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The purpose of this study was to determine the effectiveness of acoustic shields at reducing sound levels experienced by a bassoonist during rehearsals of two professional orchestras. The primary research question was as follows: Do acoustic shields reduce sound levels experienced by a bassoonist to 85 dBA or below? A preliminary research question was: without an acoustic shield, do bassoonists in professional orchestras experience sound levels that exceed 85 dBA? The 85 dBA limit has been derived from the NIOSH recommended limits of sound-level exposure.

Sound levels of a professional bassoonist were measured across sixteen rehearsals during the 2007-2008 concert season. The bassoonist wore Cirrus Research CR: 100B doseBadge sound dosimeters on each shoulder. One of two commercially available acoustic shields was placed behind the bassoonist; shields used were manufactured by Manhasset and Wenger.

The results indicated that bassoonists in professional orchestras experienced average sound levels that exceed 85 dBA, and the use of acoustic shields did not reduce average sound levels to 85 dBA.

SHIELDING A MUSICIAN: A CASE STUDY ON THE EFFECTIVENESS OF ACOUSTIC SHIELDS IN LIVE ENSEMBLE REHEARSALS

by

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CHAPTER I

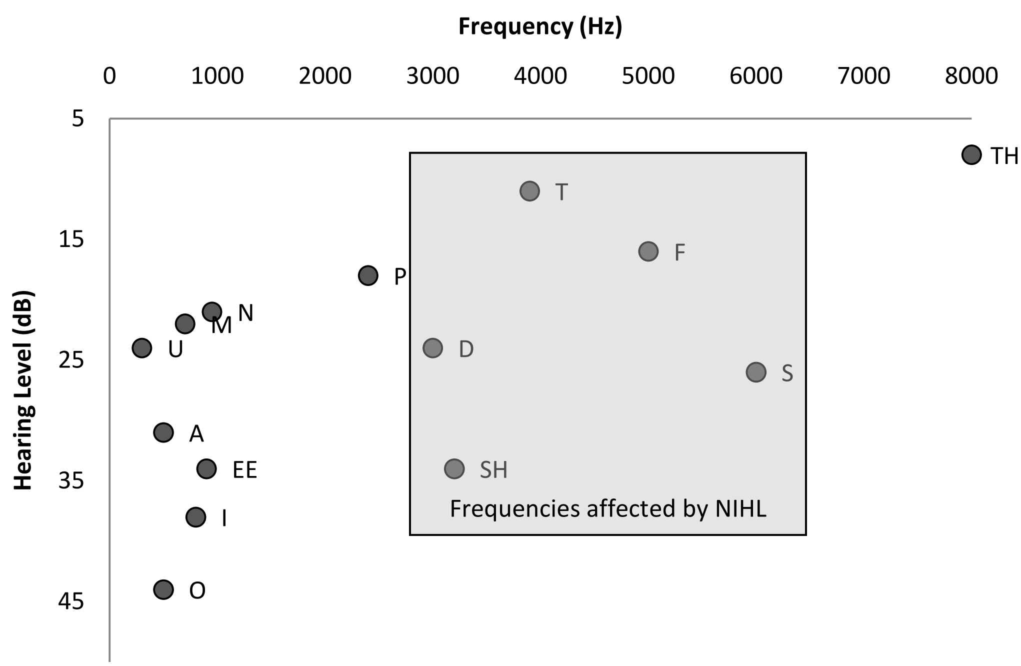
INTRODUCTION

Hearing acuity can have both a personal and professional impact on people in a variety of occupations. In particular, the professional lives of musicians' are directly affected by their hearing acuity. Excessively intense sound, such as crowd noise, industrial noise, and, under certain circumstances, musical sounds, could lead to hearing loss. As a result, hearing protection devices for musicians have been developed and are commercially available. This dissertation is based on a study of the effectiveness of one of those devices, the acoustic shield. Before the study is presented, basic descriptions of hearing as well as an overview of the related literature are provided.

Importance of Hearing

For all humans, hearing is an important part of life; benefits of good hearing extend beyond the confines of a job. From birth to death, hearing is an essential part of human learning and socialization (Berger 2003b; Haack & Hodges 1996). High-frequency hearing acuity, particularly in the 3,000 to 6,000 Hz range, is the first to be affected by noise-induced hearing loss (NIHL) (National Institute on Deafness and Other Communication Disorders 2006). This loss affects speech perception; consonants, such as "s," "t," and "p" sound in the 3,000 to 6,000 Hz range. Loss in ability to perceive consonants results in perception of speech with little to no articulation, which is perceivable, but not necessarily comprehendible. While there are many consequences of diminished hearing acuity for the musician, the loss of high frequency sound recognition can impact a musician's ability to understand verbal instructions of a conductor or section leader, just as it may affect a factory worker communicating with co-workers (Berger 2003b). In social settings, the inability to hear consonants can turn what would be an enjoyable evening with friends, or a romantic date with a spouse in a noisy restaurant into a frustrating experience. See Figure 1 for a graph of placement of specific vowels and consonants in the human speech frequencies.

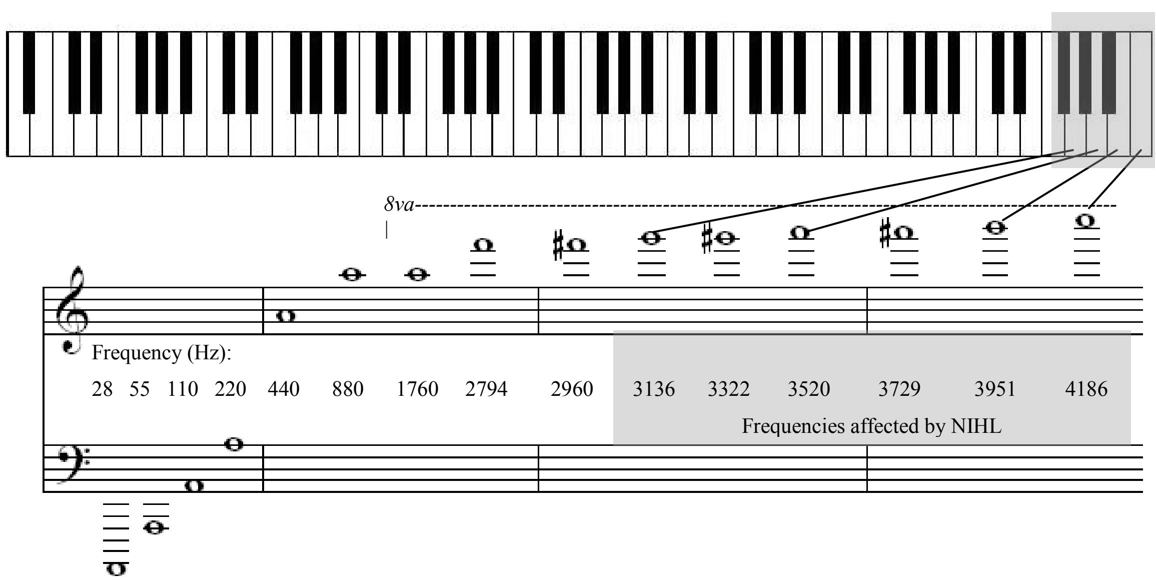
Figure 1: Frequency of Specific Vowels and Consonants.[1] NIHL begins with a loss between 3,000 and 6,000 Hz. This is precisely the location of several distinct consonants that enable speech perception. As a result of the loss in ability to hear these consonants, NIHL can make communication difficult.



[1] Information from the chart found in Ward, Royster, and Royster (2003).

In addition to musicians' need to understand verbal instructions, they are expected to be able to manipulate many fine nuances of sound. For example, a high level of hearing acuity is needed to match pitch, timbre, dynamics, and the envelope (shape) of a sound. Every aspect of making music depends on the musician's ability to control the sounds they produce; with diminished hearing acuity the manipulation of sound may become difficult. Figure 2 shows a piano keyboard with several corresponding pitches and frequencies. Some of these fundamental pitches are in the high-frequency range first affected by NIHL.

Figure 2: Piano Frequencies. A piano covers a wide range of pitch frequencies. Some of the highest pitches on the keyboard are in the 3,000 to 6,000 Hz range.



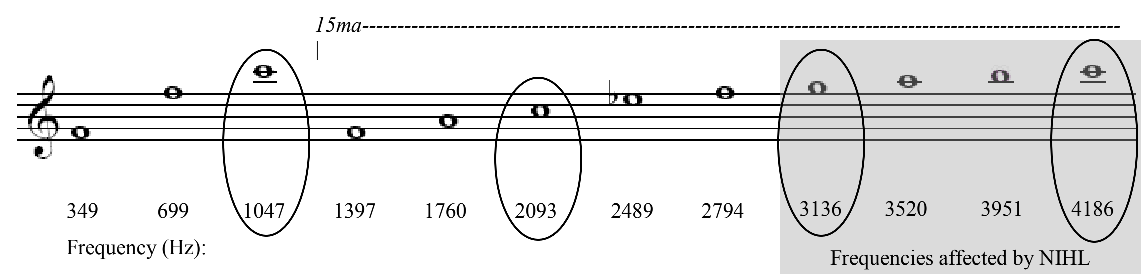
Sound, including music, is comprised of a fundamental and overtones; the fundamental is perceived as the pitch, but there are many other frequencies present.[2] To match pitch and blend timbres, musicians compare the high-frequency overtones within

[2] The exceptions to this statement are electronically created pure tone sounds.

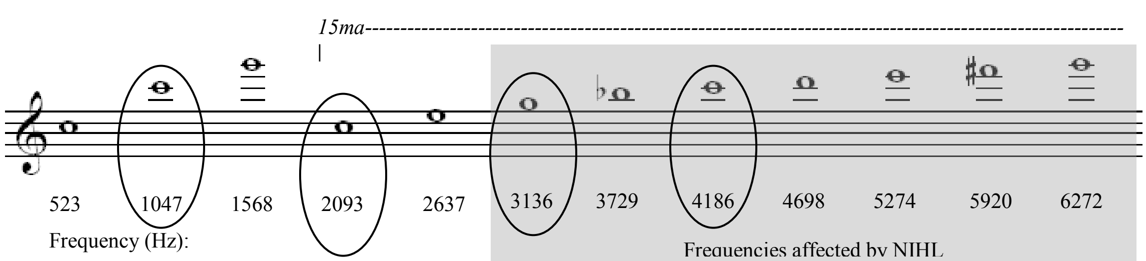
their sound to the overtones present in the sounds of others in order to be “in tune” with them (Fletcher & Rossing 1991; Chasin 1996; Titze 2006). Figure 3 further illustrates this idea. The fundamental notes through their twelfth partial are shown. Two instrumentalists playing those notes compare their own fundamental and overtones to those produced by the other instrumentalist. Note that some of the overtones occur in both series. A musician with NIHL will most likely have diminished hearing acuity for the uppermost overtones shown. This “missing information” may make matching pitch and blending timbre difficult.

Figure 3: Overtone Series on F and C, fundamental through 12th partial. Two instrumentalists playing the fundamental pitches would use the overtones shown to match pitch and timbre. Note that the circled overtones occur in both series. The marking “15ma” indicates that the written notes are sounded two octaves above the notated pitch.

F Fundamental and Overtones:



C Fundamental and Overtones:



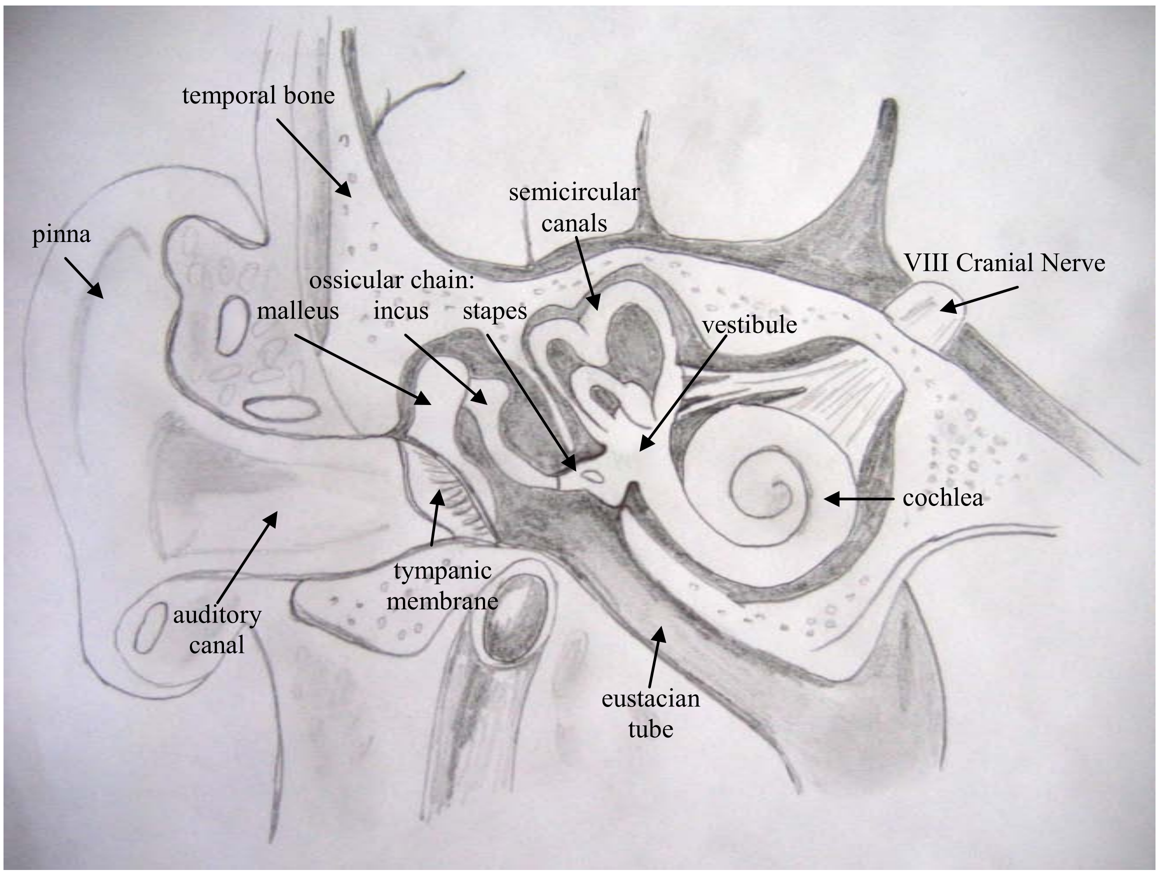
Anatomy of the Ear

In order to understand how intense sounds can cause hearing loss, it is necessary to understand the basics of the human hearing system. Information for this section comes from Yost (2007) and from lectures attended during Occupational Hearing Conservationist Training by the Workplace Group (Workplace Group 2008).[3]

The ear consists of three parts: the outer ear, the middle ear, and the inner ear. The outer ear consists of the pinna and the auditory canal (Figure 4). Made of cartilage, the many bumps and the overall funnel shape of the pinna help to collect sound waves and direct them into the auditory canal. This canal is approximately 1 ¼ inches in length and is generally “S” shaped.

[3] This is a brief description of the anatomy and mechanism of human hearing. For a more thorough discussion of anatomy and hearing see Yost or dissertations by Mace (2005) and Zeigler (1997).

Figure 4: Diagram of the Ear. (unpublished drawing by Susan M. Lynch, used with permission.) The outer ear consists of the pinna and the auditory canal. The pinna collects and funnels sound into the auditory canal, which ends at the tympanic membrane. The middle ear consists of the tympanic membrane and ossicular chain. Air pressure is regulated through a connection with the nasal cavity via the Eustachian tube. Consisting of the cochlea and semicircular canals, the inner ear is responsible for both hearing and balance.



The middle ear begins at the tympanic membrane and includes the ossicular chain. The tympanic membrane consists of three layers of tissue and transmits vibrations (Workplace Group 2008). The middle ear cavity is filled with air; air pressure is regulated in part by the Eustachian tube, which connects the middle ear to the nasal cavity. The ossicular chain consists of the three smallest bones in the body: the malleus, incus, and stapes. The malleus begins the chain and is connected to the tympanic membrane on one side and the incus on the other. The stapes completes the chain and is connected to the oval window of the inner ear (Yost 2007).

The inner ear consists of the vestibule, the semicircular canals, and the cochlea. The semicircular canals and vestibule are part of the human balance system. All three parts of the inner ear are housed in the temporal bone (Yost 2007). The cochlea is a fluid filled tube coiled upon itself, giving it a shell shaped structure. There are three fluid filled chambers within the cochlea. The innermost chamber is the cochlear duct. Within the cochlear duct is the Organ of Corti, which rest on top of the basilar membrane. Cilia, an outgrowth of hair cells, are found in the Organ of Corti. The shearing motion of the tectorial membrane[4] across the cilia creates nerve impulses that are transmitted to the brain by way of the VIII Cranial Nerve. Specific sections of the basilar membrane respond to specific frequencies.

Process of Hearing

As part of the hearing process, sound waves undergo various transformations in energy, as well as many increases in energy. The energy increase is necessary in order to transmit energy through the fluid of the inner ear. This information is summarized in Figure 5. While the hearing process is described here in a linear manner, it is a nearly instantaneous occurrence.

When the pinna collects sound waves, the sound is in the form of acoustic energy. During the process of funneling sound into the auditory canal, the intensity is increased

[4] The tectorial membrane is positioned above the Organ of Corti.

by 4 dB. Inside the auditory canal, the intensity of the sound waves is increased an additional 10 to 15 dB. When the sound waves encounter the tympanic membrane, the acoustic energy changes to mechanical energy. As the sound travels across the ossicular chain, the intensity is increased by another 25 to 30 dB. At the point at which the sound reaches the oval window, the intensity has increased by 39 to 49 dB (Workplace Group 2008). The fluid filled cochlea causes a change of energy from mechanical to hydro-mechanical. When the cilia within the Organ of Corti are stimulated, the energy changes once more to an electrochemical signal and travels to the brain.

In cases of extremely intense sound, the ossicular chain has a built in defense mechanism. Two muscles are attached to the chain: the stapedius and the tensor tympani. When a loud sound enters the ear, the signal sent from the cochlea to the brain triggers a response which makes the muscles contract, and therefore reduce the intensity of the sound reaching the inner ear (Yost 2007).

Figure 5: Summary of the Process of Hearing. Note the added energy level of the sound wave as it travels through the middle and outer ear. This is to make the sound wave strong enough to travel through the fluid of the inner ear.

	Outer Ear		**Middle Ear**		**Inner Ear**	
	Pinna	Ear Canal	Tympanic Membrane	Ossicular Chain	Cochlea	Cilia to VIII Cranial Nerve
Energy	Acoustic Energy		Mechanical Energy		Hydro-mechanical Energy	Electrochemical Energy
Increase in Intensity	+ 4 dB	+ 10 to 15 dB		+ 25-30 dB		

Types of Hearing Loss

Many types of hearing loss exist, each affecting different parts of the ear. Two classifications of hearing loss are conductive and sensorineural. A conductive hearing loss involves disorders of the outer or middle ear areas. With a conductive loss, sound often does not reach the inner ear. This type of loss can include damage to the tympanic membrane, wax build-up, infection, a collapsed auditory canal, or calcification of the ossicles, among other conditions (Workplace Group 2008). Conductive hearing loss is usually reversible via removal of the wax or surgery to repair the tympanic membrane or ossicles. Hearing aids can be used to amplify sound, helping to improve the hearing acuity of some who possess hearing loss (Ward, Royster, & Royster 2003).

