HIGH SCHOOL BAND DIRECTORS’ SOUND EXPOSURE LEVELS RELATIVE TO THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) WORKPLACE STANDARDS

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Committee:

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Dr. Vincent Kantorski
ABSTRACT

Dr. Bruce Moss, Advisor

The purpose of this study was to determine high school band directors’ sound exposure levels relative to the Occupational Safety and Health Administration (OSHA) workplace standards. Subjects for this study were four band directors from northwest Ohio and east central Illinois. Two directors regularly rehearsed in non-acoustically treated facilities, and two regularly rehearsed in facilities that have received acoustic treatments. Data were collected in the fall and early spring semesters of the 2007-2008 school year using Larson Davis Spark 706RC Personal Noise Dosimeters, devices used to measure and calculate decibel exposure. Measurement times and ensemble samples varied depending on the subject’s schedule. Two dose parameters on the dosimeters were set to correlate to the OSHA (Occupational Safety and Health Administration) standards for permissible exposure limits (PEL) and hearing conservation (HC) limits, and a third to the ACGIH (American Conference of Governmental Industrial Hygienists) threshold limit value (TLV) standard for noise exposure. Results showed that each director experienced decibel levels that would either make them eligible, or very close to eligible, for a hearing conservation program. Implications for music education included that directors should strongly consider wearing musicians’ earplugs during rehearsals. Directors should also try to determine their own decibel exposure levels through the use of noise dosimeters or decibel meters to determine their need or eligibility for a hearing conservation program. Suggestions for further research included comparing how well directors hear various aspects of musical ensembles both with and without musicians’ earplugs.
This thesis is dedicated in loving memory to my first and greatest supporter, my mother, Mary C. Messerli, without whom music may have been an afterthought in my life. Her song ended too soon, but her melody lives on.
ACKNOWLEDGEMENTS

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To my family, who have been my strength through an incredibly difficult year. I love you all, and can never thank you enough for everything you have done.
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CHAPTER I: INTRODUCTION

Statement of Problem

The human ear can differentiate between nearly 14,000 different frequencies (Gerace, Mestre, Mullin, & Vellman, 2003). However, when repeatedly exposed to dangerous hearing situations, this number drops dramatically over time. Two of the greatest risks associated with overexposure to sound are noise induced hearing loss (NIHL) and tinnitus (Davies, McIntyre, Teschke, Thom, & Winters, 2005). NIHL is a condition that results when the structures of the inner ear are damaged, either temporarily or permanently (National Institute on Deafness and Other Communication Disorders, 2002). NIHL can be accompanied by tinnitus, a constant ringing or buzzing noise in the ears. Both of these conditions are largely preventable with the use of proper hearing protection and avoidance of extraneous or dangerous audio events of excessively high decibel levels. According to the World Health Organization, noise induced hearing loss is the most prevalent occupational hazard in the world (Chepesiuk, 2005). In the United States alone, tinnitus is estimated to affect between 7.2 and 12 million people (Vernon, 1998). A temporary hearing loss is referred to as a threshold shift (sounds below the normal decibel threshold will not be heard) with the effects typically dissipating 16-48 hours after exposure to damaging sound. The muffled or muted feel after attending rock concert or very loud sporting event is an example of a threshold shift (NIDCD, 2006). Although unlikely, permanent damage can occur after only one exposure.

Several federal government agencies have established acceptable levels of noise exposure for the human ear over the course of an eight-hour workday. These agencies use what is known as the A-weighted scale (Occupational Safety and Health
Administration, 2006; National Institute for Occupational Safety and Health, 1998). The A-weighted scale means that the electronic devices (noise dosimeters and decibel meters) used to determine noise exposure are calibrated to closely replicate the human ear by reducing the importance of lower frequencies in mathematical equations used to calculate decibels (Spark & Blaze, 2000). The only sound exposure level that is legally enforced in the United States is the standard set by the Occupational Safety and Health Administration, or OSHA (OSHA, 2006). According to the OSHA, 90 decibels of continuous sound (the equivalent of standing near a car alarm) over the course of an eight-hour day is acceptable (OSHA, 2006). The eight-hour figure relates to the typical amount of time an employee works at his or her job on an average workday. Noise is considered to be continuous if variations occur at one second or less (OSHA, 2006). However, the National Institute for Occupational Safety and Health (NIOSH), which makes recommendations to OSHA, has declared that 85 decibels on the A-weighted scale (the symbol “dBa” is used to represent decibels on the A-weighted scale) is the safest exposure level for employees, citing that the risk of noise induced hearing loss for those exposed to 85 dBa per day is only 8% over a 40 year exposure, compared to a 40% risk at 90 dBa per day over the same 40 year exposure (NIOSH, 1998).

