:09:28	78.9	7:09:37	92.2
7:10:28	79.6	7:10:37	93
7:11:28	78.8	7:11:37	93.7
7:12:28	79.2	7:12:37	91.3
7:13:28	79.9	7:13:37	92.3
7:14:28	78.8	7:14:37	88.1
7:15:28	78.8	7:15:37	89.5
7:16:28	79.1	7:16:37	87.3
7:17:28	80.9	7:17:37	90.1
7:18:28	82.6	7:18:37	92.6
7:19:28	80.3	7:19:37	87.9
7:20:28	81.5	7:20:37	87.8
7:21:28	79.1	7:21:37	87.6
7:22:28	78	7:22:37	87.4
7:23:28	78.2	7:23:37	86.9
7:24:28	79.4	7:24:37	87.1
7:25:28	79.8	7:25:37	86.8
7:26:28	78.9	7:26:37	87.6
7:27:28	77.9	7:27:37	88.1
7:28:28	76.3	7:28:37	90.1
7:29:28	76.4	7:29:37	89.9
7:30:28	76.6	7:30:37	88.9

7:31:28	76.9	7:31:37	89.4
7:32:28	76.4	7:32:37	88.4
7:33:28	76	7:33:37	89.8
7:34:28	78.3	7:34:37	88
7:35:28	78	7:35:37	64.3
7:36:28	78.6	7:36:37	66.7
7:37:28	78.5	7:37:37	78
7:38:28	79	7:38:37	76.3
7:39:28	81.2	7:39:37	75.7
7:40:28	81.2	7:40:37	71.1
7:41:28	81.7	7:41:37	71.8
7:42:28	78.5	7:42:37	79.2
7:43:28	78.5	7:43:37	77.6
7:44:28	78.6	7:44:37	90.7
7:45:28	78.6	7:45:37	88.4
7:46:28	78.7	7:46:37	88.1
7:47:28	79.2	7:47:37	88.1
7:48:28	79.2	7:48:37	87.9
7:49:28	78	7:49:37	87.9
7:50:28	77	7:50:37	88.8
7:51:28	78.6	7:51:37	89.6
7:52:28	77.1	7:52:37	89.3
7:53:28	77.1	7:53:37	89.8

7:54:28	77.4	7:54:37	89.9
7:55:28	77.5	7:55:37	84.5
7:56:28	77.4	7:56:37	68.1
7:57:28	77.4	7:57:37	89.3
7:58:28	77.5	7:58:37	89.8
7:59:28	77.5	7:59:37	90.2
8:00:28	77.7	8:00:37	89.7
8:01:28	77.8	8:01:37	89.2
8:02:28	77.3	8:02:37	89.3
8:03:28	79.7	8:03:37	86.1
8:04:28	81	8:04:37	86.1
8:05:28	79.7	8:05:37	79.6
8:06:28	79.9	8:06:37	80.5
8:07:28	81.3	8:07:37	79.1
8:08:28	79.9	8:08:37	79.3
8:09:28	81.3	8:09:37	79.3
8:10:28	79	8:10:37	78.9
8:11:28	79.3	8:11:37	79.5
8:12:28	80.1	8:12:37	79.1
8:13:28	78.7	8:13:37	78.8
8:14:28	79	8:14:37	79.2
8:15:28	78.9	8:15:37	79.2
8:16:28	78.8	8:16:37	78.9

8:17:28	80.6	8:17:37	79
8:18:28	82.7	8:18:37	82.1
8:19:28	79.9	8:19:37	78.9
8:20:28	78.9	8:20:37	79
8:21:28	79	8:21:37	79.2
8:22:28	81.9	8:22:37	80
8:23:28	84.8	8:23:37	84.6
8:24:28	87.9	8:24:37	84.8
8:25:28	85.2	8:25:37	85.6
8:26:28	82.8	8:26:37	83.8
8:27:28	81.4	8:27:37	89.2
8:28:28	81.3	8:28:37	89.8
8:29:28	88.3	8:29:37	89.5
8:30:28	83.9	8:30:37	90
8:31:28	80.1	8:31:37	89
8:32:28	80.4	8:32:37	92.8
8:33:28	79.8	8:33:37	91.1
8:34:28	81.2	8:34:37	88.5
8:35:28	83.1	8:35:37	89.1
8:36:28	85.7	8:36:37	88.2
8:37:28	87.2	8:37:37	88.8
8:38:28	83.8	8:38:37	88.9
8:39:28	80.9	8:39:37	88.2

8:40:28	78.9	8:40:37	88.2
8:41:28	78.9	8:41:37	88.5
8:42:28	80.7	8:42:37	89.5
8:43:28	81.4	8:43:37	89.1
8:44:28	78.7	8:44:37	89.2
8:45:28	78.7	8:45:37	89.2
8:46:28	79	8:46:37	88.9
8:47:28	78.7	8:47:37	89.3
8:48:28	78.5	8:48:37	89
8:49:28	79.8	8:49:37	89.7
8:50:28	79.2	8:50:37	89.8
8:51:28	68.9	8:51:37	89.6
8:52:28	71.2	8:52:37	89
8:53:28	69.8	8:53:37	89.3
8:54:28	69	8:54:37	89.2
8:55:28	75.2	8:55:37	88.6
8:56:28	71	8:56:37	89.5
8:57:28	67.4	8:57:37	89.8
8:58:28	71.9	8:58:37	89
8:59:28	70.4	8:59:37	88.7
9:00:28	76.8	9:00:37	88.2
9:01:28	79.8	9:01:37	87.9
9:02:28	78.9	9:02:37	87.5