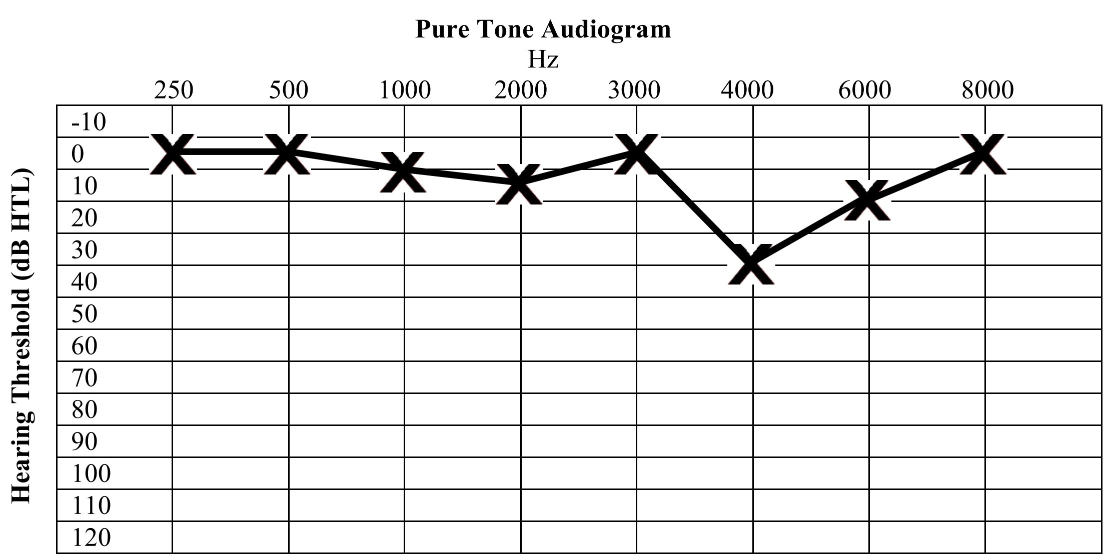
In contrast to a conductive loss, sensorineural hearing loss cannot be reversed.[5] Additionally, hearing aids are not effective for all people with a sensorineural hearing loss. If the damage to the cilia is too great, amplification in sound from the hearing aid may not produce vibrations large enough to be detected by the remaining cilia (National Institute on Deafness and Other Communication Disorders 2009). Causes of a sensorineural hearing loss are diverse, and include hereditary congenital deafness, Miniere’s disease, tumor of the VIII Cranial Nerve, loss due to medications, chemicals, or drugs, presbycusis, or noise-induced hearing loss (Workplace Group 2008). Presbycusis is “a slow and progressive deterioration of hearing that is associated with aging and not attributable to other causes” that firsts affects the 8,000 Hz range of hearing

[5] In a few years that statement may be false. There have been experimental treatments to repair damage to the cochlea and even regenerate hair cells, but none have yet been perfected.

(Schindler, Jackler, & Robinson 1997, p. 128). Musicians, as well as all people, over the age of 50 may begin to have hearing difficulty due to presbycusis, but it should not be a factor for younger musicians (Yost 2007).[6]

Noise-induced hearing loss (NIHL) is caused by damage to the cochlea of the inner ear. A preventable hearing loss, NIHL occurs as a result of three possible conditions: sounds that are too loud, moderate sounds that persist over long periods of time, or both (Berger 2003). When exposed to these sounds, cilia inside the cochlea are damaged and hair cells can die. As previously mentioned, NIHL occurs at specific frequencies, often first as a notch in the 3,000 to 6,000 Hz range (Schindler, Jackler, & Robinson 1997). Figure 6 shows an audiogram of early stage NIHL.

Figure 6: Audiogram of a Patient with NIHL. NIHL is indicated by a notch between 3,000 and 6,000 Hz. There should be a difference of a least 15 dB HTL[7] between the highest and lowest threshold, combined with a recovery after the dip.



[6] Measurable hearing loss occurs at a wide range of ages (Yost 2007). Some people may not be affected by presbycusis until much later in life.
[7] HTL stands for hearing threshold level, the lowest decibel at which the listener perceives a specific frequency. Audiometers measure perceived sound as dB HTL.

Noise-induced hearing loss is exhibited in two possible ways: a temporary threshold shift (TTS) or permanent threshold shift (PTS), both of which are an elevation in the thresholds of hearing. Possibly an early warning sign of PTS, TTS can be felt as a fullness or numbness in the ears after exposure to loud or prolonged sounds. With TTS, the cilia are not destroyed, and hearing should return to normal after 16 to 18 hours (Behar, Chasin, & Cheesman 2000). When PTS occurs, the hair cells in the cochlea are permanently damaged or destroyed, and hearing at that frequency is diminished, and in extreme cases, lost forever (Schindler, Jackler, & Robinson 1997). It should be noted that NIHL, like presbycusis, is a gradual process. Many people begin to damage their hearing at a young age, although the damage is not noticed until later in life.

Legislation and Standards

Government regulations in both the United States and abroad aim to limit the sound exposure of workers in various professions (Berger 2003b). In 1971[8] the Occupational Safety and Health Administration (OSHA) was created to oversee all manufacturing involved in interstate commerce.[9] The 1981 OSHA Noise Standard Amendment included more information on hearing conservation programs, while the 1983 revision further clarified guidelines. The 1983 revision is still in effect today

[8] The first federally mandated sound regulation in the United States was the Walsh-Healy Public Contracts Act of 1969. Industries with annual federal contracts of $10,000 or more were held to a PEL of 90 dBA for 8 hours of work (Workplace Group 2008).

[9] While this act included many government contracts with industries, it did not include mining, military, construction, or railroad. Today, The Construction Standard and the Mine Safety and Health Administration (MSHA) regulate standards for those industries (Workplace Group 2008). The U. S. Air Force and Army now have their own regulations of a PEL of 85 dBA for 8 hours with an exchange rate of 3 dB (Behar Chasin and Cheesman 2000).

(Workplace Group 2008). The current OSHA Permissive Exposure Level (PEL), or maximum allowable sound level, is 90 dBA[10] for 8 hours of work. The action level, or sound exposure level that requires enrollment in a hearing conservation program is 85 dBA TWA (time weighted average)[11] (Behar, Chasin, & Cheesman 2000). If a worker is exposed to more than an average of 85 dBA over the course of an eight hour work day, the worker and company must take steps to limit sound exposure, whether through the use of hearing protection devices or by "engineering out" noise sources.[12]

The National Institute for Occupational Health and Safety (NIOSH) is the research body that makes recommendations to OSHA. This group researches and develops health criteria for a broad range of concerns, including noise and hearing health. In 1998, NIOSH recommended a change from a PEL of 90 dBA to 85 dBA for 8 hours. They also recommended an exchange rate of 3 dBA (National Institute for Occupational Health and Safety 1998).[13] The exchange rate is the scale that determines the amount of time an employee may work in a certain noise environment before they are at risk of developing a hearing loss. With every change in the sound level of the working environment, there is a change in the amount of time a worker may be exposed to that

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[10] There are several weighting scales used to measure the intensity of sound in decibels. Human ears perceive equal intensity sounds of different frequencies as being different loudness levels. Sound level meters are equipped with filters that simulate how the ear perceives sound. One filter is known as the A frequency weighting filter, or "A" filter. This scale is used in standards and regulations that control environmental sound. Measurements are expressed in dBA (Behar, Chasin, and Cheesman 2000).

[11] A time-weighted average (TWA) specified here is an average sound exposure over the course of an eight hour work day. It is weighted with the "A" filter and is the average sound level over the eight-hour measurement period.

[12] An example of "engineering out" a noise source may be to add sound insulation around a loud piece of machinery to reduce its sound output.

[13] As of the writing of this dissertation, OSHA has not adopted these recommendations. The author speculates that concerns of increased cost to industries to implement these changes may by one reason for the lack of change.

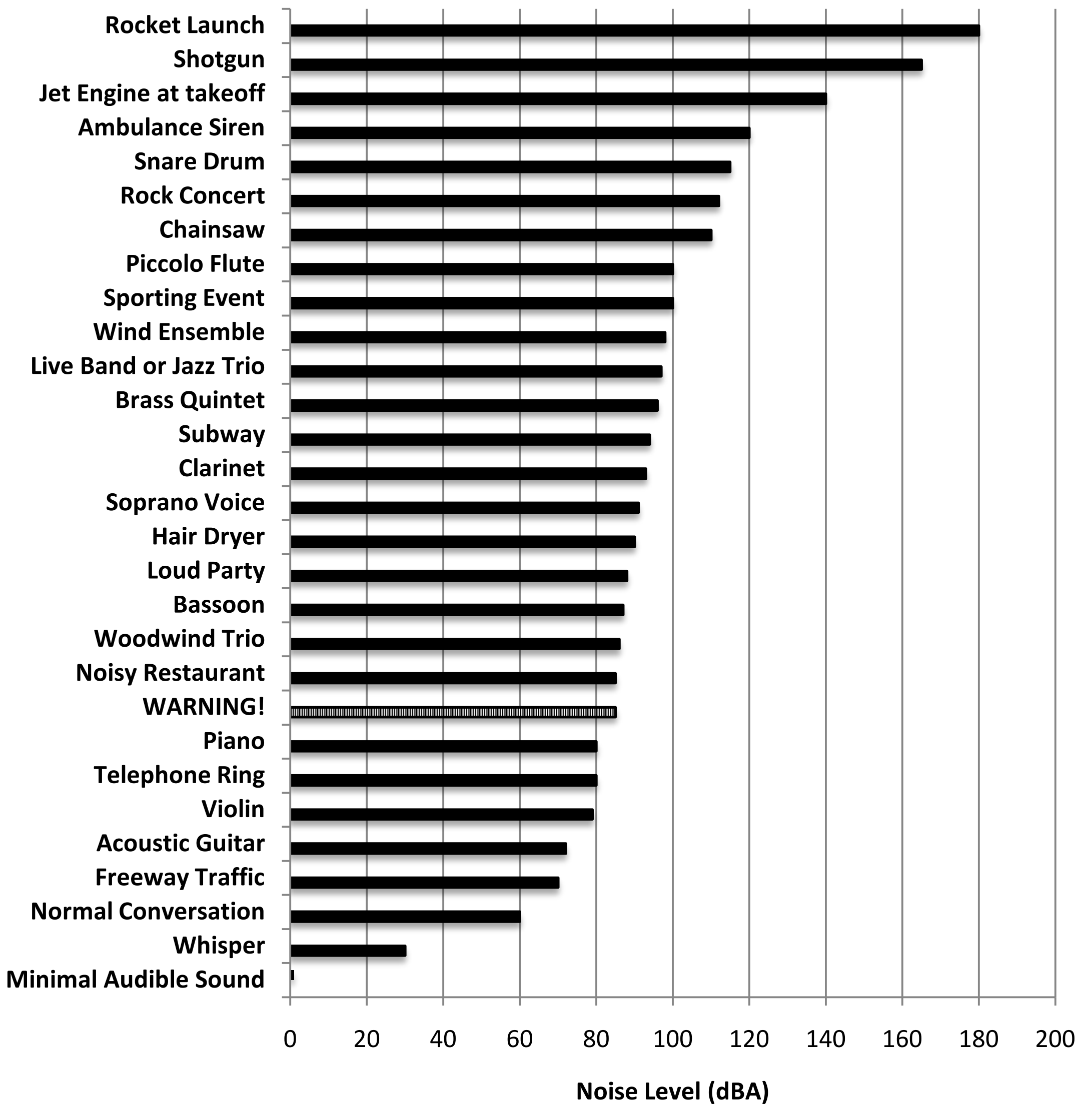
sound. For example, the OSHA recommended exchange rate is 5 dBA, therefore a worker may work for eight hours in a 90 dBA environment, but only 4 hours in a 95 dBA environment or 16 hours in an 85 dBA workplace before they are at risk of NIHL. According to the NIOSH standard with an exchange rate of 3 dBA and a recommended exposure level (REL) of 85 dBA, a worker may work for 8 hours in an 85 dBA environment, 4 hours in 88 dBA, and 16 hours in 82 dBA. Table 1 compares the two standards and exchange rates. While these numbers are very telling in the differences of what could be damaging, they mean little without a point of reference. For reference, Figure 7 is a chart of decibel levels of various human and music activities. For the purposes of this dissertation, the more conservative NIOSH standard has been used.

Table 1: Exchange Rates of NIOSH and OSHA Standards (National Institute for Occupational Safety and Health 1998; Occupational Safety and Health Administration 2009). According to each governing body, a person can safely be exposed to each decibel level for its corresponding time without risk of NIHL. For example, according to the OSHA standard, a person can withstand an environment with sound levels at 95 dBA for four hours. After four hours they are at risk for NIHL. NIOSH maintains that a person is safe in a 95 dBA environment for less than one hour.

NIOSH Standard	
Sound level (dBA)	**Duration (Hours: Minutes: Seconds)**
82	16:00:00
85	8:00:00
88	4:00:00
91	2:00:00
94	1:00:00
97	0:30:00
100	0:15:00
103	0:07:30
106	0:03:45
109	0:01:53
112	0:00:56
115	0:00:28
118	0:00:14
121	0:00:07
124	0:00:03
127	0:00:01

OSHA Standard	
Sound level (dBA)	**Duration (Hours: Minutes: Seconds)**
85	16:00:00
90	8:00:00
95	4:00:00
100	2:00:00
105	1:00:00
110	0:30:00
115	0:15:00
120	0:07:30
125	0:03:45
130	0:01:53
135	0:00:56
140	0:00:28
145	0:00:14
150	0:00:07
155	0:00:03
160	0:00:01

Figure 7: General Estimates of Human and Music Sounds (Table created from information supplied by National Institute for Occupational Safety and Health 1998, insert; Etymotic Research 2006, p. 4,; Schindler, Jackler, & Robinson 1997, p. 131, and MRi 2009). This table shows common sounds and corresponding decibel levels. From this figure and the previous NIOSH standard, it can be determined that a worker in a restaurant should work no more than 8 hours. A person attending a sporting event is only safe for 15 minutes. According to NIOSH, when engaging in an activity for eight hours that has a sound level over 85 dBA, caution should be used.



Using the time and average decibel level of an activity, a percent dose can be calculated. The percent dose is "the sound exposure expressed as a percentage of the daily allowable exposure" (Mace 2005, p. 122). In a given day, a person should not experience greater than 100% dose of sound. If the 100% dose of sound is exceeded, that person is at risk of experiencing NIHL. Using the OSHA standard, a 100% dose would be reached after 8 hours of continuous exposure to 90 dBA, while under the NIOSH recommendations, a 100% dose would occur after 8 hours of continuous exposure to 85 dBA.

Aim of the Present Study

Government regulations have lead to the development of earmuffs and earplugs for use in industry. Since hearing conservation has become of interest to musicians, hearing protection devices have been developed specifically for musicians for use in rehearsal and performance situations. One of these devices is the acoustic shield (Figure 8). Most shields are made of clear polycarbonate that allows the musician and the audience to see through the shield. The shields used in the current study include those made by Manhasset and Wenger. See Table 6 (Chapter 3, page 33) for a detailed description of these shields.

Figure 8: Three Acoustic Shields (unpublished photo by Sandra Mace, used with permission). From Left to Right: Wenger, North Carolina, Manhasset. A Wenger chair is also shown for reference of size. The Wenger and Manhasset shields are commercially available, while the North Carolina Shield was made by the staff of the North Carolina Symphony.

The aim of the present study was to determine the effectiveness of the above-mentioned acoustic shields in professional orchestral rehearsals. The one participant in the study was the author, a bassoonist. The primary research question was as follows: Do acoustic shields reduce sound levels experienced by a bassoonist to 85 dBA or below? A preliminary research question was: without an acoustic shield, do bassoonists in professional orchestras experience sound levels that exceed 85 dBA?

CHAPTER II

SURVEY OF LITERATURE

Noise-induced hearing loss is a topic that has seen much research in the last half-century. Since 1967, over 145 articles have been published about hearing loss as a result of exposure to intense sounds in a musical environment. Searches of available databases reveal articles that focus on music-induced hearing loss as a result of both leisure activities as well as a professional risk. The most common methods of data collection employed by the researchers in these studies is the survey, the use of a pure tone audiometer to measure hearing acuity, and sound level meters to measure sound levels in a music environment.[14] This chapter will describe in detail several articles that relate directly to this dissertation, including sound levels experienced when using acoustic shields, during orchestra rehearsals, and in other acoustic music making. Articles that focus on steel bands, personal music players, live discos, and live rock performances are listed in Appendix A.

[14] To measure sound levels, a microphone transforms pressure changes through the air into electrical signals that are then displayed as decibel levels. (Agrama, Sataloff, & Willcox 2006).

Acoustic Shield Studies

Thus far, only two studies have been conducted on the use and effectiveness of the shields. The second will be published in 2010. Both studies measured sound levels exclusively.

Table 2: Acoustic Shield Studies. Below is a chart summarizing studies that measured the effectiveness of acoustic shields.

Audiometry	Sound Level	Year	Authors	Title
	X	1992	Camp, J. E. & Horstman, S. W.	Musician sound exposure during performance of …
	X	2010	Libera, R. & Mace, S.	Shielding sound: a study on the effectiveness of…

In 1992, Camp and Horstman measured sound levels in the orchestra pit during a complete performance of Wagner's Ring Cycle. Using personal dosimeters, they found that sound levels were greatest for musicians in or near the brass section. Average hourly exposures for *Götterdammerung* ranged from 78.9 dBA to 101 dBA for approximately six hours. Camp and Horstman also found that sound levels were lower during rehearsals, both in the pit and in a rehearsal hall.

Of great interest to this dissertation is the evaluation of acoustic shields done by Camp and Horstman. They measured an unnamed shield in a controlled setting through the use of broadband and pure tone sound generators. A microphone, used to collect sound data, was placed at ear level 7 inches in front of the shield. When using the pure tone sound generator, they found that the shield attenuated sound levels by 17 dB at 6,000 Hz. Lower frequencies had less attenuation; at 2,000 Hz sound levels were attenuated by 13 dB, while at 500 Hz they were attenuated by only 8 dB. An interesting note is that at 250 Hz, sound levels increased by 2 dB when using an acoustic shield. Overall attenuation of a broadband sound was 3 to 4 dBA.

Libera and Mace (2010) tested the effectiveness of acoustic shields during collegiate ensemble rehearsals. The purpose was to determine which shields were the most effective. Measurements were made using one of two methods, 1. a dosimeter[15] on the shoulder of a musician sitting in front of the shield and 2. a dosimeter mounted on a tripod placed in front of a shield. With both methods, a dosimeter mounted on a tripod was placed to the right or left of the shield in order to measure levels without the protection of a shield. The two commercially available shields, manufactured by Wenger and Manhasset, performed equally during testing. Libera and Mace found that when a person was positioned in front of the trumpets, the acoustic shield reduced sound levels 75% of the time. When a tripod was used, sound levels were reduced 100% of the time. This may indicate that the movement of a musician while playing can impact effectiveness of the shields. The maximum attenuation measured was 4.6 dBA. In several instances, use of a shield resulted in an increase of sound by almost 4 dBA.

Orchestra Studies

Many studies have researched sound levels produced by an orchestra and the hearing acuity of instrumentalists in the orchestra. Studies involving sound level

[15] The dosimeter is a type of sound level meter that measures and averages sound levels across time. Dosimeters will be discussed more fully in the Chapter 3.

measurements will be described in detail, while the audiometric studies will be summarized.

Table 3: Orchestra Studies. Below is a chart summarizing studies that focused on the hearing of orchestral musicians as well as sound levels experienced while working in an orchestra.

Audiometry	Sound Level	Year	Authors	Title
X	X	1967	Flach, M. & Aschoff, E.	The risk of occupational deafness in musicians.
	X	1968	Lebo, C.P. & Oliphant, K. S.	Music as a source of acoustic trauma.
X	X	1981	Axelsson, A. & Lindgren, F.	Hearing in classical musicians.
X	X	1981	Westmore, G. & Eversden, I.	Noise-induced hearing loss and orchestral musicians
	X	1983	Jansson, E. & Karlsson, K.	Sound levels recorded within the symphony orchestra…
X		1983	Karlsson, K., Lundquist, P., & Olaussen, T.	The hearing of symphony orchestra musicians.
X		1985	Johnson, D., Sherman, R., Aldridge, J., & Lorraine, A.	Effects of instrument type and orchestral position on …
X		1986	Johnson, D., Sherman, R., Aldridge, J., & Lorraine, A.	Extended high frequency hearing sensitivity…
X		1989	Ostri, B., Eller, N., Dahlin, E., & Skylv, G.	Hearing impairment in orchestral musicians.
X	X	1991	Royster, J. D., Royster, L. H., & Killion, M. C.	Sound exposures and hearing thresholds of symphony…
X	X	1992	McBride, D., Gill, F., Proops, D., et al.	Noise and the classical musician.
X	X	1993	Fearn, R.W.	Hearing loss in musicians.
	X	1995	Lee, J., Behar, A., Kunov, H, & Wong, W.	Musicians' noise exposure in orchestra pit.
	X	1995	Mikl, K.	Orchestral music: an assessment of risk.
	X	1995	Sabesky, I. J. & Korczynski, R. E.	Noise exposure of symphony orchestra musicians.
	X	1999	Babin, A.	Orchestra pit sound level measurements …
X	X	1999	Obeling, L. & Poulsen, T.	Hearing ability in Danish symphony orchestra…
X		2001a	Kahari, K., Axelsson, A., Hellstrom, P., & Zachau, G.	Hearing assessment of classical orchestral…
X		2001b	Kahari, K., Axelsson, A., Hellstrom, P., & Zachau, G.	Hearing development in classical orchestral….
	X	2003	Laitinen, H., Toppila, E., Olkinuora, P., & Kuisma, K.	Sound exposure among the Finnish National Opera…
X	X	2007	Morais, D., Benito, J.I., & Almaraz, A.	Acoustic trauma in classical music players.

Table 3 Continued: Orchestra Studies.

Audiometry	Sound Level	Year	Authors	Title
X	X	2007	Nataletti, P., Sisto, R., Pieroni, A., et al.	Pilot study of professional exposure and hearing…
X	X	2007	Reuter, K. & Hammershøi, D.	Distortion product otoacoustic emission of…
X	X	2008	Emmerich, E., Rudel, L., & Richter, F.	Is the audiologic status of professional musicians a…
	X	2008	O'Brien, I., Wilson, W., & Bradley, A.	Nature of orchestral noise.

The results of studies that measured hearing acuity of orchestra musicians were mixed. Some researchers found evidence that exposure to high intensity sound during music making lead to NIHL, while others did not. Karlsson, Lundquist, and Olaussen (1983), Johnson, Sherman, Aldridge, and Lorraine (1986), Obeling and Poulsen (1999), Kahari, Axelsson, Hellstrom, and Zachau (2001a), Kahari, Axelsson, Hellstrom, and Zachau (2001b), all concluded that diminished hearing acuity of the musicians measured was not the result of NIHL caused by intense sounds while making music. In contrast, Axelsson and Lindgren (1981), Ostri, Eller, Dahlin, and Skylv (1989), Royster, Royster and Killion (1991), Morais, Benito, and Almaraz (2007), Emmerich, Rudel, Richter (2008), found evidence that musicians may experience NIHL as a result of their work.

Studies involving sound-level measurements have also lead to the conclusion that high-intensity sound from music does not put musicians at risk of NIHL. In 1968, Lebo and Oliphant compared sound levels of rock bands with fortissimo passages[16] of an orchestra. They found levels of the orchestra to be below 70 dB, while the rock bands

[16] The length of each measurement period was not reported, but the compositions played were. Three movements from Mussorgsky's *Pictures at an Exhibition* were used: "Bydlo," "Limoges," and "The Great Gate of Kiev." By referencing recordings by the Cleveland Orchestra and the New York Philharmonic, the author found that "Bydlo" is approximately 2 minutes and 30 seconds, "Limoges" is approximately 1 minute and 30 seconds, and "The Great Gate of Kiev" is 5 to 6 minutes in length.

levels were usually greater than 95 dB.[17] The orchestra was deemed a non-hazardous working environment.[18]

In 1995, Lee, Behar, Kunov, & Wong also determined that the music environment of their study was non-hazardous. While testing musicians in the pit of the Canadian Opera Company over the course of 18 three-hour sessions, they measured levels between 82.8 and 93.7 dB L_{Aeq},[19] but concluded that the relatively short duration of exposure to high sound levels during opera rehearsals alone was not enough to put the musicians at risk of NIHL. Lee et al. (1995) conceded that individual practice and rehearsals or performances with other orchestras was not taken into consideration. More time performing will increase the exposure time and may put a musician at risk of NIHL.

In 1999, Obeling and Poulsen concluded that working in an orchestra does not lead to NIHL. Fifty-seven musicians from symphonies in Denmark were tested. Resulting audiograms showed an age-related hearing loss, not a noise-induced hearing loss. Sound-level measurements taken with a personal dosimeter were found to be between 83.5 and 95.1 dB L_{Aeq}, with the peak in the horn section at 140.6 dBA.

In contrast to the above articles, a study conducted by Axelsson and Lindgren (1981) found evidence that classical music can be performed at levels that cause NIHL. They measured sound levels between 78 and 94 dB L_{Aeq}. Pure-tone audiometry indicated NIHL in 32% of the musicians tested, while 43% had poorer hearing acuity than their age

[17] Weighting scale not specified (i.e. dBA, or dBC). Decibel levels were reported in dB.
[18] It should be noted that the orchestra was tested in an empty auditorium, from the center of the room, not among the musicians. Measurements taken close to the sound source may produce different sound levels than those taken from a distance. Generally, a close proximity to the source would produce a higher sound level.
[19] L_{Aeq} (equivalent continuous sound level) is “a measure of the average sound level during a period of time in dBA” (Cirrus Research 2002, p. 50).

group. Westmore and Eversden (1981) also concluded that musicians are exposed to potentially damaging sound levels. They found hearing thresholds that indicate NIHL, but reported them as "slight and asymptomatic," and did not limit any of the musicians' ability to do their job (Westmore & Eversden 1981, p. 764).

Royster, Royster and Killion (1991) administered audiometric testing to members of the Chicago Symphony Orchestra. Of the musicians tested, 52.5% had a notch consistent with NIHL. The researchers also measured sound levels and found a mean of 89.9 dB L_{Aeq} for large ensemble rehearsals. A correlation was found between a musician's individual sound exposure and hearing loss: those with hearing loss had been exposed to high sound levels.

In 1995, Mikl published an extensive study to measure sound levels over a long period of time. A problem with previous studies of sound levels was that they only measured a limited amount of time. Mikl measured levels over an entire season of the pit[20] orchestra of the Australian Opera and Ballet Company. He found that musicians are at repeated risk due to high levels. The only person in the pit not at risk was the conductor. Levels for musicians were as low as 85 dB L_{Aeq} to well above 90 dB L_{Aeq}.[21]

Also in 1995, Sabesky and Korczynski found levels that exceed Canadian Standards.[22] Sound levels measured in the rehearsal room of the Winnipeg Symphony

[20] A pit is an area below stage level, with a portion of it often below the stage itself. The space is usually small. The low roof over part of the orchestra can create an increase in sound due to greater reflections of the sound waves.
[21] Exact data was not reported. From the graphs provided, it could be seen that some levels were above 90 dB $L_{Aeq.}$
[22] A conservation program is required in sound environments that exceed 80 dBA during an eight hour work day. Hearing protection must be used when the average sound level exceeds 90 dBA for eight hours. Hearing protection devices must be available at the worker's request when the 8-hour LA_{eq} reaches 85dBA.

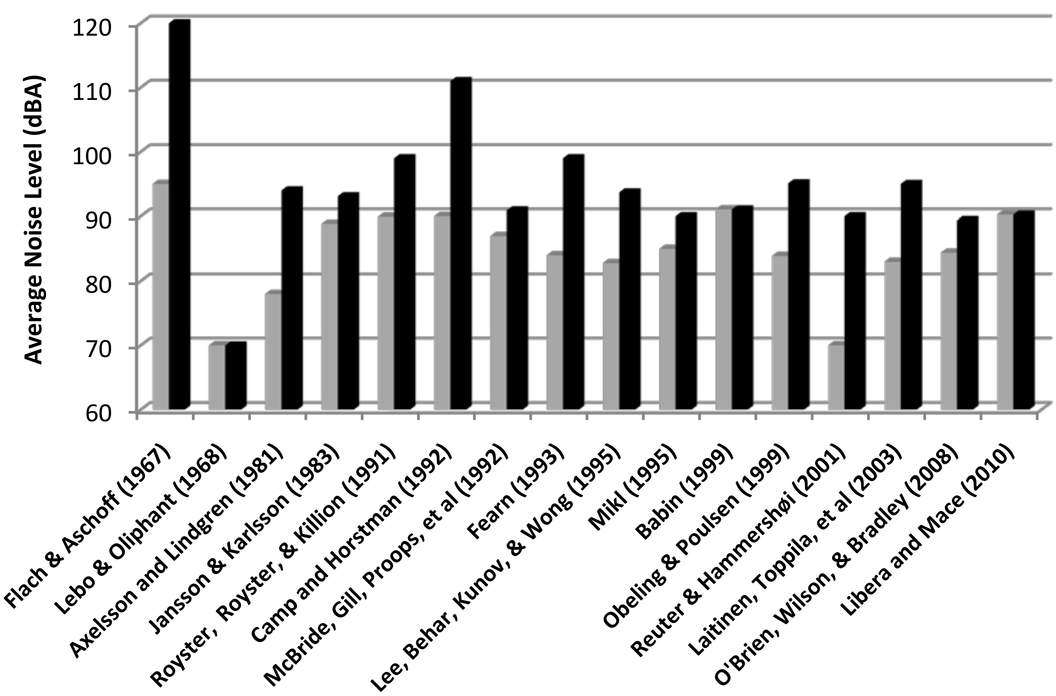
Orchestra were between 88 and 90 dB L_{Aeq} across a six-hour rehearsal. Exposure for 2.5 hours in the pit was lower, between 85 and 86 dB L_{Aeq}. Performance on the main concert stage resulted in levels of 82, 94, and 88 dB L_{Aeq} across 2.5 to 3 hours.

In perhaps the most thorough investigation of sound exposure to date, O'Brien, Wilson, and Bradley (2008) studied the Queensland Orchestra of Brisbane, Australia over the course of three years. The mean ranges of exposure were between 84.4 and 89.8 dB L_{Aeq}.[23] The authors noted that three key variables influenced sound exposure: venue, repertoire, and position within the orchestra. Principal trumpet, first and third horns, and principal trombone were found to have experienced the highest levels of sound.

The remaining studies by Flach and Aschoff (1967), Jansson and Karlsson (1983), McBride, Gill, Proops, Harrington, Gardiner, and Attwell (1992), Fearn (1993), Babin (1999), Laitinen, Toppila, Olkinuora, and Kuisma (2003), and Reuter and Hammershøi (2007) measured sound levels that exceed recommended levels. The results of all sound level measurements taken within orchestras are summarized in Figure 9.

[23] Time of each measurement period was not reported.

Figure 9: Average Sound Level of Orchestras. Summary of sound levels from studies conducted on orchestras. Studies with two different decibel levels indicate that a range was given. Reuter & Hammershøi, McBride, Gill & Proops, and Lebo & Oliphant measured sound level from the area of the conductor. Other members in the orchestra may have experienced much higher sound levels. Also note, Flach and Aschoff reported maximum sound levels. Time of exposure varied between each study.



Acoustic Music Studies

This category of research includes articles that focused on music making by ensembles that consist mostly of acoustic (non-amplified) instruments.[24] These include choral ensembles, jazz bands, Chinese Classical Music, and research conducted in practice rooms and on particular instrumental groups and music teachers. Selected studies are described in detail.

[24] The exception to this is jazz bands. Jazz bands often use electric guitars, amplified bass and piano, and sometimes amplified soloists.

Table 4: Acoustic Music Studies. Below is a chart summarizing studies involving both audiometry and the measuring of sound levels of classical music making. Here nearly all instruments are acoustic, or non-amplified.

Audiometry	Sound Level	Year	Authors	Title
X	X	1972	Jahto, K. & Hellman, H.	Loss of hearing in orchestral musicians.
X	X	1981	Pang-Ching, G.	Hearing levels of secondary school band directors.
	X	1988	Hartenstein, R.W. & Brittain, S.M.	A piper's warning.
X	X	1989	Cutietta, R., Millin, J., & Royse, D.	Noise induced hearing loss among school band directors.
X	X	1992	Bu, G.	Prevention of NIHL in musicians of Chinese opera.
X		1994	Cutietta, R., Klich, R., Royse, D., & Rainbolt, H.	Incidence of NIHL among music teachers.
X		1994	Fearn R.W. & Hanson D.R.	Hearing disability in music and non-music students
X		1994	Schmidt, J. M., Verschuure, J., & Brocaar, M. P.	Hearing loss in students at a conservatory.
	X	1996	Early, K. L. & Hortsman, S. W.	Noise exposure to musicians during practice.
X		1998	Steurer, M., Simak, S., Denk, D.M., Kautzky, M.	Does choir singing cause noise-induced hearing loss?
	X	2000b	Chesky, K. & Henoch, M.	Sound exposure levels experienced by a college…
(survey)		2000a	Chesky, K. & Henoch, M.	Instrument-specific reports of hearing loss…
X		2003	Kahari, K., Zachau, G., Eklof, M., et al.	Assessment of hearing and hearing disorders in…
	X	2004	Behar, A., MacDonald, E., Lee, J., et al.	Noise exposure of music teachers.
X		2006	Cunningham, D., Hoffman, J., & Lorenz, D.	Auditory thresholds and factors contributing to…
	X	2007	Mendes, M.H., Morata, T.C., Marques, J.M	Acceptance of hearing protection aids in…
	X	2007	Presley, D	An analysis of sound-level exposures of drum and…
X		2008	Hamdan, A., Abouchacra, K., Zeki, A., et al.	Transient-evoked otoacoustic emissions in a group of…
	X	2008	Phillips, S. & Mace, S.	Sound level measurements in music practice rooms.

In many of the following studies, sound levels measured were in excess of NIOSH recommended limits. As described above, there has been much research on the effects of sound to music performers. Music teachers are also exposed to this sound on a daily basis as part of their profession. Pang-Ching (1982) and Cutietta, Klich, Royse, and Rainbolt (1994) tested for the hearing thresholds of elementary choral or general music teachers, elementary instrumental music teachers, and high school band directors. Both studies found evidence of NIHL.

Cutietta, Millin, and Royse (1989) measured sound levels in high school bands. They found that the levels experienced are above standards set for industry, and that sound levels of bands can be 7 to 12 dBA higher than levels produced by orchestras. Behar, MacDonald, Lee, Cui, Kunov, and Wong (2004) tested 15 teachers in Canada. The continuous equivalent sound level for an eight-hour measurement period was above 85 dBA for 78% of the teachers observed.

Musicians of all levels spend a great amount of time practicing. At colleges and universities, music majors practice in small rooms. Phillips and Mace (2008) studied the sound levels experienced by brass, woodwind, string, percussion, and voice students in these practice rooms. The average sound level for the five groups was found to be between 87 and 95 dB L_{Aeq}. The three hours of exposure to the levels produced percent dose measurements between 59.5% and 180%. The researchers discovered that nearly half of all students would exceed their daily allowable dose of sound from these three hours of practicing. Brass-playing students produced the highest sound levels, followed by woodwinds, then percussion. Vocalists and string players produced the lowest sound levels.

Jazz is another type of music often studied in university schools of music. In 2003, Kahari, Zachau, Eklof, Sandsjo, and Moller tested 139 rock/jazz musicians and found that 74% had some form of hearing damage.[25] Sound levels ranged from 90.8 dB L_{Aeq} to 115 dB L_{Aeq} during measurement periods ranging from 50 minutes to 3 hours. The authors note that while NIHL was not present among all musicians, other hearing disorders were found. Chesky and Henoch (2000b) measured sound levels in the University of North Texas Jazz ensemble. Over the course of three days, 15 measurements were obtained. Ten of the 15, or 66% of students exceeded the maximum allowable daily dose set by OSHA in three hours.

In 2007, Presley measured sound levels experienced by percussionists in a drum corps. He found that levels ranged from 92.5 dB L_{Aeq} for a vibraphone player to 103.1 dB L_{Aeq} for a snare drum player. Twelve-hour measurements were made during an all-day camp. The extended time period combined with the high sound levels produced percent doses that ranged from 897.97% to 9455.49%.

Remaining Studies

The remaining studies all investigate instances of NIHL as the result of high-intensity music, but are not relevant to this dissertation and will not be described here. Studies involving steel bands, headphone use, live rock, and clubs/discos are listed in Appendix A for reference purposes.

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[25] The authors did distinguish between jazz and rock musicians in this study. Amplified instruments were present for all groups studied.

Summary of the Literature

Camp and Horstman (1992) and Libera and Mace (2010) found that acoustic shields attenuated non-pure tone sounds between 0 and 4.6 dBA. Camp and Horstman used a controlled setting for their measurements, while Libera and Mace tested the shields during rehearsals. Possibly due to movement of the musicians while they played, Libera and Mace found that in certain situations the shields were not effective. In both studies, the use of an acoustic shield sometimes resulted in increased sound levels.