9:03:28	78.5	9:03:37	83.4
9:04:28	78.6	9:04:37	83.3
9:05:28	81.3	9:05:37	81.8
9:06:28	81.3	9:06:37	73.6
9:07:28	81.5	9:07:37	71.7
9:08:28	80.5	9:08:37	76.2
9:09:28	79.9	9:09:37	75.8
9:10:28	78.6	9:10:37	74.2
9:11:28	78.7	9:11:37	71.4
9:12:28	79	9:12:37	62.5
9:13:28	79.3	9:13:37	61.7
9:14:28	79.2	9:14:37	64.4
9:15:28	79.1	9:15:37	68.7
11:10:28	83.5	11:10:37	86.9
11:11:28	83.5	11:11:37	86.9
11:12:28	82.6	11:12:37	87.1
11:13:28	83.5	11:13:37	89.5
11:14:28	80.1	11:14:37	85.4
11:15:28	79	11:15:37	61.3
11:16:28	78.8	11:16:37	61.1
11:17:28	78.8	11:17:37	59.8
11:18:28	78.6	11:18:37	72.2
11:19:28	78.7	11:19:37	84.2

11:20:28	78.6	11:20:37	76.5
11:21:28	78.6	11:21:37	77.8
11:22:28	78.5	11:22:37	82.9
11:23:28	78.5	11:23:37	87.8
11:24:28	78.5	11:24:37	87.3
11:25:28	78.4	11:25:37	91
11:26:28	78.4	11:26:37	88.2
11:27:28	78.4	11:27:37	88.1
11:28:28	78.4	11:28:37	88
11:29:28	78.4	11:29:37	89.5
11:30:28	78.1	11:30:37	89.3
11:31:28	78.1	11:31:37	87.1
11:32:28	78.2	11:32:37	86.6
11:33:28	78.2	11:33:37	94.3
11:34:28	78.8	11:34:37	87.6
11:35:28	78.6	11:35:37	85.1
11:36:28	78.6	11:36:37	83.6
11:37:28	80.4	11:37:37	82.5
11:38:28	79.4	11:38:37	85.2
11:39:28	79	11:39:37	81.8
11:40:28	78.9	11:40:37	81.7
11:41:28	79.6	11:41:37	86.6
11:42:28	79	11:42:37	87.1

11:43:28	78.8	11:43:37	87.4
11:44:28	79.1	11:44:37	86.8
14:15:28	78.8	14:15:37	81.7
14:16:28	78.9	14:16:37	81.1
14:17:28	78.8	14:17:37	81.4
14:18:28	79	14:18:37	82.6
14:19:28	78.8	14:19:37	83.2
14:20:28	79.1	14:20:37	79.9
14:21:28	78.8	14:21:37	81.3
14:22:28	78.7	14:22:37	81.3
14:23:28	78.6	14:23:37	81.1
14:24:28	78.7	14:24:37	80.8
14:25:28	78.9	14:25:37	81.7
14:26:28	78.4	14:26:37	81.8
14:27:28	79	14:27:37	82.7
14:28:28	80.2	14:28:37	82.2
14:29:28	79.5	14:29:37	82.3
14:30:28	79.5	14:30:37	82.1
14:31:28	79.6	14:31:37	81.2
14:32:28	79.5	14:32:37	81
14:33:28	79.5	14:33:37	81.1
14:34:28	83.4	14:34:37	80.7
14:35:28	79.2	14:35:37	79.5

14:36:28	79.3	14:36:37	80.7
14:37:28	79.4	14:37:37	80.7
14:38:28	79.1	14:38:37	81.2
14:39:28	79.7	14:39:37	81.1
14:40:28	79.9	14:40:37	80.7
14:41:28	79.9	14:41:37	80.5
14:42:28	79.8	14:42:37	84.4
14:43:28	79.7	14:43:37	85.5
14:44:28	79.3	14:44:37	85.6
14:45:28	79.2	14:45:37	89.8
14:46:28	79.2	14:46:37	87.1
14:47:28	79.7	14:47:37	84.3
14:48:28	79.9	14:48:37	87.6
14:49:28	79.6	14:49:37	80.5
14:50:28	79.6	14:50:37	81.1
14:51:28	79.6	14:51:37	85.2
14:52:28	79.5	14:52:37	77.4
14:53:28	79.7	14:53:37	93.3
14:54:28	79.7	14:54:37	96.4
14:55:28	79.7	14:55:37	76.7
14:56:28	79.5	14:56:37	77.1
14:57:28	79.1	14:57:37	76.3
14:58:28	79	14:58:37	77.8

14:59:28	79.2	14:59:37	74.1
15:00:28	79.7	15:00:37	78.1
15:01:28	79.3	15:01:37	74
15:02:28	80.3	15:02:37	87.8
15:03:28	79.5	15:03:37	87.5
15:04:28	79.5	15:04:37	82.4
15:05:28	79.7	15:05:37	79.8
15:06:28	82	15:06:37	82.7
15:07:28	86.3	15:07:37	85.6
15:08:28	73.5	15:08:37	85
15:09:28	69	15:09:37	86.2
15:10:28	69	15:10:37	84.3
15:11:28	68.9	15:11:37	82.6
15:12:28	72.7	15:12:37	80.3
15:13:28	83.7	15:13:37	81.2
15:14:28	80.2	15:14:37	79.1
15:15:28	79	15:15:37	79
15:16:28	78.9	15:16:37	79
15:17:28	79	15:17:37	83.9
15:18:28	79	15:18:37	91.3
15:19:28	79.1	15:19:37	69.4
15:20:28	78.9	15:20:37	68.2