Sound levels measured during a high school band rehearsal were above industry standards (Cutietta, Millin, and Royse 1989), and music teachers have been found to have NIHL (Pang-Ching 1982 and Cutietta, Klich, Royse, and Rainbolt 1994). Phillips and Mace (2009) found that university student musicians are exposed to high sound levels while practicing, producing percent dose measurements between 59.5% and 180%.

Studies conducted on the hearing acuity of orchestral musicians often contradict each other. Based on the measurements of hearing acuity, some researchers have found evidence that high intensity sounds experienced while working as a musician can lead to NIHL, while others concluded that these sounds have not caused NIHL. Similarly, the measurements of noise levels in orchestras have led some researchers to conclude that musicians are exposed to potentially hazardous sound levels, while others maintain that the orchestral working environment is non-hazardous.

CHAPTER III

PROCEDURES

The purpose of this dissertation was to determine the effectiveness of acoustic shields at reducing sound levels experienced by a bassoonist during rehearsals of two professional orchestras. The study by Camp and Horstman (1992), as well as in-house testing by Wenger,[26] measured the shields' effectiveness in a controlled setting. In contrast, this current study measured effectiveness of the shield during use in live rehearsals. The researcher obtained sound-level measurements during rehearsals with and without the use of acoustic shields. By comparing results, the effectiveness of the shields can be assessed. This study incorporated variables that are present in a live situation that may not be present in a laboratory setting. These variables include the possibility of multiple sound sources and the influence of musician movement on the effectiveness of the shield.

The primary research question was as follows: Do acoustic shields reduce sound levels experienced by a bassoonist to 85 dBA or below? A preliminary research question was: without an acoustic shield, do bassoonists in professional orchestras experience sound levels that exceed 85 dBA? The National Institute of Occupational Safety and Health (NIOSH) recommended exposure level is 85 dBA for an eight-hour workday. The Occupational Safety and Health Administration (OSHA) requires hearing safety

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[26] The results of the Wenger testing were reported on a promotional flier about the product. It was found that "the initial wave from a loud musical sound (like a trumpet blast) can be reduced up to 40% in perceived loudness of the higher frequencies (above 2 KHz)" (Wenger Corporation 2006).

education and access to hearing protection for workers exposed to an average of 85 dBA. Musicians should consider using hearing protection during activities averaging 85 dBA or greater. Although rehearsal periods measured were 2.8 hours, the subject's music activities in a typical workday totaled 8.8 hours, thus NIOSH recommendations are appropriate. Table 5 summarizes a typical day for the bassoonist in the study.

Table 5: Typical Day of the Bassoonist. The time of all musical activities in a day total 8.8 hours, making NIOSH recommendations appropriate. The TWA is above this recommendation, and the percent dose is over two times the recommended maximum amount.

Activity	**Decibel Level**	**Percent Dose**
Lesson (1 hour)	77.20 dBA	2.92 %
Chamber music (1 hour)	85.85 dBA	15.99 %
Practicing (3 hours)	86.08 dBA	60.15 %
Wind Ensemble (1 hour)	90.48 dBA	46.81 %
Professional Rehearsal (2.8 hours)	88.40 dBA	76.78 %
TOTAL (8.8 hours)	**88.07 dBA TWA**	**202.65%**

Selection of Subject and Venues

The author was the single participant in this study.[27] As a member of two orchestras, access was simple and a matter of convenience for the researcher. Orchestras that granted permission for data collection to occur during rehearsals were the Western Piedmont Symphony, John Gordon Ross, music director, and the Salisbury Symphony Orchestra, David Hagy music director.[28]

[27] As the author was the test subject, the Institutional Research Board of UNCG did not require an application for this study.
[28] The Western Piedmont Symphony is located in Hickory, NC. The Salisbury Symphony is based in Salisbury, NC.

Acoustic Shields Tested

Based on the findings of Libera and Mace (2010), two commercially available shields were used in this study. These shields were made by Wenger and Manhasset (Figures 10 and 11).[29] See Table 6 for a detailed description of the shields. The total number of rehearsals measured was sixteen. Due to scheduling requirements, the Wenger shield was used in nine rehearsals and the Manhasset in seven. Both the Wenger and Manhasset shields were used in rehearsals for both symphonies.

Figure 10: Manhasset Acoustic Shield (unpublished photo by Sandra Mace, used with permission). This shield features a base that can be adjusted with one hand as well as a large surface area.

[29] See Figure 8 (Chapter 1, pg. 16) for a side by side view of the shields.

Figure 11: Wenger Acoustic Shield (unpublished photo by Sandra Mace, used with permission). This shield features a folding base for easy portability and side panels.

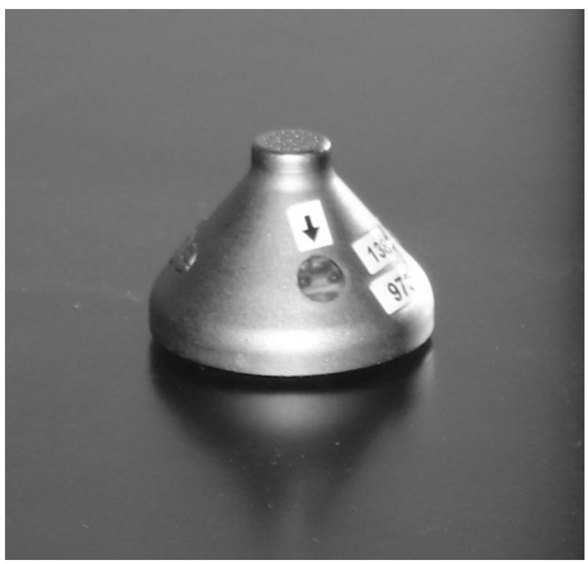
Table 6: Description of Shields (adapted from Libera & Mace 2010). For this study two commercially available acoustic shields were measured.

	Manhasset	**Wenger**
Shield Material	• Clear polycarbonate • 5/32 in. thick	• Clear polycarbonate • 7/32 in. thick
Description of Base	• Straight • One hand allows height adjustment • Enables shield to tilt • 20 in. diameter	• Can be angled • Two hands needed for height adjustment • Base allows close position to chair and musician • 22.5 in. diameter
Shield Dimensions (width x height)	• 26 in. x 22 in.	• 17.5 in. x 17 in. (excluding side panels)
Side Panel Dimensions	• None • Does have bottom ledge (1.5 in.)	• 3 in. x 17 in.
Side Panel Angle	• NA	• 153°
Min / Max Height	• 45/67in.	• 29.75/60 in.
Portability	• Top Heavy • Shield can be removed from stand • Base collapses onto stand	• Folds • Base includes handle • Balanced when folded

Data Collection Methodology

A CR: 100B doseBadge (Figure 12) was used to measure sound levels during the orchestra rehearsals. This personal dosimeter, made by Cirrus Research®, measures and reports the average decibel level for each minute of rehearsal, as well as an average for the entire measurement period. Using the time of rehearsal and average decibel level of each rehearsal, the percent dose was calculated.[30] Results obtained using the doseBadge are specific to the bassoonist's instrument and location in ensembles. Other orchestra members may have experienced lower or higher sound levels.

Figure 12: Picture of a doseBadge (unpublished photo by author). This device is worn on the shoulder and measures the sound level experienced by that person.



[30] See Appendix B for method of percent dose calculation.

During rehearsals, the author wore a doseBadge on each shoulder and was protected by an acoustic shield placed behind the chair. Sound levels outside the protected area of the shield were measured by dosimeters on two tripods positioned 10 inches beyond the left and right edges of the shield. (Figures 13 and 14).

Figure 13: Picture of Rehearsal Set-up (unpublished photo by author). This picture shows the Wenger shield and tripods in use at a rehearsal for the Salisbury Symphony.

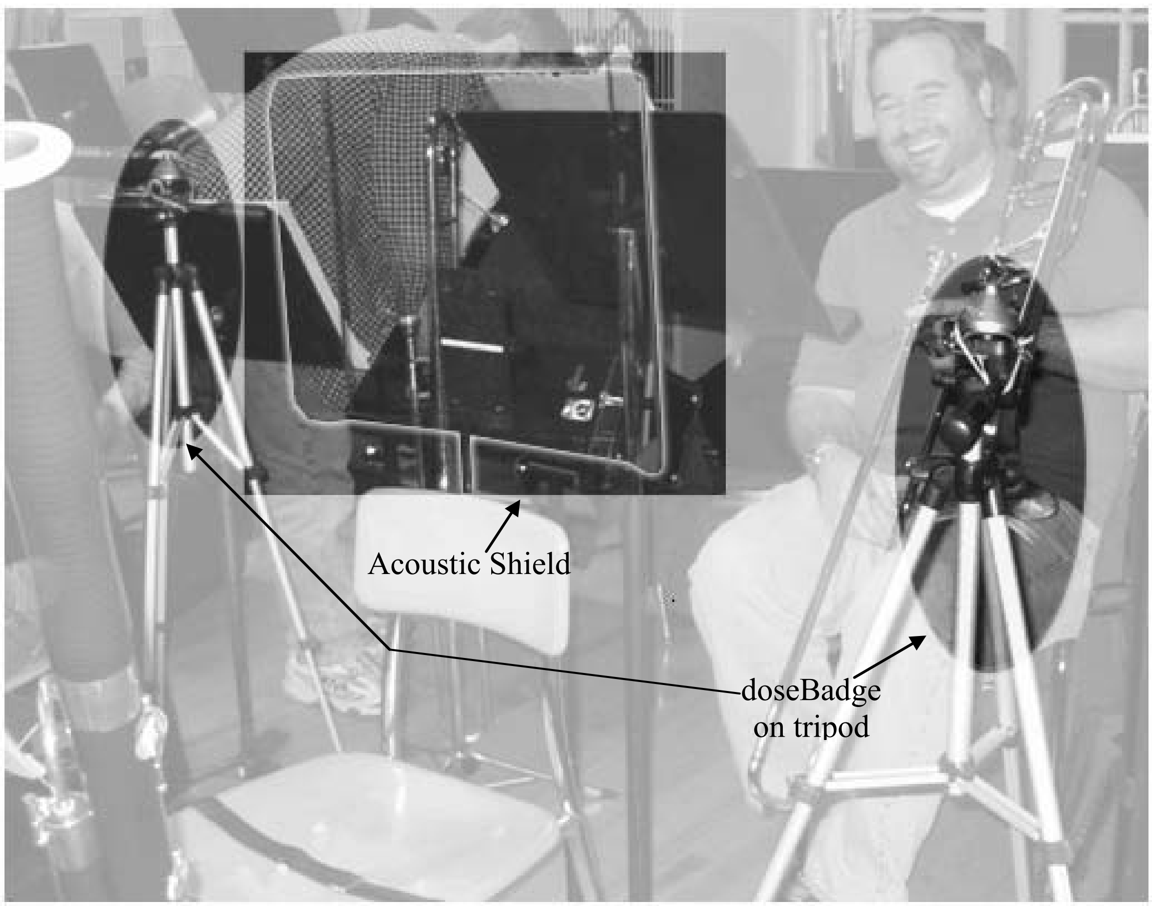
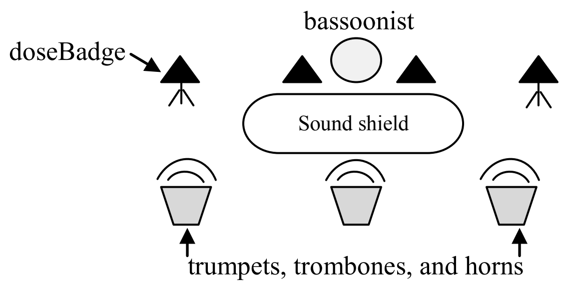


Figure 14: Diagram of Testing Set-up (aerial view). The test subject wore two doseBadges on her shoulders while protected by an acoustic shield. Two doseBadges on tripods were placed to the sides in order to obtain unprotected sound levels.



Data Collection and Measurement Period

Data were collected during the 2007-2008 season, specifically between October 29, 2007 and April 10, 2008. Measurements were made over the course of sixteen rehearsals. The typical length of each rehearsal period was 2.8 hours, or 168 minutes. Several minutes prior to and at the conclusion of each rehearsal were included in data analysis as musicians surrounding the bassoonist continued to produce high intensity sound during that time.

CHAPTER IV

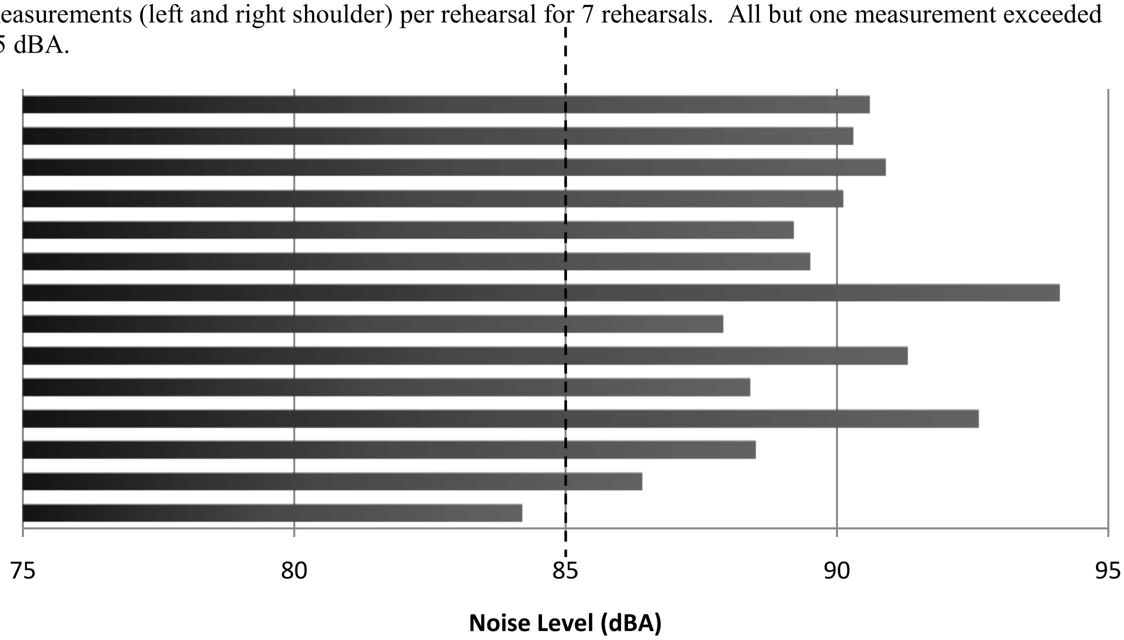
RESULTS

Results of this study are discussed in context of two research questions. For tables summarizing the data, please see Appendix C.

Preliminary Research Question

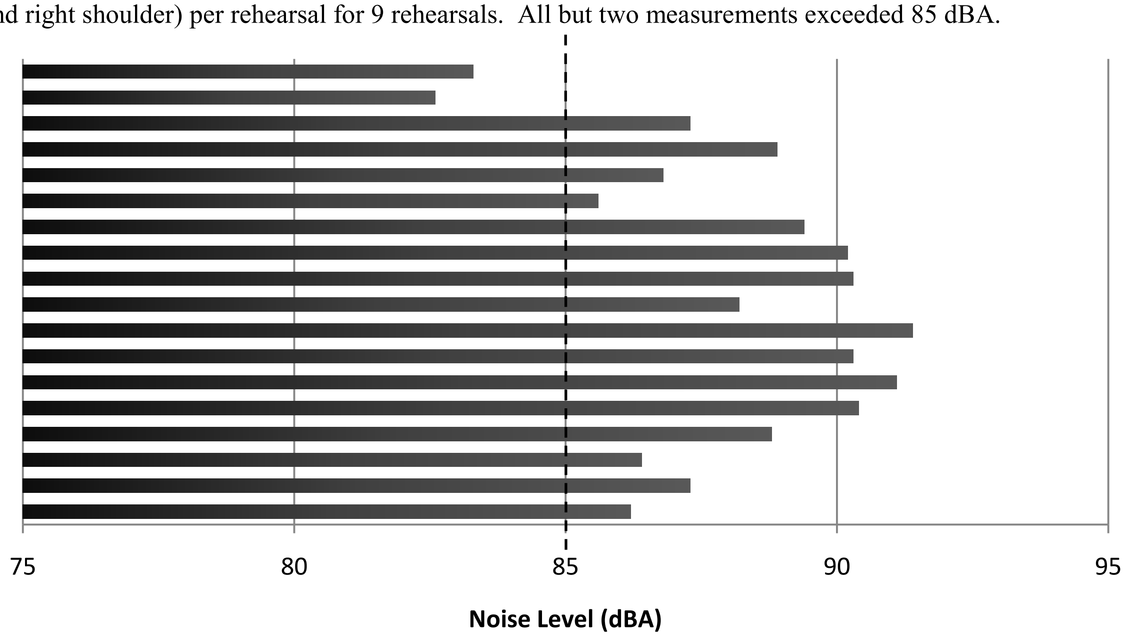
Without an acoustic shield, do bassoonists in professional orchestras experience sound levels that exceed 85 dBA? Figures 15 and 16 show the results of sound measurements in various rehearsals. These data were collected without the use of acoustic shields. For easier readability, the data were separated into charts representing days on which each shield was used.

Figure 15: Non-shielded Sound Levels, Manhasset Shield. This chart shows the non-shielded sound levels experienced during rehearsals in which the Manhasset shield was used. This reflects two measurements (left and right shoulder) per rehearsal for 7 rehearsals. All but one measurement exceeded 85 dBA.



Mean: 89.57 Median: 89.80 Standard Deviation: 2.49

Figure 16: Non-shielded Sound Levels, Wenger Shield. This chart shows the non-shielded sound levels experienced during rehearsals in which the Wenger shield was used. This reflects two measurements (left and right shoulder) per rehearsal for 9 rehearsals. All but two measurements exceeded 85 dBA.



Mean: 88.02 Median: 88.50 Standard Deviation: 2.56

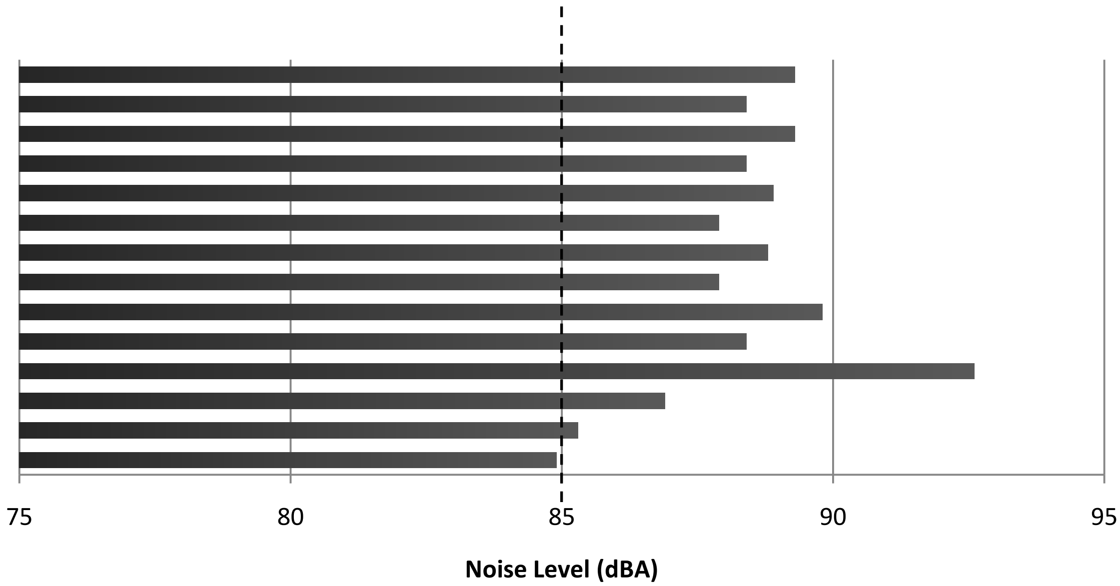
Of the above 34 rehearsals measurements,[31] 3 were below 85 dBA. Ninety-one percent of the rehearsals measured greater than 85 dBA, thus, the answer to the preliminary research question is “yes.” Without an acoustic shield, bassoonists in professional orchestras do experience sound levels that exceed 85 dBA.