 June 13, 2008

Worker		Fixed Point Sound Level Meter	
21210 Time	21210 SPL	21209 Time	21209 SPL
7:00:07	59	7:00:37	94.2
7:01:07	59	7:01:37	91.2
7:02:07	59.4	7:02:37	86.7
7:03:07	60.6	7:03:37	83.4
7:04:07	60.7	7:04:37	84.5
7:05:07	60.8	7:05:37	89.4
7:06:07	61.2	7:06:37	90.1
7:07:07	61.2	7:07:37	87.8
7:08:07	62.3	7:08:37	88.3
7:09:07	63	7:09:37	92.2
7:10:07	63.3	7:10:37	93
7:11:07	63.3	7:11:37	93.7
7:12:07	63.4	7:12:37	91.3
7:13:07	63.5	7:13:37	92.3
7:14:07	63.6	7:14:37	88.1
7:15:07	63.9	7:15:37	89.5
7:16:07	64.1	7:16:37	87.3
7:17:07	64.5	7:17:37	90.1
7:18:07	64.7	7:18:37	92.6

7:19:07	64.8	7:19:37	87.9
7:20:07	65.1	7:20:37	87.8
7:21:07	65.2	7:21:37	87.6
7:22:07	65.3	7:22:37	87.4
7:23:07	65.6	7:23:37	86.9
7:24:07	65.7	7:24:37	87.1
7:25:07	66	7:25:37	86.8
7:26:07	66.1	7:26:37	87.6
7:27:07	66.3	7:27:37	88.1
7:28:07	66.4	7:28:37	90.1
7:29:07	66.4	7:29:37	89.9
7:30:07	66.5	7:30:37	88.9
7:31:07	66.7	7:31:37	89.4
7:32:07	66.7	7:32:37	88.4
7:33:07	67	7:33:37	89.8
7:34:07	67	7:34:37	88
7:35:07	67.1	7:35:37	64.3
7:36:07	67.3	7:36:37	66.7
7:37:07	67.6	7:37:37	78
7:38:07	67.7	7:38:37	76.3
7:39:07	67.8	7:39:37	75.7
7:40:07	68	7:40:37	71.1
7:41:07	68	7:41:37	71.8

7:42:07	68.1	7:42:37	79.2
7:43:07	68.2	7:43:37	77.6
7:44:07	68.3	7:44:37	90.7
7:45:07	68.5	7:45:37	88.4
7:46:07	68.8	7:46:37	88.1
7:47:07	68.8	7:47:37	88.1
7:48:07	68.9	7:48:37	87.9
7:49:07	69	7:49:37	87.9
7:50:07	69	7:50:37	88.8
7:51:07	69.1	7:51:37	89.6
7:52:07	69.6	7:52:37	89.3
7:53:07	69.7	7:53:37	89.8
7:54:07	69.7	7:54:37	89.9
7:55:07	70.3	7:55:37	84.5
7:56:07	70.4	7:56:37	68.1
7:57:07	70.5	7:57:37	89.3
7:58:07	71.1	7:58:37	89.8
7:59:07	71.3	7:59:37	90.2
8:00:07	71.4	8:00:37	89.7
8:01:07	71.6	8:01:37	89.2
8:02:07	71.6	8:02:37	89.3
8:03:07	71.7	8:03:37	86.1
8:04:07	71.9	8:04:37	86.1

8:05:07	72.1	8:05:37	79.6
8:06:07	72.2	8:06:37	80.5
8:07:07	72.3	8:07:37	79.1
8:08:07	72.5	8:08:37	79.3
8:09:07	72.6	8:09:37	79.3
8:10:07	72.9	8:10:37	78.9
8:11:07	72.9	8:11:37	79.5
8:12:07	73	8:12:37	79.1
8:13:07	73	8:13:37	78.8
8:14:07	73	8:14:37	79.2
8:15:07	73.2	8:15:37	79.2
8:16:07	73.3	8:16:37	78.9
8:17:07	73.3	8:17:37	79
8:18:07	73.3	8:18:37	82.1
8:19:07	73.4	8:19:37	78.9
8:20:07	73.6	8:20:37	79
8:21:07	73.6	8:21:37	79.2
8:22:07	73.7	8:22:37	80
8:23:07	73.8	8:23:37	84.6
8:24:07	73.8	8:24:37	84.8
8:25:07	74.2	8:25:37	85.6
8:26:07	74.2	8:26:37	83.8
8:27:07	74.2	8:27:37	89.2

8:28:07	74.4	8:28:37	89.8
8:29:07	74.4	8:29:37	89.5
8:30:07	74.4	8:30:37	90
8:31:07	74.4	8:31:37	89
8:32:07	74.5	8:32:37	92.8
8:33:07	74.6	8:33:37	91.1
8:34:07	74.8	8:34:37	88.5
8:35:07	74.8	8:35:37	89.1
8:36:07	74.9	8:36:37	88.2
8:37:07	75	8:37:37	88.8
8:38:07	75.4	8:38:37	88.9
8:39:07	75.5	8:39:37	88.2
8:40:07	75.6	8:40:37	88.2
8:41:07	75.9	8:41:37	88.5
8:42:07	76	8:42:37	89.5
8:43:07	76.1	8:43:37	89.1
8:44:07	76.1	8:44:37	89.2
8:45:07	76.2	8:45:37	89.2
8:46:07	76.5	8:46:37	88.9
8:47:07	76.6	8:47:37	89.3
8:48:07	76.7	8:48:37	89
8:49:07	76.7	8:49:37	89.7
8:50:07	76.9	8:50:37	89.8