Primary Research Question

The primary research question was as follows: Do acoustic shields reduce sound levels experienced by a bassoonist to 85 dBA or below? Figures 17 and 18 show the sound level measured during each rehearsal when the bassoonist was using an acoustic shield.

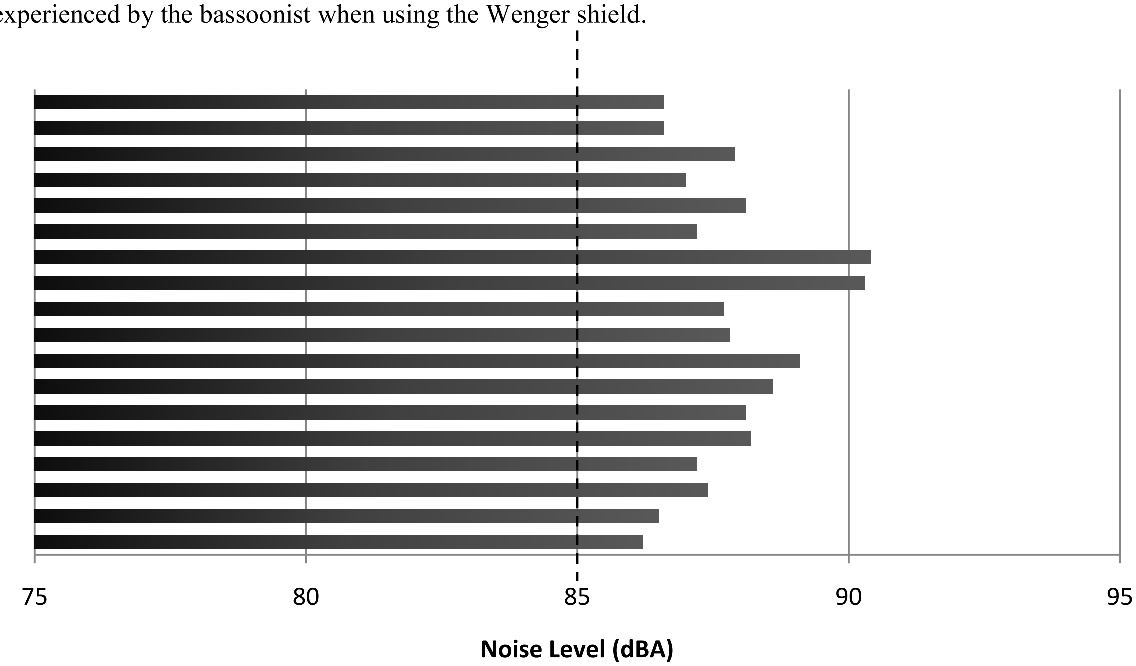
[31] Sixteen rehearsals, with two measurements (one on each side of the bassoonist) each rehearsal equals 34 rehearsal measurements.

Figure 17: Sound Levels, with Protection by Manhasset Shield. This chart shows the sound levels experienced by the bassoonist when using the Manhasset shield.



Mean: 88.34 Median: 88.40 Standard Deviation: 1.89

Figure 18: Sound Levels, with Protection by Wenger Shield. This chart shows the sound levels experienced by the bassoonist when using the Wenger shield.



Mean: 87.83 Median: 87.75 Standard Deviation: 1.20

Of the 34 measurements, only one had a sound-level average below 85 dBA when using an acoustic shield. The use of acoustic shields actually increased the sound level in several cases, making a situation that was considered safe, unsafe. The answer to the primary research question is “no,” the use of acoustic shields does not reduce sound levels to 85 dBA or below.

CHAPTER V

DISCUSSION, SUMMARY, AND CONCLUSIONS

While the acoustic shields did not reduce the sound levels to 85 dBA, in many instances sound was reduced. Because of the relatively short duration of rehearsal, this reduction of sound levels may be enough for a bassoonist to avoid overexposure. In the following sections, the influence of time and the use of shields will be discussed. Differences in sound levels between using a shield and not using a shield will also be outlined. The author proposes an explanation for some of the increases in sound levels.

Differences and Sound Sources

In general, sound levels were reduced when using a shield, although as already noted, all but one measurement was above 85 dBA when using a shield. Figures 19 and 20 show differences of sound levels with and without the protection of a shield. The graph shows time as a reference for the percent dose reading, the differences in sound levels, and the differences in the percent doses. A positive number for the differences in sound level and percent dose indicates that the sound level was reduced when using an acoustic shield, while a negative number indicates that the sound level was greater when using an acoustic shield. Each of these measurements was taken when the primary sound source was located behind the bassoonist. Not included in Figures 19 and 20 are some abnormal data that occurred as the result of side-positioned sound sources.

Figure 19: Differences when Using Manhasset Shield. This graph shows the results of the measurements taken with the Manhasset shield. This shield did reduce sound levels most of the time. One instance in which the sound level increased when using a shield is indicated by a negative number. Adjacent bars with the same time represent different readings from different shoulders during the same rehearsal. Also note that due to space, "Time" and "Difference in Percent Dose" have been divided by 10.

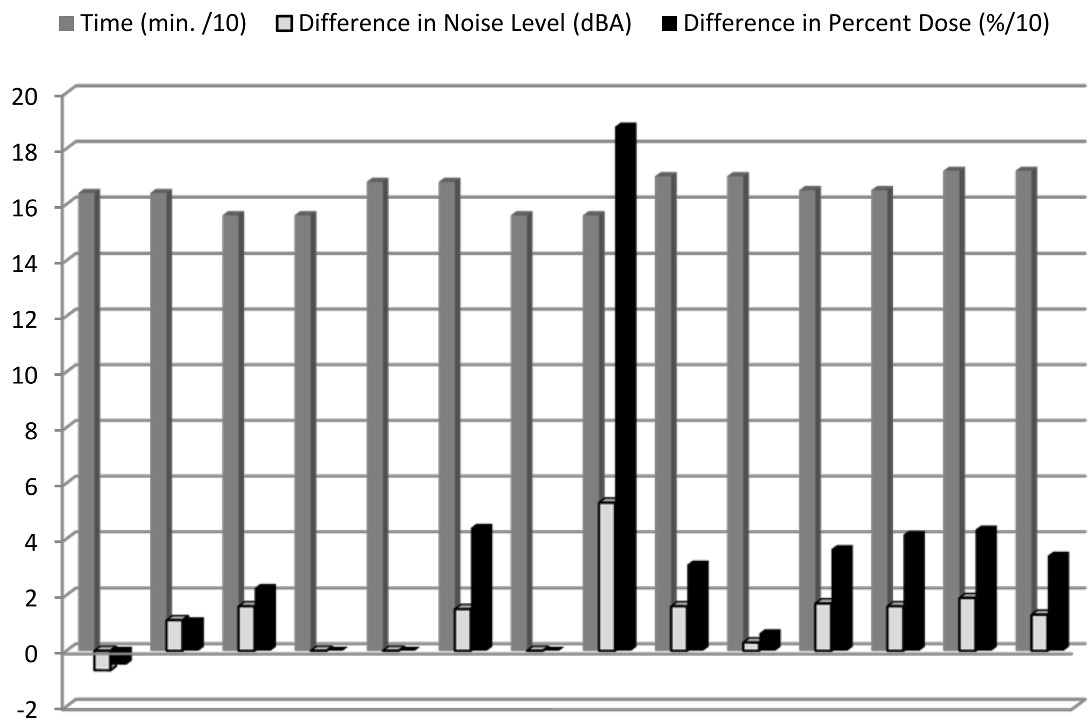
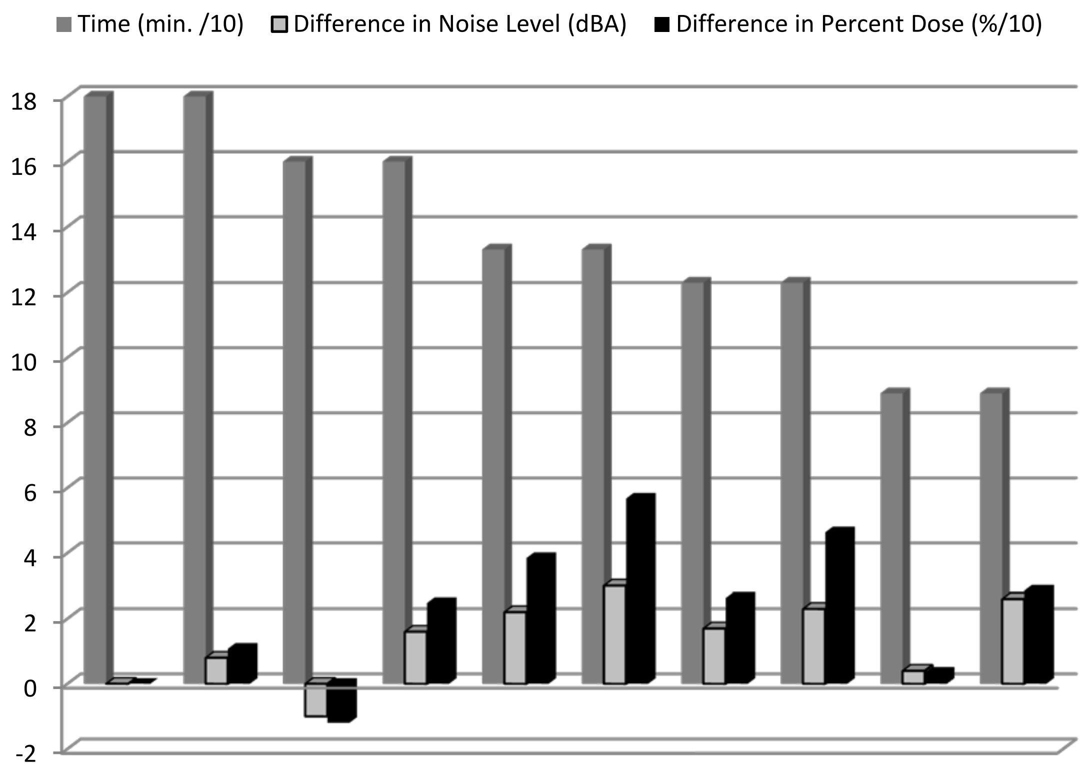


Figure 20: Differences when Using Wenger Shield. Like the Manhasset, nearly all recorded data showed a reduction in sound levels when using the Wenger shield. Due to space, “Time” and “Difference in Percent Dose” have both been divided by 10.



When using the shields, sound levels were reduced in all but one instance. The consistency may be due in part to the authors’ ability to keep her head close to the shield. The average reduction of sound levels when using a shield was 1.28 dBA. During four additional rehearsals, the bassoonist experienced an increase in sound levels. The differences in sound level and percent dose for those rehearsals are shown in Figure 21. These have been shown separately because the difference in arrangement of the ensemble may explain the increase in sound level. In each of these rehearsals, a significant sound source was located at the side of the bassoonist. Figure 22 shows the ensemble arrangement used for two of the four rehearsals, while Figure 23 shows the arrangement for the others.

Figure 21: Side Sound Source Differences. This graph shows the differences in sound levels when sound approached the bassoonist from the side while using a shield. Only one instance resulted in reduced sound levels. Adjacent bars with the same time represent different measurements from different shoulders during the same rehearsal. Also note that due to space, Time has been divided by 10, but Difference in Percent Dose has not.

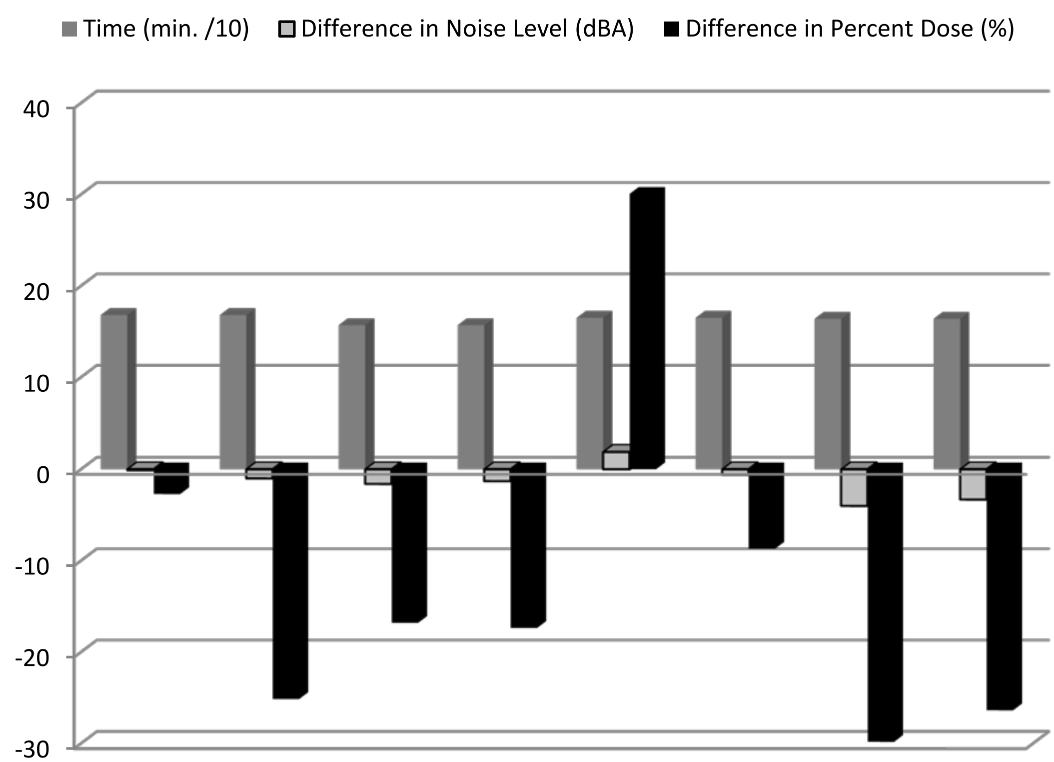


Figure 22: Diagram of Nutcracker Rehearsal Arrangement. This set-up differed from the usual ensemble placement because of a wall directly to the left of the bassoonist.

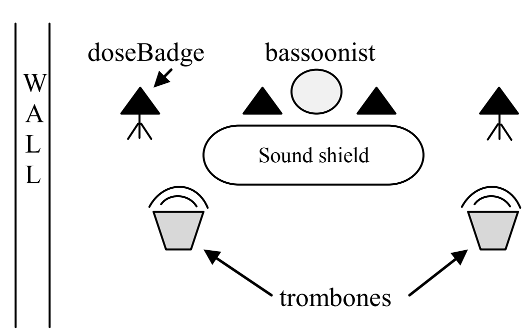
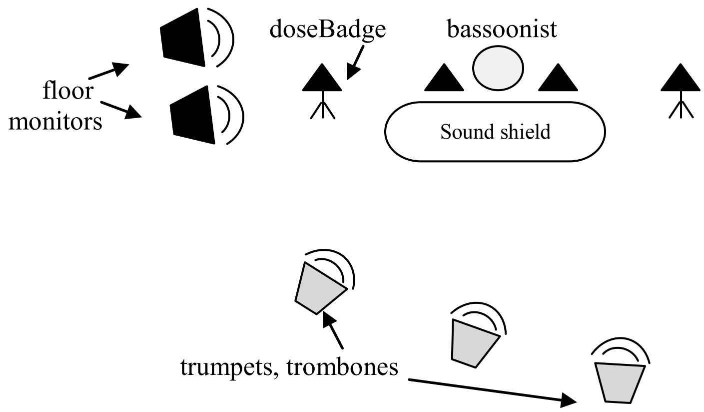


Figure 23: Diagram of Another Unusual Rehearsal Arrangement. This arrangement was unique due to the placement of two synthesizer speakers in close proximity to and on the side of the bassoonist. The trumpets and trombones were approximately 6 feet behind the bassoonist.



By chance, both rehearsals occurred with the Salisbury Symphony. The first two rehearsals (Figure 22) were for a production of Tchaikovsky's *The Nutcracker*. Although the rehearsal did not occur in a pit, the ensemble was in a pit arrangement, placing the bassoonist next to a wall. The second two rehearsals involved the use of synthesizers, with floor monitors directly to the side of the bassoonist (Figure 23). In both rehearsals, the combination of a side-positioned sound source and the use of the acoustic shield allowed for additional reflection and resulted in increased sound levels.

As sound travels, the waves can reflect, diffract, be absorbed, refract, or interfere with another wave (Lathom-Rodacy & Rodacy 1996).[32] When attempting to reduce sound levels, it is extremely important to control reflection. In some instances, reflection can increase the sound level that is experienced (Behar, Chasin, & Cheesman 2000). The amount of increase can vary in relation to the size of the room. In general, a small and enclosed room will allow for reflection and increased sound levels more so

[32] Of these five, refraction has the least to do with indoor concert spaces.

than a larger room. In contrast, in an outdoor space, with little or no reflection, sounds will seem quiet. Larger spaces reduce the likelihood of reflection.[33] The position of the bassoonist next to a wall while using an acoustic shield and music stand created three reflective surfaces, which caused an increase in sound levels.

Following this discovery, it is recommended that the use of an acoustic shield should be avoided in situations in which a sound source, whether an instrument or a wall, is directly next to the musician. In all other cases, it seems that both the Manhasset shield and the Wenger shield were equally effective at reducing sound levels. The choice of which shield to use can be based on cost, availability, and portability.

Influence of Time

While it is true that both shields reduced sound levels, levels were not reduced enough for the bassoonist who participates in music activities eight hours a day. For those bassoonists who do not perform, practice, or teach eight hours a day, the sound reduction provided by the shield may be enough to help them avoid the risk of NIHL. As both shields reduced sound levels, the effect will be discussed in general.

In the study by Libera and Mace (2010), it was determined that the shields did not reduce sound enough to make the daily percent dose of student musicians below 100%. Student musicians make music a minimum of four to five hours each day. The typical day of the test subject used for this study was shown in Table 5 (Chapter 3, page 31).

[33] Other factors also affect reflection, such as shape of the room.