8:51:07	76.9	8:51:37	89.6
8:52:07	77.1	8:52:37	89
8:53:07	77.5	8:53:37	89.3
8:54:07	77.8	8:54:37	89.2
8:55:07	77.8	8:55:37	88.6
8:56:07	78.1	8:56:37	89.5
8:57:07	78.2	8:57:37	89.8
8:58:07	78.5	8:58:37	89
8:59:07	78.6	8:59:37	88.7
9:30:07	80.5	9:30:37	63.1
9:31:07	80.5	9:31:37	69.5
9:32:07	80.5	9:32:37	77.1
9:33:07	80.5	9:33:37	83.7
9:34:07	80.5	9:34:37	69
9:35:07	80.5	9:35:37	65.1
9:36:07	80.5	9:36:37	74.1
9:37:07	80.5	9:37:37	59.4
9:38:07	80.5	9:38:37	69.5
9:39:07	80.6	9:39:37	67.3
9:40:07	80.6	9:40:37	64.4
9:41:07	80.6	9:41:37	66.1
9:42:07	80.6	9:42:37	54.1
9:43:07	80.7	9:43:37	63.6

9:44:07	80.7	9:44:37	85.7
9:45:07	80.7	9:45:37	82.3
9:46:07	80.7	9:46:37	78.4
9:47:07	80.7	9:47:37	79.9
9:48:07	80.7	9:48:37	86.1
9:49:07	80.7	9:49:37	78.6
11:10:07	81.2	11:10:37	86.9
11:11:07	81.2	11:11:37	86.9
11:12:07	81.2	11:12:37	87.1
11:13:07	81.2	11:13:37	89.5
11:14:07	81.2	11:14:37	85.4
11:15:07	81.2	11:15:37	61.3
11:16:07	81.2	11:16:37	61.1
11:17:07	81.3	11:17:37	59.8
11:18:07	81.3	11:18:37	72.2
11:19:07	81.3	11:19:37	84.2
11:20:07	81.3	11:20:37	76.5
11:21:07	81.3	11:21:37	77.8
11:22:07	81.3	11:22:37	82.9
11:23:07	81.3	11:23:37	87.8
11:24:07	81.3	11:24:37	87.3
11:25:07	81.3	11:25:37	91
11:26:07	81.4	11:26:37	88.2

11:27:07	81.4	11:27:37	88.1
11:28:07	81.4	11:28:37	88
11:29:07	81.4	11:29:37	89.5
11:30:07	81.4	11:30:37	89.3
11:31:07	81.4	11:31:37	87.1
11:32:07	81.5	11:32:37	86.6
11:33:07	81.5	11:33:37	94.3
11:34:07	81.5	11:34:37	87.6
11:35:07	81.5	11:35:37	85.1
11:36:07	81.5	11:36:37	83.6
11:37:07	81.5	11:37:37	82.5
11:38:07	81.6	11:38:37	85.2
11:39:07	81.6	11:39:37	81.8
11:40:07	81.6	11:40:37	81.7
14:15:07	86.3	14:15:37	81.7
14:16:07	86.3	14:16:37	81.1
14:17:07	86.3	14:17:37	81.4
14:18:07	86.3	14:18:37	82.6
14:19:07	86.3	14:19:37	83.2
14:20:07	86.4	14:20:37	79.9
14:21:07	86.4	14:21:37	81.3
14:22:07	86.4	14:22:37	81.3
14:23:07	86.4	14:23:37	81.1

14:24:07	86.4	14:24:37	80.8
14:25:07	86.5	14:25:37	81.7
14:26:07	86.5	14:26:37	81.8
14:27:07	86.5	14:27:37	82.7
14:28:07	86.5	14:28:37	82.2
14:29:07	86.5	14:29:37	82.3
14:30:07	86.6	14:30:37	82.1
14:31:07	86.6	14:31:37	81.2
14:32:07	86.6	14:32:37	81
14:33:07	86.7	14:33:37	81.1
14:34:07	86.7	14:34:37	80.7
14:35:07	86.8	14:35:37	79.5
14:36:07	86.8	14:36:37	80.7
14:37:07	86.8	14:37:37	80.7
14:38:07	86.8	14:38:37	81.2
14:39:07	86.9	14:39:37	81.1
14:40:07	86.9	14:40:37	80.7
14:41:07	86.9	14:41:37	80.5
14:42:07	87	14:42:37	84.4
14:43:07	87	14:43:37	85.5
14:44:07	87	14:44:37	85.6
14:45:07	87	14:45:37	89.8

 June 16, 2008

Worker		Fixed Point Sound Level Meter	
21210 Time	21210 SPL	21208 Time	21208 SPL
11:00:32	82.3	11:00:09	80.6
11:01:32	79.3	11:01:09	80.6
11:02:32	79.6	11:02:09	80.6
11:03:32	78.8	11:03:09	80.6
11:04:32	81.2	11:04:09	80.6
11:05:32	78.6	11:05:09	80.5
11:06:32	79	11:06:09	80.5
11:07:32	78.3	11:07:09	80.5
11:08:32	81.5	11:08:09	80.5
11:09:32	82.8	11:09:09	80.5
11:10:32	81.8	11:10:09	80.5
11:11:32	81.7	11:11:09	80.5
11:12:32	82.7	11:12:09	80.5
11:13:32	78.5	11:13:09	80.5
11:14:32	78.4	11:14:09	80.5
11:15:32	78.2	11:15:09	80.5
11:16:32	78.3	11:16:09	80.5
11:17:32	78.2	11:17:09	80.5
11:18:32	78.3	11:18:09	80.5

11:19:32	78.3	11:19:09	80.4
11:20:32	78.4	11:20:09	80.5
11:21:32	78.5	11:21:09	80.4
11:22:32	78.9	11:22:09	80.5
11:23:32	80.2	11:23:09	80.5
11:24:32	78.6	11:24:09	80.5
11:25:32	78.6	11:25:09	80.5
11:26:32	78.6	11:26:09	80.5
11:27:32	78.6	11:27:09	80.6
11:28:32	78.6	11:28:09	80.5
11:29:32	78.6	11:29:09	80.5
11:30:32	78.8	11:30:09	80.5
11:31:32	79.7	11:31:09	80.6
11:32:32	81.2	11:32:09	80.6
11:33:32	78.7	11:33:09	80.5
11:34:32	78.7	11:34:09	80.6
11:35:32	80	11:35:09	80.6
14:20:32	68.8	14:20:09	80.4
14:21:32	70	14:21:09	80.4
14:22:32	80.2	14:22:09	80.3
14:23:32	90.7	14:23:09	80.3
14:24:32	88.1	14:24:09	80.4
14:25:32	84.9	14:25:09	80.3

14:26:32	87.6	14:26:09	80.4
14:27:32	84.7	14:27:09	80.3
14:28:32	83	14:28:09	80.3
14:29:32	87	14:29:09	80.4
14:30:32	85.6	14:30:09	80.4
14:31:32	82	14:31:09	80.3
14:32:32	83.3	14:32:09	80.3
14:33:32	81.9	14:33:09	80.4
14:34:32	86.7	14:34:09	80.4
14:35:32	80.1	14:35:09	80.4
14:36:32	85.5	14:36:09	80.2
14:37:32	82.2	14:37:09	80.2
14:38:32	82.4	14:38:09	80.3
14:39:32	81.8	14:39:09	80.3
14:40:32	86.8	14:40:09	80.5
14:41:32	86.3	14:41:09	80.5
14:42:32	87.8	14:42:09	80.5
14:43:32	85.7	14:43:09	80.5
14:44:32	87.6	14:44:09	80.5
14:45:32	88.4	14:45:09	80.5
14:46:32	83.2	14:46:09	80.5
14:47:32	79.7	14:47:09	80.6
14:48:32	81.7	14:48:09	81.4

14:49:32	81.7	14:49:09	81.7
14:50:32	81.7	14:50:09	80.9
14:51:32	82.4	14:51:09	80.7
14:52:32	82	14:52:09	80.6
14:53:32	83.8	14:53:09	80.7
14:54:32	86.6	14:54:09	80.9
14:55:32	81.4	14:55:09	80.4
14:56:32	83	14:56:09	80.4
14:57:32	84.6	14:57:09	80.5
14:58:32	81.6	14:58:09	80.5
14:59:32	85.2	14:59:09	80.5
15:00:32	78.6	15:00:09	80.2
15:01:32	78.4	15:01:09	80.3
15:02:32	77.7	15:02:09	80.3
15:03:32	77.4	15:03:09	79.5
15:04:32	82.2	15:04:09	77.4
15:05:32	77.2	15:05:09	77.5
15:06:32	77.4	15:06:09	77.3
15:07:32	77.4	15:07:09	77.3
15:08:32	77.3	15:08:09	77.4
15:09:32	77.1	15:09:09	78.4
15:10:32	77.3	15:10:09	77.4
15:11:32	77.4	15:11:09	77.5

15:12:32	78.2	15:12:09	77.4
15:13:32	80.9	15:13:09	79.5
15:14:32	80.7	15:14:09	80.1
15:15:32	80.9	15:15:09	80
15:16:32	80.2	15:16:09	80.1
15:17:32	80.5	15:17:09	80.1
15:18:32	80.7	15:18:09	80.7
15:19:32	80.7	15:19:09	80.7
15:20:32	81.4	15:20:09	80.7
15:21:32	81.3	15:21:09	80.8
15:22:32	81	15:22:09	80
15:23:32	80.9	15:23:09	80.1
15:24:32	81.2	15:24:09	80
15:25:32	80.7	15:25:09	80
15:26:32	80.8	15:26:09	80
15:27:32	81.3	15:27:09	80
15:28:32	81	15:28:09	80
15:29:32	80.8	15:29:09	80.1
15:30:32	85.4	15:30:09	80

 June 16, 2008

Worker		Fixed Point Sound Level Meter	
21207 Time	21207 SPL	21208 Time	21208 SPL
7:30:45	78.2	7:30:09	80.6
7:31:45	78.2	7:31:09	80.5
7:32:45	78.2	7:32:09	80.6
7:33:45	78.1	7:33:09	80.5
7:34:45	78.1	7:34:09	80.5
7:35:45	78.1	7:35:09	80.6
7:36:45	78.2	7:36:09	80.5
7:37:45	78	7:37:09	80.5
7:38:45	78.3	7:38:09	80.5
7:39:45	78.2	7:39:09	80.4
7:40:45	78.1	7:40:09	80.5
7:41:45	78.2	7:41:09	80.5
7:42:45	78.2	7:42:09	80.5
7:43:45	79.3	7:43:09	80.4
7:44:45	78.4	7:44:09	80.4
7:45:45	78.1	7:45:09	80.5
7:46:45	78.6	7:46:09	80.4
7:47:45	78	7:47:09	80.4
7:48:45	78.5	7:48:09	80.4