For the following discussion, one point about NIHL is important to remember: time matters as much as sound intensity. Very few of the measured rehearsals were excessively loud, but the duration of rehearsal, combined with the moderate intensity experienced, resulted in over exposure. According to the data, acoustic shields are not only ineffective in arrangements including side-positioned sound sources, but can increase sound-level exposure and probably should be avoided in such arrangements.

If a musician wants to avoid over exposure,[34] their sound exposure must be below 85 dBA and percent dose below 100% per day. For the bassoonist who does not make any other music outside of orchestra rehearsal, the total amount of time participating in music activities is approximately 2.8 hours. Table 7 shows this hypothetical day.[35]

Table 7: Hypothetical Day 1 of the Bassoonist Without a Shield. This day's music activities consisted of a rehearsal only. These results are without the use of a sound shield.

Activity	**Decibel Level**	**Percent Dose**
Professional Rehearsal (2.8 hours)	88.40 dBA	76.78 %
TOTAL (2.8 hours)		**76.78%**

According to the findings of this study, the shields reduced sound levels an average of 1.28 dBA. Table 8 shows the hypothetical Day 1 with the use of a sound shield. In general, with or without a sound shield, the bassoonist would most likely not exceed a 100% dose from the orchestra rehearsal alone, and thus avoid over exposure. Note, that sound-level averages of some rehearsals were greater than 88.40 dBA. In certain cases of a higher intensity rehearsal, the sound shield may not be effective.

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[34] Over exposure means over a 100% dose. Consistent over exposure to sound could lead to NIHL. For the musician who is exposed to a 100% dose five days a week for 35 years, this exposure could lead to NIHL.
[35] Numbers used here are from the Typical Day of the Bassoonist, Table 5, Chapter 3, page 31.

Table 8: Hypothetical Day 1 of the Bassoonist With a Shield. This day's music activities consisted of a rehearsal only. The use of a sound shield lower the percent dose by 19.66%.

Activity	Decibel Level	Percent Dose
Professional Rehearsal (2.8 hours)	87.12 dBA [88.40 dBA (actual)- 1.28 dBA]	57.12 %
TOTAL (2.8 hours)		**57.12%**

If a bassoonist were to practice for two hours in addition to the almost three hour rehearsal, for a total of nearly five hours of musical activities the total percent dose increases by 32.09%. Table 9 shows this hypothetical day without the use of a shield during orchestra rehearsals, while Table 10 shows the day when the shield is used in rehearsal. Note that the use of a shield may still reduce sound levels enough to keep the total percent dose below 100%.

Table 9: Hypothetical Day 2 of the Bassoonist Without a Shield. This day includes a rehearsal as well as two of practicing. These results are without the use of a sound shield.

Activity	Decibel Level	Percent Dose
Practicing (2 hours)	86.08 dBA	32.09%
Professional Rehearsal (2.8 hours)	88.40 dBA	76.78 %
TOTAL (4.8 hours)		**108.87%**

Table 10: Hypothetical Day 2 of the Bassoonist With a Shield. This day includes a rehearsal as well as two of practicing. These results are with the use of a sound shield.

Activity	Decibel Level	Percent Dose
Practicing (2 hours)	86.08 dBA	32.09%
Professional Rehearsal (2.8 hours)	87.12 dBA [88.40 dBA (actual)- 1.28 dBA]	57.12 %
TOTAL (4.8 hours)		**89.21%**

Finally, some bassoonists practice, teach, or have more than one rehearsal in a day. Tables 11 and 12 show a hypothetical day with two symphony rehearsals, commonly called “a double.” Note that without a shield the percent dose is 171.30%, and with a shield it is 127.44%, resulting in overexposure with and without the use of a shield.

Table 11: Hypothetical Day 3 of the Bassoonist Without a Shield. This day includes a double rehearsal. These results are without the use of a sound shield.

Activity	Decibel Level	Percent Dose
Professional Rehearsal 1 (2.8 hours)	88.40 dBA	76.78%
Professional Rehearsal 2 (2.8 hours)	89.30 dBA	94.52%
TOTAL (5.6 hours)		**171.30%**

Table 12: Hypothetical Day 3 of the Bassoonist With a Shield. This day includes a double rehearsal. These results are with the use of a sound shield.

Activity	Decibel Level	Percent Dose
Professional Rehearsal 1 (2.8 hours)	87.12 dBA [88.40 dBA (actual)- 1.28 dBA]	57.12%
Professional Rehearsal 2 (2.8 hours)	88.02 dBA [89.30 dBA (actual)- 1.28 dBA]	70.32 %
TOTAL (5.6 hours)		**127.44%**

These considerations show that time can have a great influence on the safety of a musician, as well as any other worker who experiences a noisy environment. Each bassoonist must be aware of their environment and their schedule in order to maintain healthy hearing.

Alternate Methods of Hearing Protection

Changes can be made in the areas of ensemble set-up, use of risers, and use of earplugs to help reduce sound exposure. While each of these methods of sound reduction may be used alone, a combination of methods would likely be the best option. Additionally, knowledge of the music being performed and resultant sound levels experienced would also aid in making appropriate and effective hearing protection choices. A violinist would likely be safe without earplugs during a rehearsal of Samuel Barber's *Adagio for Strings,* but probably not for Karel Husa's *Music for Prague 1968.*

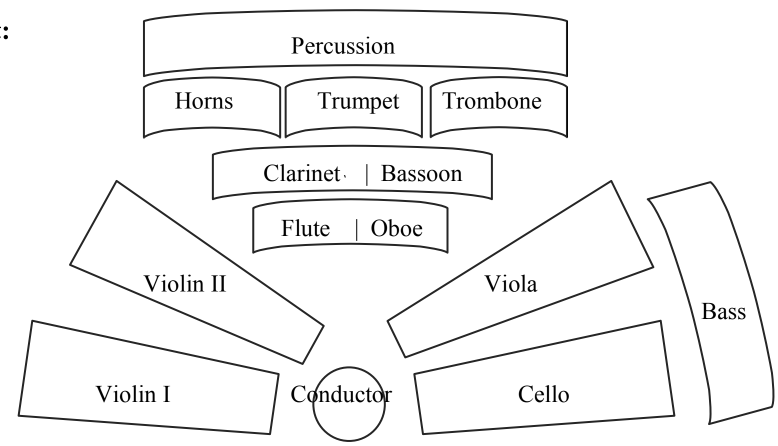
Each instrument in a band or orchestra has unique acoustical properties. While some instruments may actually be louder than others, some are simply more directional. Directionality refers to the path which the sound of an instrument travels. All instruments can be directional; the higher the frequency an instrument is producing, the greater the directionality (Campbell & Greated 1988, Howard & Angus 2006, Fletcher & Rossing 1991). Brass instruments are often considered to be the loudest, but this may not be due to greater amplitude, but to the fact that they are the most directional instruments, creating the perception of loudness. With their bells functioning as an aiming mechanism, nearly their entire range is directional (Fletcher & Rossing 1991). Percussion instruments can produce sudden changes in intensity, thus caution should be used when performing in close proximity to them. Although the stapedius and the tensor tympani muscles of the middle ear help to protect the ear from sounds that gradually increase, percussive instruments can provide sudden surprises that leave our ears unprepared.[36]

One way to decrease sound levels for instruments directly in front of brass or percussion would be to alter the ensemble arrangement. While wind ensemble arrangements can vary, a section will always be in front of the brass or percussion. With orchestras, however, the percussion, trumpets, and trombones could be placed on either side of the orchestra allowing for space between their instruments and the musician in front of them (Figure 24). The greater the distance between the sound source and receiver, the greater the sound dissipation. This would result in a slightly lower sound level when the brass or percussion sound reaches other members of the orchestra (Howard and Angus 2006). This space would also allow room for acoustic shields.

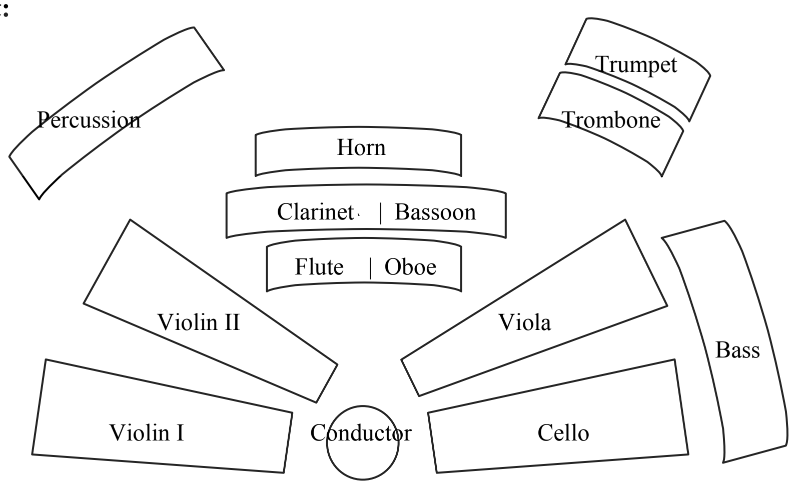
[36] Percussive instruments should not receive all the blame for sudden sounds. Certain dynamics and articulation in winds, strings, and brass can have the same effect.

Figure 24: Two Orchestral Arrangements. In the first arrangement, used by the Western Piedmont Symphony, the trumpets, trombones, and percussion are directly behind other members of the orchestra. Moving the trumpets, trombones and percussion to the side, or farther back from the rest of the orchestra may create more space for acoustic shields and distance in which a sound wave may lose energy. Horns, while directional, are less of a danger to others as their bell points behind the horn player.

Western Piedmont Symphony Arrangement:



Alternate Arrangement:



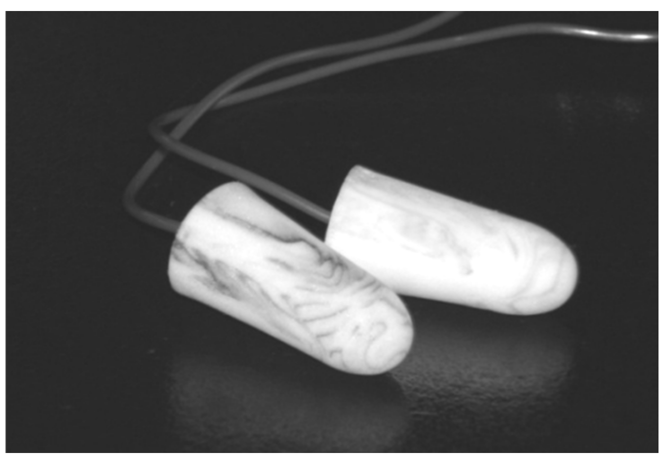
Another possibility that may help both the brass player and those seated directly in front of them would be to use risers (Chasin 1996). Risers allow sound to travel out toward the audience, saving the hearing of the musicians sitting in front of the directional instruments. Risers would also enable the directional instrumentalists, whose sound is often blocked by the presence of other players, to produce better tone with less emphasis on volume. Because of the instrument-playing position of most brass players, the use of risers can potentially increase sound levels rather than reduce sound levels. If all trumpet and trombone players played at a 90° angle, then risers would reduce sound levels. However, most performers play at a downward angle, thus the use of risers may actually put the bell of their instrument even closer to the ear of those in front of them. The combination of risers and an altered ensemble arrangement may be a productive solution.

The most personal type of hearing protection is the earplug. Earplugs are probably the most appreciated and most disliked form of hearing protection for musicians. When used properly, the earplug reduces sound levels, yet they are disliked because they can change our perception of timbre. The best earplugs reduce sound levels while minimally altering timbre perception.

Like nearly all hearing protection devices, the effectiveness of the earplug can be reduced due to certain limitations and misuse (3M 2006b, p. G22-G23). One problem is improper sizing. Many earplugs come as one-size-fits-all, which generally do not fit all people. Plugs that are too loose will not seal the auditory canal properly, allowing sound into the ear. Plugs that are too tight can lead to discomfort. Related to improper size is the problem of improper insertion. Most often, earplugs are worn too loosely, allowing for sound to get past the plug. Another way in which musicians reduce the effectiveness of earplugs is by removing them to hear the conductor or a stand partner and not reinserting them when playing resumes. Most earplugs reduce higher frequencies more than lower frequencies. This makes speech difficult to understand, and can be a valid reason to remove an earplug (Chasin 1996). A final reason for the ineffectiveness of earplugs is due to wear and tear or user modification. Many earplugs are reusable, but most only a certain number of times.

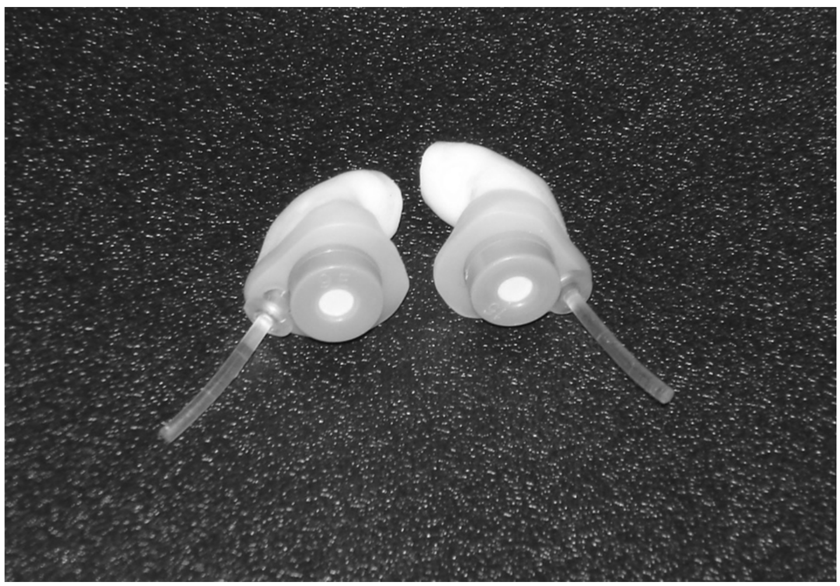
A common earplug is made of foam (Figure 25). The advantages of a foam plug, due to its soft material, include great comfort, a good seal, and a decreased possibility of improper sizing (Berger 2003a). These plugs are also inexpensive; each pair usually costs less than $1. One manufacturer (3M) states that these plugs reduce sound levels by 28 to 29 dBA (3M 2006a). As they significantly reduce high frequency sound, these ear plugs could make matching pitch and timbre difficult for musicians.

Figure 25: Foam Ear Plugs (unpublished photo by author). Advantages of these plugs include comfort, and ability to fit many people. A disadvantage may be too much high frequency reduction for musicians. The chord that attaches the plugs can be helpful for quick removal and insertion.



Musician's earplugs have been developed to attenuate, or reduce sound levels, equally across all frequencies. Etymotic Research is one manufacturer of musician's earplugs. These earplugs are custom molded for each individual, resulting in the proper fit (Figure 26). There are three degrees of attenuation; the user is encouraged to find the right level of reduction needed. For instance, woodwinds and large strings may choose the ER-15 or ER-25, while the ER-25 is recommended for percussionists and the ER-9 for other instruments (Chasin 1996, p. 159).[37] The primary negative aspect of the Musicians Earplugs is the cost; one pair costs between $150 and $200 (Etymotic Research 2006).

Figure 26: Custom Molded Musician's Earplugs, by Etymotic Research (unpublished photo by author). Available with various attenuation rates, these plugs are effective, but also expensive.



A more affordable solution may by the ER-20, a "one-size-fits-most" solution from Etymotic Research (Figure 27). Like its more expensive counterparts, the ER-20 Earplugs reduce sound levels fairly evenly at all frequency levels, although not as consistently as the Musicians Earplugs. The cost of the pre-molded ER-20 is between

[37] The ER-9 reduces sound levels by 9 dBA, the ER-15 by 15 dBA, and the ER-25 by 25 dBA (Etymotic Research 2006).

$10 and $12. The major disadvantage of this earplug is that it may not fit every ear correctly, resulting in reduced effectiveness.

Figure 27: Etymotic ER-20, Non-custom Musician's Earplug (unpublished photo by author). Like the custom models, this earplug attenuates evenly across all frequencies. While cost is minimal, the size of the earplug may not be suitable for all musicians.

A combination of earplug use and acoustic shield use may also be an effective solution. A professional bassoonist in North Carolina regularly wears earplugs loosely in the ears. This allows him to hear during soft passages, but may still provide minimal protection. Additionally, he uses an acoustic shield. During passages of high intensity sound, he leans back toward the shield. The result is a perceived decrease in loudness. This has not been scientifically documented, but serves as anecdotal evidence for the use of multiple methods of hearing protection.

Summary

When addressing the two research questions of this dissertation, it was found that professional bassoonists do experience sound levels that exceed 85 dBA and the use of acoustic shields did not reduce the sound levels to 85 dBA. Despite this result, the shields might still be useful in hearing conservation efforts. The two shields measured, Manhasset and Wenger, both reduced sound levels, possibly due to a conscientious effort by the bassoonist to remain close to the shield. Both shields would be similarly effective for use by other bassoonists.

It was discovered that a position close to a wall or with a side-positioned sound source renders the shield ineffective. In those situations, the sound levels increased, putting a bassoonist at greater risk. A shield should be avoided in these situations.

Another factor considered in this study is the influence that time has on whether a shield is effective. In general, if a bassoonist practices outside of rehearsal, even with the use of an acoustic shield in rehearsal, that person may still be at risk of NIHL. Because the percent dose was not less than 100% for every instance a shield was used, they are not effective enough to be the only source of hearing protection for a professional classical musician. Alternative methods of hearing protection, such as different ensemble arrangements and earplugs may prove to be effective when used in combination with acoustic shields.

Limitations of the Study

Limitations to this research include the subject and the ensembles. With just one subject, it is not known how many other musicians would experience similar sound levels. Also, because only two local orchestras participated, it is difficult to know if these results would hold true for larger orchestras, or orchestras with different rehearsal facilities. Despite these limitations, it is likely that the sound levels experienced by bassoonists and the amount of attenuation that resulted from the use of acoustic shields would be similar for other musicians in the orchestra.

Recommendations for Future Research

Future research on the topic of effectiveness of acoustic shields should continue testing the shields in live situations rather than in laboratory settings. A live rehearsal accounts for sound from the performer, sound from other musicians on the sides and front, as well as musician movement. Musicians move in order to communicate with others around them, to reduce tension, and to express musicality. In a laboratory setting, these factors are likely not present.

It is also recommended that sound levels experienced by other instrumentalists outside of the bassoon section be measured when researching professional orchestras. Other members of the orchestra may also be in danger of NIHL due to directional instruments near them. What was experienced by a bassoonist may occur elsewhere.

A study of literature performed would be a valuable resource for musicians. Knowing which style of music produces the greatest and least sound levels in different areas of an orchestra may enable performers to make decisions about what type of hearing protection would be most suitable. Research into the effectiveness of risers, different ensemble arrangements, room acoustics, and ear plugs would also be beneficial.

Finally research into the role of education on the use of acoustic shields may be worthwhile. Through non-scientific observations, many musicians have been seen placing a shield somewhere between the sound source and the subject to be protected. Proximity of the shield to the musician desiring protection is essential for the shields to be effective.