7:49:45	78.9	7:49:09	80.5
7:50:45	78.9	7:50:09	80.5
7:51:45	79.1	7:51:09	80.5
7:52:45	79	7:52:09	80.5
7:53:45	77.6	7:53:09	80.5
7:54:45	71.4	7:54:09	80.5
7:55:45	74.3	7:55:09	80.5
7:56:45	77.6	7:56:09	80.5
7:57:45	72.2	7:57:09	80.5
7:58:45	74.1	7:58:09	80.5
7:59:45	79.1	7:59:09	80.5
8:00:45	75.4	8:00:09	80.5
8:01:45	72.2	8:01:09	80.5
8:02:45	73.5	8:02:09	80.4
8:03:45	72.6	8:03:09	80.4
8:04:45	75.5	8:04:09	80.4
8:05:45	72.8	8:05:09	80.4
8:06:45	79.8	8:06:09	80.4
8:07:45	79.2	8:07:09	80.4
8:08:45	85.7	8:08:09	80.4
8:09:45	87.7	8:09:09	80.4
8:10:45	86.9	8:10:09	80.4
8:11:45	86.1	8:11:09	80.4

8:12:45	86.1	8:12:09	80.5
8:13:45	85.6	8:13:09	80.4
8:14:45	86	8:14:09	80.5
8:15:45	85.7	8:15:09	80.4
8:16:45	86.4	8:16:09	80.5
8:17:45	86.4	8:17:09	80.5
8:18:45	87.6	8:18:09	80.4
8:19:45	83.1	8:19:09	80.4
8:20:45	79.6	8:20:09	80.5
8:21:45	79.1	8:21:09	80.4
8:22:45	85.3	8:22:09	80.3
8:23:45	86.2	8:23:09	80.4
8:24:45	87.1	8:24:09	80.5
8:25:45	83.9	8:25:09	80.5
8:26:45	80.3	8:26:09	80.5
8:27:45	79.7	8:27:09	80.4
8:28:45	78.8	8:28:09	80.3
8:29:45	78.6	8:29:09	80.3
8:30:45	78.6	8:30:09	80.3
8:31:45	80.7	8:31:09	80.3
8:32:45	82.6	8:32:09	80.3
8:33:45	81.2	8:33:09	80.3
8:34:45	80.9	8:34:09	80.3

8:35:45	83.1	8:35:09	80.4
8:36:45	80.9	8:36:09	80.4
8:37:45	85.2	8:37:09	80.4
8:38:45	89.3	8:38:09	80.3
8:39:45	81.2	8:39:09	80.4
8:40:45	77.5	8:40:09	80.4
8:41:45	76.5	8:41:09	80.5
8:42:45	76.2	8:42:09	80.3
8:43:45	76.1	8:43:09	80.3
8:44:45	76.3	8:44:09	80.4
8:45:45	76.2	8:45:09	80.3

June 16, 2008

Worker		Fixed Point Sound Level Meter	
21209 Time	21209 SPL	21208 Time	21208 SPL
13:00:19	61.2	13:00:09	80.5
13:01:19	62.3	13:01:09	80.4
13:02:19	62.7	13:02:09	80.4
13:03:19	63.1	13:03:09	80.4
13:04:19	64.5	13:04:09	80.4
13:05:19	65.2	13:05:09	80.4
13:06:19	69.5	13:06:09	80.3

13:07:19	70.3	13:07:09	80.3
13:08:19	75	13:08:09	80.4
13:09:19	75	13:09:09	80.4
13:10:19	75.1	13:10:09	80.3
13:11:19	75.1	13:11:09	80.3
13:12:19	75.4	13:12:09	80.3
13:13:19	75.4	13:13:09	80.3
13:14:19	75.9	13:14:09	80.3
13:15:19	76.9	13:15:09	80.4
13:16:19	77	13:16:09	80.5
13:17:19	77.1	13:17:09	80.3
13:18:19	79.3	13:18:09	80.4
13:19:19	80.4	13:19:09	80.3
13:20:19	80.9	13:20:09	80.4
13:21:19	81.2	13:21:09	80.4
13:22:19	81.8	13:22:09	80.4
13:23:19	82.1	13:23:09	80.3
13:24:19	82.8	13:24:09	80.4
13:25:19	82.9	13:25:09	80.3
13:26:19	82.9	13:26:09	80.5
13:27:19	83	13:27:09	80.5
13:28:19	83.1	13:28:09	80.6
13:29:19	83.3	13:29:09	80.5

13:30:19	83.7	13:30:09	80.7
13:31:19	84.4	13:31:09	80.6
13:32:19	84.4	13:32:09	80.6
13:33:19	84.5	13:33:09	80.6
13:34:19	84.8	13:34:09	80.5
13:35:19	84.9	13:35:09	80.5
13:36:19	85.1	13:36:09	80.6
13:37:19	86.2	13:37:09	80.5
13:38:19	86.3	13:38:09	80.5
13:39:19	86.4	13:39:09	80.5
13:40:19	86.6	13:40:09	80.5
13:41:19	86.7	13:41:09	80.5
13:42:19	87.1	13:42:09	80.6
13:43:19	87.7	13:43:09	80.4
13:44:19	87.7	13:44:09	80.4
13:45:19	87.8	13:45:09	80.4
13:46:19	88.2	13:46:09	80.4
13:47:19	88.3	13:47:09	80.5
13:48:19	88.3	13:48:09	80.5
13:49:19	88.7	13:49:09	80.5
13:50:19	88.7	13:50:09	80.5
13:51:19	88.7	13:51:09	80.5
13:52:19	89.4	13:52:09	80.5

13:53:19	89.4	13:53:09	80.4
13:54:19	90.2	13:54:09	80.4
13:55:19	90.3	13:55:09	80.4
13:56:19	90.5	13:56:09	80.5
13:57:19	91.2	13:57:09	80.5
13:58:19	92	13:58:09	80.5
13:59:19	93	13:59:09	80.5
14:00:19	93.1	14:00:09	80.5

June 18, 2009

Worker		Fixed Point Sound Level Meter	
21208 Time	21208 SPL	17623 Time	17623 SPL
13:15:48	78.5	13:15:42	82.4
13:16:48	78.6	13:16:42	82.4
13:17:48	78.6	13:17:42	82.4
13:18:48	78.8	13:18:42	82.4
13:19:48	78.8	13:19:42	82.4
13:20:48	78.9	13:20:42	82.4
13:21:48	78.9	13:21:42	82.4
13:22:48	78.8	13:22:42	82.4
13:23:48	78.8	13:23:42	82.4
13:24:48	78.7	13:24:42	82.4

13:25:48	78.8	13:25:42	82.4
13:26:48	78.8	13:26:42	82.4
13:27:48	78.7	13:27:42	82.4
13:28:48	78.9	13:28:42	82.4
13:29:48	79.1	13:29:42	82.4
13:30:48	79.1	13:30:42	82.4
13:31:48	79	13:31:42	82.4
13:32:48	78.9	13:32:42	82.4
13:33:48	79	13:33:42	82.4
13:34:48	78.9	13:34:42	82.4
13:35:48	79.2	13:35:42	82.4
13:36:48	79.3	13:36:42	82.4
13:37:48	79.2	13:37:42	82.4
13:38:48	79.2	13:38:42	82.4
13:39:48	79.1	13:39:42	82.4
13:40:48	79.1	13:40:42	82.4
13:41:48	79.2	13:41:42	82.3
13:42:48	79.2	13:42:42	82.4
13:43:48	78.9	13:43:42	82.4
13:44:48	78.7	13:44:42	82.3
13:45:48	78.9	13:45:42	82.4
13:46:48	78.8	13:46:42	82.4
13:47:48	78.8	13:47:42	82.4

13:48:48	78.7	13:48:42	82.3
13:49:48	78.7	13:49:42	82.4
13:50:48	78.7	13:50:42	82.4
13:51:48	79	13:51:42	82.3
13:52:48	78.5	13:52:42	82.4
13:53:48	78.5	13:53:42	82.3
13:54:48	78.7	13:54:42	82.4
13:55:48	82.3	13:55:42	82.3
13:56:48	78.7	13:56:42	82.4
13:57:48	78.9	13:57:42	82.4
13:58:48	78.9	13:58:42	82.4
13:59:48	78.7	13:59:42	82.4
14:00:48	78.7	14:00:42	82.4
15:00:48	78.4	15:00:42	82.2
15:01:48	78.7	15:01:42	82.2
15:02:48	78.7	15:02:42	82.2
15:03:48	78.7	15:03:42	82.2
15:04:48	78.8	15:04:42	82.2
15:05:48	78.9	15:05:42	82.2
15:06:48	79.9	15:06:42	82.2
15:07:48	79	15:07:42	82.2
15:08:48	78.7	15:08:42	82.2
15:09:48	78.8	15:09:42	82.2

15:10:48	79.2	15:10:42	82.2
15:11:48	78.7	15:11:42	82.2
15:12:48	78.6	15:12:42	82.2
15:13:48	78.6	15:13:42	82.2
15:14:48	78.8	15:14:42	82.2
15:15:48	78.7	15:15:42	82.2

June 19, 2008

Worker		Fixed Point Sound Level Meter	
21208 Time	21208 SPL	21210 Time	21210 SPL
7:00:54	74.3	7:00:01	76.8
7:01:54	59.5	7:01:01	76.8
7:02:54	55.1	7:02:01	76.7
7:03:54	55.4	7:03:01	76.6
7:04:54	55.2	7:04:01	76.6
7:05:54	54.7	7:05:01	76.8
7:06:54	57.7	7:06:01	78
7:07:54	75.9	7:07:01	76.8
7:08:54	78.8	7:08:01	76.9
7:09:54	77.1	7:09:01	76.8
7:10:54	77.3	7:10:01	76.8
7:11:54	77.3	7:11:01	76.8

7:12:54	77	7:12:01	76.9
7:13:54	76.9	7:13:01	76.9
7:14:54	77	7:14:01	76.9
7:15:54	80.8	7:15:01	76.9
7:16:54	83.6	7:16:01	77
7:17:54	77.3	7:17:01	76.9
7:18:54	77.4	7:18:01	76.9
7:19:54	77.3	7:19:01	76.8
7:20:54	77.3	7:20:01	76.9
7:21:54	77.3	7:21:01	77
7:22:54	77.3	7:22:01	76.9
7:23:54	77.8	7:23:01	77.2
7:24:54	78.9	7:24:01	78.6
7:25:54	77.7	7:25:01	77.6
7:26:54	77.4	7:26:01	77.9
7:27:54	77.1	7:27:01	78.3
7:28:54	77.8	7:28:01	77.8
7:29:54	77.2	7:29:01	77.8
7:30:54	77.2	7:30:01	77.9
7:31:54	77.5	7:31:01	77.9
7:32:54	78.5	7:32:01	78.5
7:33:54	77.5	7:33:01	78.7
7:34:54	77.4	7:34:01	78.3

7:35:54	78	7:35:01	78.2
7:36:54	77.7	7:36:01	78.8
7:37:54	78.2	7:37:01	78.2
7:38:54	79.2	7:38:01	78.5
7:39:54	78.3	7:39:01	78.5
7:40:54	77.8	7:40:01	78.4
7:41:54	78.2	7:41:01	77.9
7:42:54	78	7:42:01	77.9
7:43:54	78.1	7:43:01	78.2
7:44:54	78	7:44:01	77.9
7:45:54	77.8	7:45:01	77.4
7:46:54	77.8	7:46:01	77.6
7:47:54	77.8	7:47:01	77.8
7:48:54	77.4	7:48:01	77.3
7:49:54	77.3	7:49:01	77.2
7:50:54	77.5	7:50:01	77.3
7:51:54	77.3	7:51:01	77
7:52:54	77.3	7:52:01	77
7:53:54	77.5	7:53:01	77.4
7:54:54	87.5	7:54:01	77.4
7:55:54	85.5	7:55:01	77.1
7:56:54	79	7:56:01	77
7:57:54	77.2	7:57:01	77