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APPENDIX A

ADDITIONAL STUDIES

Steel Band Studies. Below is a chart summarizing studies involving both audiometry and the measuring of sound levels of steel bands.

Audiometry	Sound Level	Year	Authors	Title
X		1977	Kruvilla, K.T.	Survey of hearing loss in panmen.
X	X	1995	Griffiths, S. K. & Samaroo, A. L.	Hearing sensitivity among professional pannists.
X		2004	Juman, S., Karmody, C.S., & Simeon, D.	Hearing loss in steelband musicians.

Headphone Studies. Below is a chart summarizing studies conducted on the sound levels through headphones and/or measured hearing changes as a result of listening to music through headphones in conjunction with personal music players. These devices include cassette players, CD players, and MP3 players. The type of music listened to through the headphones varies from pop to classical music, with some studies testing a variety of music genres.

Audiometry	Sound Level	Year	Authors	Title
X	X	1970	Dey, F.L.	Auditory fatigue and predicted permanent…
X		1981	Axelsson, A., Jerson, T., & Lindgren, F.	Noisy leisure time activities in teenage boys.
X		1982	Carter, N.L., Waugh, R.L., Keen, K., et al.	Amplified music and young people's hearing…
X		1983	Axelsson, A. & Lindgren, F.	Temporary threshold shift after exposure to noise…
X		1986	Miyake, S. & Kumashiro, M.	Effects of listening to music with headphones on …
	X	1987	Rice, C.G., Breslin, M., & Roper, R.G.	Sound levels from personal cassette players.
	X	1987	Rice, C.G., Rossi, G., & Olina, M.	Damage risk from personal cassette players.
	X	1989	Gallagher, G.	Hot music, hot noise, and hurt ears.
X		1990	Wong, T.W., Van Hasselt, C.A., Tang, L.S., & Yiu, P.C.	The use of personal cassette players among youths…
X	X	1991	Turunen-Rise, I., Flottorp, G., & Tvete, O.	Personal cassette players ('Walkman')…
X		1992	Loth, D., Avan, P., Menguy, C., & Teyssou, M.	Secondary auditory risks from listening to portable…
X		1992	Tsumura, T.K. & Dicus, G.	Degree of hearing loss due to personal stereo use.
X	X	1993	Fearn, R.W.	Hearing loss in musicians.
	X	1994	Ising, H., Hanel, J., Pilgramm, M., et al.	Risk of hearing loss caused by listening to music …
	X	1995	Barrett, D. & Hodges, D.	Music loudness preferences of middle school …

Headphone Studies, Continued

Audiometry	Sound Level	Year	Authors	Title
X		1996	Meyer-Bisch, C.	Epidemiological evaluation of hearing damage related …
X	X	1998	Hellström, P.A., Axelsson, A., & Costa, O.	Temporary threshold shift induced by music.
X		1998	LePage, E.L. & Murray, N.M.	Latent cochlear damage in personal stereo users…
X		1998	Mostafapour, S.P., Lahargoue, K., & Gates, G.	Noise-induced hearing loss in young adults…
X		1999	Job, A., Raynal, M., & Rondet, P.	Hearing loss and use of personal stereos in young …
X		1999	Smith, P. & Davis, A.	Social noise and hearing loss.
X		2001	Maassen, M., Babisch, W., Bachmann, K.D., et al.	Ear damage caused by leisure noise.
	X	2002	Eggemann, C., Koester, M., & Zorowka, P.	Hearing loss due to leisure time noise is on the rise…
	X	2004	Fligor, B.J. & Cox, L.C.	Output levels of commercially available…
X	X	2005	Biassoni, E. C., Serra, M. R., Richtert, U., et al.	Recreational noise exposure and its effects ... Part I…
X	X	2005	Biassoni, E. C., Serra, M. R., Richtert, U., et al.	Recreational noise exposure and its effects … Part II…
X		2006	Park, J.S., Oh, S.H., Kang, P.S., Kim, C.Y., et al.	Effects of the personal stereo system on hearing in…
	X	2007	Hodgetts, W.E,, Rieger, J.M., & Szarko, R.A.	The effects of listening environment and earphone…
	X	2007	Rudy, S.F.	The sounds of handheld audio players.
	X	2008	Cassano, E., Bavaro, P., Aloise, I., et al.	Music by earphones: an underestimated risk.
(survey)		2008	Rawool, V.W. & Colligon-Wayne, L.A.	Auditory lifestyles and beliefs related to hearing …
	X	2008	Torre, P. 3rd.	Young adults' use and output level settings …

Club/Disco Studies. Below is a chart summarizing studies that focus on the hearing levels and sound exposures experienced by DJs as well as other employees of dance clubs. [38]

Audiometry	Sound Level	Year	Authors	Title
	X	1970	Abrol, B.M., Nath, L.M., & Sahai, A.N.	Noise and acoustic…Noise levels in discotheques…
X	X	1970	Dey, F.L.	Auditory fatigue and predicted permanent…
	X	1973	Flottorp, G.	Music--a noise hazard?
	X	1977	Darcy, F.J.	Noise exposure of live music groups and other…
X	X	1979	Wood, B.D., Bogden, J.D., & Shapiro, M.J.	Elevated sound levels in New Jersey discotheques.
X		1989	Babisch, W. & Ising, H.	The effect of music in discothèques on hearing…
	X	1990	Tan ,T.C., Tsang, H.C., & Wong, T.L.	Noise surveys in discotheques in Hong Kong.
X		1990	West, P.D. & Evans, E.F.	Early detection of hearing damage in young listeners…
	X	1995	Hétu, R. & Fortin, M.	Potential risk of hearing damage associated with…
X		1997	Gunderson, E., Moline, J., & Catalano, P.	Risks of developing noise-induced hearing loss …
X	X	1999	Lee, L.T.	A study of the noise hazard to employees in local…
X		1999	Mansfield, J.D., Baghurst, P.A., & Newton, V.E.	Otoacoustic emissions in 28 young adults exposed to…
X		1999	Metternich, F.U. & Brusis, T.	Acute hearing loss and tinnitus caused by…
X		1999	Smith, P. & Davis, A.	Social noise and hearing loss.
	X	2000	Tin, L.L. & Lim, O.P.	A study on the effects of discotheque noise …
(survey)		2001	Meecham, E.A. & Hume, K.I.	Tinnitus, attendance at night-clubs and …
X	X	2002	Emmerich, E., Richter, F., Hagner, H., et al.	Effects of discotheque music on audiometric results …
X	X	2002	Sadhra, S., Jackson, C.A., Ryder, T., & Brown, M.J.	Noise exposure and hearing loss among student…
X	X	2004	Bray, A., Szymanski, M., & Mills, R.	Noise induced hearing loss in dance music disc jockeys …
X		2004	Wazen, S.R. & Russo, I.C.	A study of hearing and of the auditory habits of young …
	X	2005	Cassano, F., Bavaro, P., De Marinis, G., & Aloise, I.	No-occupational exposure to noise.
X		2006	Rosanowski, F., Eysholdt, U., & Hoppe, U.	Influence of leisure-time noise on outer hair cell…
X	X	2007	Santos, L., Morata, T.C., Jacob, L.C., et al.	Music exposure and audiological findings in…

[38] Tan ,T.C., Tsang, H.C., and Wong, T.L. (1990) has also been listed as Chew, T.T., et al.

Live Pop/Rock Studies. Below is a chart summarizing studies involving both audiometry and the measuring of sound levels of music experiences involving rock bands and popular music. These include studies on musicians as well as a few on audience members. Some of the following studies were broad in their investigation and also appeared above as part of the headphone studies.

Audiometry	Sound Level	Year	Authors	Title
X		1878a	Axelsson, A. & Lindgren, F.	Hearing in pop musicians.
	X	1967	Lebo, C.P., Oliphant, K. S., & Garrett, J.	Acoustic trauma from rock and roll music.
	X	1968	Lebo, C.P. & Oliphant, K. S.	Music as a source of acoustic trauma.
X	X	1968	Rintelmann, W.F. & Borus, J.F.	Noise-induced hearing loss and rock and roll music.
	X	1969	Flugrath, J.M.	Modern-day rock-and-roll music and damage-risk…
X		1969	Lipscomb, D.M.	Ear damage from exposure to rock and roll music.
	X	1970	Hickling, S.	Noise-induced hearing loss and pop music.
X		1970	Jerger, J. & Jerger, S.	Temporary Threshold Shift in Rock and Roll Musicians.
	X	1970	Speaks, C, Nelson, D., & Ward, W.D.	Hearing loss in rock and roll musicians.
(summary)		1970	Voorhees, R.L.	Rock music and hearing.
		1971	Truex, D.[39]	Hearing loss & loud rock music.
X		1972	Reddell, R.C. & Lebo, C.P.	Ototraumatic effects of hard rock music.
X	X	1972	Rintlemann W.F., Lindberg, R.F., & Smitley, E.K.	Temporary threshold shift and recovery patterns from…
X	X	1974	Ulrich, R.F. & Pinheiro, M.L.	Temporary hearing losses in teen-agers attending…
X		1975	Hanson, D.R. & Fearn, R.W.	Hearing acuity in young people exposed to pop…
X		1976	Lipscomb, D. M.	Hearing Loss of Rock Musicians.
X		1977a	Axelsson, A. & Lindgren, F.	Does pop music cause hearing damage?
X		1977b	Axelsson, A. & Lindgren, F.	Factors increasing the risk for hearing loss in 'pop'…
X	X	1978b	Axelsson, A. & Lindgren, F.	Temporary threshold shift after exposure to pop music.
X		1981	Axelsson, A. & Lindgren, F.	Pop music and hearing.
X		1981	Axelsson, A., Jerson, T., & Lindgren, F.	Noisy leisure time activities in teenage boys.
X		1982	Carter, N.L., Waugh, R.L., Keen, K., et al.	Amplified music and young people's hearing…
X	X	1986	Ono, H., Deguchi T., Ino, T. Okamoto, K., & Takyu, H.	The level of the musical loud sound and noise induced…

[39] The type of data collected for this article is unknown. The author was unable to locate the study.

Live Pop/Rock Studies, Continued

Audiometry	Sound Level	Year	Authors	Title
	X	1989	Gallagher, G.	Hot music, hot noise, and hurt ears.
X		1992	Drake-Lee, A.	Beyond music: auditory temporary threshold shift…
X	X	1993	Fearn, R.W.	Hearing loss in musicians.
X	X	1993	Yassi, A., Pollock, N., Tran, N., & Cheang, M.	Risks to hearing from a rock concert.
X		1995	Axelsson, A., Eliasson, A., & Israelsson, B.	Hearing in pop/rock musicians: A follow-up…
X		1996	Meyer-Bisch, C.	Epidemiological evaluation of hearing damage related …
(survey)		2000a	Chesky, K. & Henoch, M.	Instrument-specific reports of hearing loss…
X		2001	Maassen, M., Babisch, W., Bachmann, K.D., et al.	Ear damage caused by leisure noise.
	X	2002	Eggemann, C., Koester, M., & Zorowka, P.	Hearing loss due to leisure time noise is on the rise…
X		2003	Kahari, K., Zachau, G., Eklof, M., et al.	Assessment of hearing and hearing disorders in…
	X	2003	Mercier, V., Luy, D., & Hohmann, B.W.	The sound exposure of the audience at a music festival.
X	X	2005	Biassoni, E. C., Serra, M. R., Richtert, U., et al.	Recreational noise exposure and its effects ... Part I…
X	X	2005	Biassoni, E. C., Serra, M. R., Richtert, U., et al.	Recreational noise exposure and its effects … Part II…
(survey)		2005	Bogoch, I.I., House, R.A., & Kudla, I.	Perceptions about hearing protection and …
X		2006	Schmuziger, N., Patascheke, J., & Probst, R.	Hearing in nonprofessional pop/rock musicians.
X		2008	El Dib, R., Silva, E., Morais, J., & Trevisani, V.	Prevalence of high frequency hearing loss consistent…
	X	2008	Federman, J. & Ricketts, T.	Preferred and minimum acceptable listening levels…
X		2008	Maia, J.R. & Russo, I.C.	Study of the hearing of rock and roll musicians.
(survey)		2008	Rawool, V.W. & Colligon-Wayne, L.A.	Auditory lifestyles and beliefs related to hearing …

APPENDIX B

METHOD OF PERCENT DOSE CALCULATION

Method quoted from Mace (2005, p. 49-50).

"A calculator designed by Associates in Acoustics, Inc. (available at www.esion.com) written in Microsoft Excel® was designed to estimate noise-exposure. Original formulas in the Excel file were created using OSHA standards (90 dBA for 8 hours). Formulas were altered such that both NIOSH and OSHA estimates of dose percentages were calculated. The original formula, created in the cell in row 25, column K, was

=IF(E25>=80,I25*(100/(480/(2^((E25-90)/5)))),0), where:

(a). E25>=80 is the condition that if the value in column E row 25 is greater than or equal to 80 (dBA) then,
(b). I25*= the value in column I row 25 is,
(c). ((E25-90)/5))= the difference between value in column E row 25 and 90 (the lowest sound level accepted for calculations) divided by 5 (the exchange rate),
(d). 2^= 2 to the power of the quotient of the previous statement,
(e). 480= the dividend to be divided by the product of the previous equation, and
(f). 100= dividend to be divided by the quotient of the previous equation.

This formula calculates the dose percentage according to OSHA standards. Because some average sound levels were lower than 80 dBA, the value was changed to 60 when calculating dose percentages according to OSHA. To calculate the dose percentage according to NIOSH standards, values in the original formula were altered resulting in the following formula, =IF(E25>=60,I25*(100/(480/(2^((E25-85)/3)))),0), where 60 represented the lowest sound level accepted for calculations, 85 represented the dBA level recommended for an 8-hour day, and 3 represented the exchange rate. Use of the calculator designed in Excel allowed for all calculations to be estimated using a consistent source.

The L_{eq} as measured by the dosimeter was entered into the cell in row 25, column E. The criterion time of 480 minutes (eight hours) was entered in the cell in row 25, column H and the measurement period (in minutes) was entered in the cell in row 25, column I. The estimated dose percentage is calculated in the cell in row 25, column K."

APPENDIX C

DATA

Data collected when using Manhasset shield.

Date	Ear	Shield	time (min)	dBA	% dose	dif. dBA	dif. % dose	% dose/60 min
2/24/2008	L	without	180	84.2	28.4	-0.7	-4.99	10.39
2/24/2008	L	with	180	84.9	33.39			12.22
2/24/2008	R	without	180	86.4	47.22	1.1	10.6	17.28
2/24/2008	R	with	180	85.3	36.62			13.40
2/25/2008	L	without	160	88.5	72.96	1.6	22.55	28.06
2/25/2008	L	with	160	86.9	50.41			19.39
2/25/2008	R	without	160	92.6	188.15	0	0	72.37
2/25/2008	R	with	160	92.6	188.15			72.37
3/3/2008	L	without	168	88.4	76.78	0	0	27.42
3/3/2008	L	with	168	88.4	76.78			27.42
3/3/2008	R	without	168	91.3	150.05	1.5	43.95	53.59
3/3/2008	R	with	168	89.8	106.1			37.89
3/6/2008	L	without	157	87.9	63.52	0	0	24.43
3/6/2008	L	with	157	87.9	63.52			24.43
3/6/2008	R	without	157	94.1	266.08	5.3	187.88	102.34
3/6/2008	R	with	157	88.8	78.2			30.08
3/31/2008	L	without	165	89.5	100.17	1.6	30.95	35.35
3/31/2008	L	with	165	87.9	69.22			24.43
3/31/2008	R	with	165	89.2	93.47	0.3	6.26	32.99
3/31/2008	R	with	165	88.9	87.21			30.78
4/7/2008	L	without	164	90.1	111.68	1.7	36.27	40.61
4/7/2008	L	with	164	88.4	75.41			27.42
4/7/2008	R	without	164	90.9	134.36	1.6	41.52	48.86
4/7/2008	R	with	164	89.3	92.84			33.76
4/10/2008	L	without	133	90.3	121.93	1.9	43.32	42.53
4/10/2008	L	with	133	88.4	78.61			27.42
4/10/2008	R	without	133	90.6	130.68	1.3	33.9	45.59
4/10/2008	R	with	133	89.3	96.78			33.76

Data collected when using Wenger shield.

Date	Ear	Shield	time (min)	dBA	% dose	dif. dBA	dif. % dose	% dose/60 min
11/5/2007	L	without	180	86.2	49.48	0	0	16.49
11/5/2007	L	with	180	86.2	49.48			16.49
11/5/2007	R	without	180	87.3	63.8	0.8	10.77	21.27
11/5/2007	R	with	180	86.5	53.03			17.68
11/7/2007	L	without	160	86.4	46.06	-1	-11.98	17.27
11/7/2007	L	with	160	87.4	58.04			21.77
11/7/2007	R	without	160	88.8	80.2	1.6	24.78	30.08
11/7/2007	R	with	160	87.2	55.42			20.78
11/18/2007	L	without	168	90.2	116.37	-0.1	-2.72	41.56
11/18/2007	L	with	168	90.3	119.09			42.53
11/18/2007	R	without	168	89.4	96.73	-1	-25.15	34.55
11/18/2007	R	with	168	90.4	121.88			43.53
11/20/2007	L	without	157	85.6	37.57	-1.6	-16.81	14.36
11/20/2007	L	with	157	87.2	54.38			20.78
11/20/2007	R	without	157	86.8	49.58	-1.3	-17.37	18.95
11/20/2007	R	with	157	88.1	66.95			25.59
1/13/2008	L	without	165	88.9	84.64	1.9	30.07	30.78
1/13/2008	L	with	165	87	54.57			19.84
1/13/2008	R	without	165	87.3	58.48	-0.6	-8.7	21.27
1/13/2008	R	with	165	87.9	67.18			24.43
1/15/2008	L	without	164	82.6	19.62	-4	-29.83	7.18
1/15/2008	L	with	164	86.6	49.45			18.09
1/15/2008	R	without	164	83.3	23.07	-3.3	-26.38	8.44
1/15/2008	R	with	164	86.6	49.45			18.09
1/28/2008	L	without	133	90.4	96.49	2.2	38.45	43.53
1/28/2008	L	with	133	88.2	58.04			26.18
1/28/2008	R	without	133	91.1	113.42	3	56.71	51.17
1/28/2008	R	with	133	88.1	56.71			25.58
2/4/2007	L	without	123	90.3	87.19	1.7	28.32	42.53
2/4/2007	L	with	123	88.6	58.87			28.72
2/4/2007	R	without	123	91.4	112.42	2.3	46.34	54.84
2/4/2007	R	with	123	89.1	66.08			32.23
2/7/2008	L	without	89	88.2	38.84	0.4	3.43	26.18
2/7/2008	L	with	89	87.8	35.41			23.87
2/7/2008	R	without	89	90.3	63.09	2.6	28.49	42.53
2/7/2008	R	with	89	87.7	34.6			23.33

APPENDIX D

OCCUPATIONAL HEARING CONSERVATIONIST CERTIFICATION

COUNCIL FOR ACCREDITATION IN OCCUPATIONAL HEARING CONSERVATION

organized to establish standards to elevate and maintain the quality of occupational hearing conservation in industry