7:58:54	77.2	7:58:01	77
7:59:54	77.4	7:59:01	77
8:00:54	77.3	8:00:01	76.9
8:01:54	77.4	8:01:01	77
8:02:54	77.1	8:02:01	77
8:03:54	77.2	8:03:01	77
8:04:54	77.1	8:04:01	77
8:05:54	77.9	8:05:01	77
8:06:54	77.4	8:06:01	77
8:07:54	77.4	8:07:01	77
8:08:54	77.7	8:08:01	77.1
8:09:54	77.6	8:09:01	76.9
8:10:54	77.6	8:10:01	76.9
8:11:54	77.7	8:11:01	76.9
8:12:54	78	8:12:01	77.1
8:13:54	77.8	8:13:01	77.1
8:14:54	77.8	8:14:01	77
8:15:54	77.7	8:15:01	77
8:16:54	77.6	8:16:01	77
8:17:54	77.4	8:17:01	77
8:18:54	77.7	8:18:01	77
8:19:54	77.4	8:19:01	77.2
8:20:54	77.6	8:20:01	77.1

8:21:54	77.4	8:21:01	76.8
8:22:54	77.5	8:22:01	77
8:23:54	78.8	8:23:01	76.9
8:24:54	79.5	8:24:01	76.9
8:25:54	80.1	8:25:01	77.1
8:26:54	77.3	8:26:01	77.2
8:27:54	77.2	8:27:01	77.1
8:28:54	77.3	8:28:01	77
8:29:54	79.8	8:29:01	76.9
8:30:54	78.9	8:30:01	77.1
8:31:54	76.9	8:31:01	77.2
8:32:54	77.3	8:32:01	76.9
8:33:54	76.5	8:33:01	77.1
8:34:54	77	8:34:01	77
8:35:54	77	8:35:01	77
8:36:54	77.9	8:36:01	77
8:37:54	77.8	8:37:01	77
8:38:54	78	8:38:01	77
8:39:54	76.1	8:39:01	77.2
8:40:54	76.2	8:40:01	77
8:41:54	76.2	8:41:01	77.1
8:42:54	76.2	8:42:01	77.1
8:43:54	76.2	8:43:01	77.2

8:44:54	77.2	8:44:01	77.2
8:45:54	76.5	8:45:01	77.1
8:46:54	78.2	8:46:01	76.9
8:47:54	72.1	8:47:01	77.1
8:48:54	69.8	8:48:01	77
8:49:54	74.6	8:49:01	77.1
8:50:54	78.3	8:50:01	77
8:51:54	76.9	8:51:01	77
8:52:54	75.4	8:52:01	76.9
8:53:54	77	8:53:01	77
8:54:54	77.4	8:54:01	77
8:55:54	76.6	8:55:01	76.9
8:56:54	77.2	8:56:01	77.2
8:57:54	77.1	8:57:01	77.1
8:58:54	77	8:58:01	76.9
8:59:54	77.5	8:59:01	76.9
9:00:54	65.8	9:00:01	77

Appendix E: UW-Stout Protection of Human Subjects in Research Form



Research Services
152 Voc Rehab Building
University of Wisconsin-Stout
P.O. Box 790
Menomonie, WI 54751-0790

715/232-1126
715/232-1749 (fax)
<http://www.uwstout.edu/rs/>

Date: April 11, 2008
To: Jennifer Sheffer
Cc: Dr. Eugene Ruenger
From: Sue Foxwell, Research Administrator and Human
Protections Administrator, UW-Stout Institutional
Review Board for the Protection of Human
Subjects in Research (IRB)
Subject: Protection of Human Subjects

Your project, "**Worker Exposure to Noise During Computer Manufacturing: Measurement and Control**," has been approved by the IRB through the expedited review process. The measures you have taken to protect human subjects are adequate to protect everyone involved, including subjects and researchers.

Please copy and paste the following message to the top of your survey form before dissemination:

This research has been approved by the UW-Stout IRB as required by the Code of Federal Regulations Title 45 Part 46.

This project is approved through April 8, 2009. Modifications to this approved protocol need to be approved by the IRB. Research not completed by this date must be submitted again outlining changes, expansions, etc. Federal guidelines require annual review and approval by the IRB.

Thank you for your cooperation with the IRB and best wishes with your project.

***NOTE:** This is the only notice you will receive – no paper copy will be sent.

Appendix F: American Industrial Hygiene Association Copyright Permission



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fax +1 703-207-3561
web www.aiha.org

American Industrial Hygiene Association

October 5, 2009

Jennifer Sheffer
5350 Old Dowlen Road, Apt. 635
Beaumont, TX 77706

Dear Jennifer,

This letter is in response to your request to reproduce Figure 4.1 (Cross-sectional view of the human ear) from *The Noise Manual*, Revised 5th edition. This figure would be used in your dissertation to further explain the physiology of the human ear.

AIHA grants this request providing the figure is not modified in any way. Please make sure to provide the following credit line with the figure where it is used: "Used with permission of the American Industrial Hygiene Association (2009)."

Thank you for your interest, and if you have any further questions, please don't hesitate to give me a call.

Sincerely,

Katie Robert
Manager, Product Development
American Industrial Hygiene Association