This is to Certify that

Rebecca Libera, COHC

having demonstrated proficiency and special knowledge, and having successfully completed the required course in occupational hearing conservation following the requirements set forth by the CAOHC Council; is therefore a

Certified Occupational Hearing Conservationist

June 13, 2008
Valid Date

June 13, 2013
Expiration Date

465651
Certificate No.

CAOHC®

Mary M. McDaniel

Chair: Mary M. McDaniel, MS CCC-A

Robert D. Bruce, PE EE INCE Bd Cert FASA

APPENDIX E

SAMPLE REHEARSAL DATA FORM

Date: ____________________________

Event: ____________________________

Event Location: ____________________________

Call sheet #:_________

Time start: ____________________________

Time finish: ____________________________

Diagram: (identify surrounding instruments)

```
             _____  X   _____
   _______   \______________/    _______
```

Rehearsal Schedule:

__________   ____

__________   ____

__________   ____

__________   ____

__________   ____

__________   ____

__________   ____

__________   ____

APPENDIX F

CALL SHEETS FOR REHEARSALS

Western Piedmont Symphony

John Gordon Ross, Music Director and Conductor
[redacted], Executive Director
[redacted], Personnel Manager
[redacted], e-mail <[redacted]> cell phone/voice mail [redacted]

Masterworks # 2 Call Sheet

PROGRAM

Total: 2(1)-2+1-2(bcl)-2 / 4-3-3-1 / timp+2 / harp-piano / strings

Florence Price .... Dance in the Canebrakes
2(1)-2-2(bcl)-2+AltoSax / 3-3-2-0 / timp + 2 / harp / strings

Samuel Barber .... Violin Concerto
[redacted], Violin
2(1)-2-2-2 / 2-2-0-0 / timp + sd / piano / strings

Edward Kennedy "Duke" Ellington .... Suite from The River
2-2(1)-2-2 / 4-3-3-1 / timp+2 / harp-piano / strings

SCHEDULE

Monday, October 29, 2007	Full Orchestra	7:30-10 p.m.	WPS RR
Thursday, November 1, 2007	String Sectional	7:30-10 p.m.	WPS RR
Monday, November 5, 2007	Full Orchestra	7:30-10 p.m.	WPS RR
Thursday, November 8, 2007	Dress Rehearsal 1	7:30-10 p.m.	FirstBaptistChurch
Saturday, November 10, 2007	Dress Rehearsal 2	2:30-5 p.m.	FBC
Saturday, November 10, 2007	Concert	8:00 p.m.	FBC

PERSONNEL

Flute
[redacted]

Piccolo
[redacted]

Oboe
[redacted]

English horn
[redacted]

Clarinet
[redacted]

Bass Clarinet
[redacted]

Bassoon
[redacted]

Alto Sax
[redacted]

Horn
[redacted]

Trumpet
[redacted]

Trombone
[redacted]

Bass Trombone
[redacted]

Tuba
[redacted]

Timpani
[redacted]

Percussion
[redacted]

Harp
[redacted]

Violin 1 (10)
[redacted]

Violin 2 (8)
[redacted]

Viola (6)
[redacted]

Piano
[redacted]

Cello (6)
[redacted]

Bass (5)
[redacted]

Properties
[redacted]

Salisbury Symphony Orchestra
P.O. Box 4264 Salisbury, NC 28145-4264
Telephone 704.637.4314 • Fax 704.637.4268
www.salisburysymphony.org

David Hagy, Music Director/Conductor
Telephone [redacted] • [redacted]
[redacted], Executive Director
Telephone [redacted] • [redacted]
[redacted], Director of Education
Telephone [redacted] • [redacted]

SALISBURY SYMPHONY ORCHESTRA
CONCERTS: SUNDAY, DECEMBER 16, 2007 2:30 & 6:30 PM

1. Sun, **NOVEMBER** 18 7:00-9:30 PM
Salisbury HS, Music Building

6:00	Childrens Chorus Rehearsal
7:00	9. Waltz of the Snow Flakes
7:20	1. Christmas Tree
7:32	6. Scene: Rats Entrance & Dream
7:55	7. Battle Scene
8:10	8. Scene
8:25	Break
8:40	14a. Pas de Deux
8:50	10. Castle of Sweets
9:00	13. Waltz of the Flowers Intro
9:10	14c. Pas de Deux: Var II
9:15	15. Final Waltz & Apotheose

Tue, **NOVEMBER** 20 7:30-10:00
Salisbury HS, Music Building
NO HARPS, CELESTE OR PERCUSSION 2

7:30	Overture
7:45	2. March
7:55	4. Drosselmeyer
8:15	5. Scene & Grandfather Dance
8:30	11. Clara & Prince end
8:40	12. Divertissements: a, c, e, b
9:00	Break
9:05	12. Divertissements: (b), d, f
9:25	13. Waltz of the Flowers after Intro
9:40	14bd. Pas de Deux Var I, Coda & others as needed

3. Sat, December 15 10:30-1:15
Catawba College, Keppel Auditorium

10:00	Childrens Chorus
10:30	Act I
11:20	Fix any "Snow Flakes" problems
11:30	Break
11:40	Act II
12:25	Break
12:40	Fix any problems

Sun December 16 **2:30 & 6:30**
Catawba College, Keppel Auditorium

2:30	Performance
4:45	Dinner provided
6:30	Performance

DRESS Men: Black suit, solid color shirt, long tie, black shoes
Women: Solid color long sleeve blouse, black long skirt or slacks, black shoes

DIRECTIONS ON BACK

PLEASE NOTE: Movement No. 10 will be completed by a fermata on the final note. There will be a cut in Movement No. 11 from the beginning to and including the downbeat of rehearsal 19. OBOE, ENGLISH HORN AND CLARINETS WILL NEED TO PLAY THE FIRST FIVE BARS AT REHEARSAL 19 <u>ONE-HALF STEP HIGHER!</u> From the sixth bar on the music will proceed as written.

Salisbury Symphony Orchestra

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Telephone 704.637.4314 • Fax 704.637.4268
www.salisburysymphony.org

David Hagy, Music Director/Conductor
Telephone [redacted] • [redacted]

[redacted], Executive Director
Telephone [redacted] • [redacted]

[redacted], Director of Education
Telephone [redacted] • [redacted]

SALISBURY SYMPHONY ORCHESTRA
CONCERT: SATURDAY, JANUARY 19, 2008 7:30 PM

1. Sun, Jan 13 **7:00**-9:30 PM
   Salisbury High Salisbury
   7:00 Hindemith
   8:15 break
   8:30 Peck

2. Tue, Jan 15 7:30-10:00 PM
   Salisbury High School (chamber orchestra)
   7:30 Briccetti: I
   7:50 Briccetti: II
   8:10 Briccetti: IV
   8:40 Briccetti: III
   9:00 break
   9:15 Rossini
   9:40 Vivaldi

3. Thu, Jan 17 7:30-10:00 PM
   Catawba College, Keppel Auditorium
   7:30 Peck
   8:45 break
   9:00 Hindemith

4. Fri, Jan 18 7:30-10:00 PM
   Catawba College, Keppel Auditorium
   7:30 Vivaldi
   7:40 Briccetti: III
   8:00 Rossini
   8:25 Briccetti: IV
   9:00 break
   9:15 Briccetti: II
   9:25 Briccetti: I

5. Sat, Jan 19 3:30-5:45 PM
   Catawba College, Keppel Auditorium
   3:30 Rossini
   3:45 Vivaldi
   3:55 Peck
   4:30 break
   4:45 Briccetti (in order)
   5:15 Hindemith

6. CONCERT: Sat, Jan 19 7:30 PM
   Catawba College, Keppel Auditorium
   Rossini — Intermission
   Vivaldi — Briccetti
   Peck — Hindemith

DRESS:
Men: Black tux, white shirt, bow tie, black shoes
Women: Black long sleeve blouse, black long skirt or slacks, black shoes

Mileage forms will be available at the first rehearsal.

Western Piedmont Symphony

John Gordon Ross, Music Director and Conductor
[redacted], Executive Director
[redacted], Personnel Manager
[redacted], e-mail <[redacted]> cell phone/voice mail [redacted]

Masterworks # 3 Call Sheet

PROGRAM

Total: 2+1-2+1-2+1-2+1 / 4-3-3-1 / timp+4 / harp / strings

Modeste Mussorgsky .... A Night on Bald Mountain
2+1-2-2-2 / 4-2-3-1 / timp+3 / harp / strings

W.A. Mozart .... Sinfonia Concertante, K. 297b
0-2-0-0 /-2-0-0-0 / strings

Edmund Cionek .... Symphony #1 "The Adirondacks"
2+1-2+1-2+1-2+1 / 4-3-3-1 / timp + 4 / harp / strings

SCHEDULE

Monday,	January 28, 2008	Full Orchestra	7:30-10 p.m.	WPS RR
Thursday,	January 31, 2008	String Sectional	7:30-10 p.m.	WPS RR
Monday,	February 4, 2008	Full Orchestra	7:30-10 p.m.	WPS RR
Thursday,	February 7, 2008	Full Orchestra	7:30-10 p.m.	Broyhill Civic Ctr Aud., Lenoir
Saturday,	February 9, 2008	Dress Rehearsal	2:30-5 p.m.	Broyhill Civic Ctr Aud., Lenoir
Saturday,	February 9, 2008	Concert	8:00 p.m.	Broyhill Civic Ctr Aud., Lenoir

PERSONNEL

Flute
[redacted]

Piccolo
[redacted]

Oboe
[redacted]

English horn
[redacted]

Clarinet
[redacted]

Bass Clarinet
[redacted]

Bassoon
[redacted]

Contrabassoon
[redacted]

Horn
[redacted]

Trumpet
[redacted]

Trombone
[redacted]

Bass Trombone
[redacted]

Tuba
[redacted]

Timpani
[redacted]

Percussion
[redacted]

Harp
[redacted]

Violin 1 (9)
[redacted]

Violin 2 (8)
[redacted]

Viola (6)
[redacted]

Cello (6)
[redacted]

Bass (5)
[redacted]

Properties
[redacted]

REHEARSAL ORDER
Mon., Jan 28 & Feb 3
Cionek: 7:30
Mussorgsky: 8:30
Mozart:
Thurs. Jan 31: Strings
Thurs. Feb 7:
Mozart: 7:30
Cionek: 8:30
Mussorgsky
Sat. Feb. 9:
Concert order

Salisbury Symphony Orchestra

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Telephone 704.637.4314 • Fax 704.637.4268
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David Hagy, Music Director/Conductor
Telephone [redacted] • [redacted]
[redacted], Executive Director
Telephone [redacted] • [redacted]
[redacted], Director of Education
Telephone [redacted] • [redacted]

SALISBURY SYMPHONY ORCHESTRA
CONCERT: SATURDAY, MARCH 1, 2008 7:30 PM

1. Sun, Feb 24 **7:00**-9:30 pm
   Salisbury High School
   7:00 Beethoven
   8:25 break
   8:40 Brahms

2. Tue, Feb 26 7:30-10:00 pm
   Catawba College, Keppel Auditorium
   7:30 Beethoven: II
   7:40 Beethoven I, III
   8:40 break
   8:55 Beethoven: IV
   9:30 Bach

3. Fri, Feb 29 7:30-10:00 pm
   Catawba College, Keppel Auditorium
   7:30 Bach
   8:20 Brahms
   9:00 break
   9:15 Brahms
   9:45 Beethoven as needed

4. Sat, Mar 1 3:00-5:15 pm
   Catawba College, Keppel Auditorium
   3:00 Bach
   3:30 Brahms
   4:15 break
   4:30 Beethoven

CONCERT: Sat, Sep 30 7:30 pm
Catawba College, Keppel Auditorium
Bach
Brahms
Intermission
Beethoven

DRESS Men: Black tux, white shirt, bow tie, black shoes
Women: Black long sleeve blouse, black long skirt or slacks, black shoes

DIRECTIONS are on the other side.

Bach parts will be available at the first rehearsal.

Western Piedmont Symphony

John Gordon Ross, Music Director and Conductor
[redacted], Executive Director
[redacted], Personnel Manager
[redacted], e-mail <[redacted]> cell phone/voice mail [redacted]

Masterworks # 4 Call Sheet

PROGRAM

Total: 2+1-2+1-2+1e-flat, 1 bcl)-2+1 / 4-3-3-1 / timp+4 / harp, keyboard / strings

Aaron Copland .... El Salon Mexico
2+1-2+1-2+1e-flat, 1 bass-2+1 / 4-3-3-1 / timp+4 / piano / strings

Manuel Ponce .... *Chapultepec*
2+1-2-2+1-2 / 4-3-3-1 / timp+3 / celeste / strings

Pablo Sarasate .... *Fantasy on Bizet's "Carmen,"* Op. 25
1(1)-2-2-2 / 4-2-3-0 / timp+1 / harp / strings

Alberto Ginastera .... *Danzas del Ballet "Estancia,"* Op. 8a
2(2)-2-2-2 / 4-2-0-0 / timp+6 / piano / strings

SCHEDULE

Monday, February 25, 2008	Full Orchestra	7:30-10 p.m.	WPS RR
Thursday, February 28, 2008	String Sectional	7:30-10 p.m.	WPS RR
Monday, March 3, 2008	Full Orchestra	7:30-10 p.m.	WPS RR
Thursday, March 6, 2008	Dress Rehearsal 1	7:30-10 p.m.	FirstBaptistChurch
Saturday, March 8, 2008	Dress Rehearsal 2	2:30-5:30 p.m.	FBC
Saturday, March 8, 2008	Concert	8:00 p.m.	FBC

PERSONNEL

Flute
[redacted]

Piccolo
[redacted]

Oboe
[redacted]

English horn
[redacted]

Bb Clarinet
[redacted]

Eb Clarinet
[redacted]

Bass Clarinet
[redacted]

Bassoon
[redacted]

Contrabassoon
[redacted]

Horn
[redacted]

Trumpet
[redacted]

Trombone
[redacted]

Bass Trombone
[redacted]

Tuba
[redacted]

Timpani
[redacted]

Percussion
[redacted]

Violin 1 (10)
[redacted]

Violin 2 (8)
[redacted]

Viola (6)
[redacted]

Piano/Celeste
[redacted]

Cello (7)
[redacted]

Bass (5)
[redacted]

Properties
[redacted]

Harp
[redacted]

REHEARSAL ORDER

Mon., Feb. 25 & Mar 3:
Copland 7:30 p.m.
Ponce 8:15 p.m.
Ginastera 9:00 p.m.
Sarasate 9:35 p.m.
Thurs., Feb 28: Strings
Thurs., Mar 6:
Sarasate, Ginastera, Copland, Ponce
Sat., Mar 8: Concert Order

Western Piedmont Symphony

John Gordon Ross, Music Director and Conductor
[redacted], Executive Director
[redacted], Personnel Manager
[redacted], e-mail <[redacted]> cell phone/voice mail [redacted]

Masterworks # 5 Call Sheet

PROGRAM

Total:4(2)-4(1)-4(1 e-flat 1 bcl)-3(1) / 7-5-4-1 / 2 timp+3 / harp / strings

Ludwig van Beethoven .... Overture to *The Creatures of Prometheus*, Op. 43
2-2-2-2 / 2-2-0-0 / timp / strings

Franz Liszt .... *Totentanz (Dance of Death),* S. 126
3(1)-2-2-2 / 2-2-3-1 / timp+3 / strings

Gustav Mahler .... Symphony #1 in D Major *"Titan"*
4(2)-4(1)-4(1 e-fl+bcl)-3(1) / 7-5-4-1 / 2 timp+3 / harp / strings

SCHEDULE

Monday, March	31, 200	Full Orchestra	7:30-10 p.m.	WPS RR
Thursday, April	3, 2008	String Sectional	7:30-10 p.m.	WPS RR
Monday, April	7, 2008	Full Orchestra	7:30-10 p.m.	WPS RR
Thursday, April	10, 2008	Dress Rehearsal	7:30-10 p.m.	FirstBaptistChurch
Saturday, April	12, 2008	Dress Rehearsal 2	2:30-5 p.m.	FBC
Saturday, April	12, 2008	Concert	8:00 p.m.	FBC

PERSONNEL

Flute/Piccolo
[redacted]

Oboe
[redacted]

English Horn
[redacted]

Clarinet
[redacted]

E-flat Clarinet
[redacted]

Bass Clarinet
[redacted]

Bassoon
[redacted]

Contrabassoon
[redacted]

Horn
[redacted]

Trumpet
[redacted]

Trombone
[redacted]

Bass Trombone
[redacted]

Tuba
[redacted]

Timpani
[redacted]

Percussion
[redacted]

Harp
[redacted]

Violin 1 (10)
[redacted]

Violin 2 (8)
[redacted]

Viola (6)
[redacted]

Cello (7)
[redacted]

Bass (5)
[redacted]

Properties
[redacted]

REHEARSAL ORDER
Mon., Mar.31 & Apr 7:
7:30: Mahler
9:15: Liszt
9:40: Beethoven
Thurs., Apr 3: Strings
Thurs., Apr 10:
7:30: Liszt
8:30: Mahler
9:45: Beethoven
Sat., Apr 12:
Concert Order
2:30: Bethoven
2:45: Liszt
3:10: Mahler

APPENDIX G

PERMISSION TO USE MATERIALS

Spartan

Rebecca Hammontree <rchammon@uncg.edu>

permission to use materials

Susan Lynch <susan.lynch79@yahoo.com> **Mon, Apr 20, 2009 at 1:25 PM**
To: rchammon@uncg.edu

Dear Rebecca,

You have my permission to use my unpublished diagram of the ear in your dissertation. I understand that the dissertation will be available online through The University of North Carolina at Greensboro Library and through Proquest.

Susan Lynch
Systems Engineer
susan.lynch79@yahoo.com

Spartan

Rebecca Hammontree <rchammon@uncg.edu>

Photo Use in Libera Dissertation

Sandra Mace <stmace@uncg.edu> **Mon, Apr 20, 2009 at 1:02 PM**
To: Rebecca Hammontree <rchammon@uncg.edu>

Dear Rebecca,

You have my permission to use my unpublished photos in your dissertation. I understand that the dissertation will be available online through The University of North Carolina at Greensboro Library and through Proquest.

Sandra Teglas Mace, Ph.D.
Program Coordinator
Music Research Institute
School of Music
University of North Carolina Greensboro
(336)256-2581

THE UNIVERSITY *of* NORTH CAROLINA
GREENSBORO

School of Music
University Bands

Room 344, Music Building
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336.334.5299 *Phone* 336.334.5349 *Fax*
www.smcamp.org

April 21, 2009

Ms. Rebecca Libera
[redacted]
Greensboro, NC 27406

Dear Rebecca:

You have my permission to to adapt a figure from the article "Shielding sound: A study on the effectiveness of acoustic shields" submitted for publication in the Journal of Band Research for use in your dissertation.

I understand that the dissertation will be available online through The University of North Carolina at Greensboro Library and through Proquest.

Yours sincerely,

John R. Locke

John R. Locke, Editor
Journal of Band Research