Need for the Study

According to a 1994 study by Cutietta, Klich, Rainbolt, and Royse, there have been at least 11 studies done on the effect of noise on orchestral musicians. However, the amount of research performed on wind band instrumentalists has been relatively small, especially on the effect of noise exposure to band directors in public schools (Cutietta et. al., 1994). As of 2008, there still has been little research done specifically in this area.
Harding and Owens (2002) and Mace (2005) investigated collegiate ensemble conductors and private instrumental lesson instructors, but these subjects were not from public schools. Staley (2001) investigated room acoustics in relation to hearing conservation, but did not measure an ensemble director’s actual decibel exposure level. A possible theory about band directors’ exposure levels is that, since these directors stand in front of ensembles throughout the day that typically play quite loudly with a small dynamic range, their exposure levels would be much higher than that of a professional orchestral conductor (Cutietta et. al., 1994).

**Purpose of the Study**

The purpose of this study was to determine high school band directors’ sound exposure levels relative to the Occupational Safety and Health Administration (OSHA) workplace standards. Four high school band directors were selected for this study. Two directors were chosen from non-acoustically treated facilities, and two were chosen from facilities that have received acoustic treatments. A treated facility contained three or more of the following four characteristics: (a) designed specifically for band usage, (b) employed effective professional acoustical treatments designed to reflect and diffuse sound, (c) the room was of proper shape and dimensions for size of ensemble, and (d) usage of flat floors. Untreated facilities contained three or more of the following four characteristics: (a) they were designed as a “music” room, or as another non-music space, (b) the usage of non-effective amateur acoustical treatments, such as drapes and carpet squares, (c) the room size and shape was not adequate for the ensembles using it, and (d) the usage of built in concrete risers.
Definition of Terms

**Acoustic Reflex** - Reflexive contraction of the intra-aural muscles in response to loud sound (Stach, 1998, p. 3)

**Audio Dosimeter (Noise Dosimeter)** - A body-worn instrument used to measure accumulated level and duration of noise to which a person is exposed over a specified time (Stach, 1998, p. 17)

**Audiometric Tests** - Procedures used to determine the nature and degree of hearing disorder (Stach, 1998, p. 19)

**Auricle** - External or outer ear, which serves as a protective mechanism, as a resonator, and as a baffle for directional hearing of front-versus-back and in the vertical plane (Stach, 1998, p. 25)

**Cochlea** - Auditory portion of the inner ear, consisting of fluid-filled membranous channels within a spiral canal around a central core (Stach, 1998, p. 43)

**Cochlear Duct** - Spiral membranous canal that is the cochlear portion of the membranous labyrinth, located between the osseous spiral lamina and external bony wall of the cochlea (Stach, 1998, p. 44)

**Conductive Hearing Loss** - Reduction in hearing sensitivity, despite normal cochlear function, due to impaired sound transmission through the external auditory meatus, tympanic membrane, and ossicular chain (Stach, 1998, p. 49)

**Decibel (dB)** - Unit of sound intensity, based on a logarithmic relationship of one intensity to a reference intensity (Stach, 1998, p. 59)
**Exchange Rate**- the change in sound level corresponding to a doubling or halving of the duration of sound level while a constant percentage of criterion exposure is maintained (Larson Davis, 2000, p. B-2)

**Incus**- Middle bone of the ossicular chain, located in the epitympanic recess (Stach, 1998, p. 105)

**Malleus**- Largest and lateralmost most bone of the ossicular chain, articulated on one end to the tympanic membrane and on the other to the incus (Stach, 1998, p. 124)

**Meatus**- Any anatomical passageway or channel, especially the external opening of a canal (Stach, 1998, p. 127)

**Noise Induced Hearing Loss (NIHL)**- Permanent sensorineural hearing loss caused by acoustic trauma from exposure to excessive sound levels (Stach, 1998, p. 142)

**Organ of Corti**- Hearing organ, composed of sensory and supporting cells, located on the basilar membrane in the cochlear duct (Stach, 1998, p. 150)

**Ossicles**- The three small bones of the middle ear- the malleus, incus, and stapes- extending from the tympanic membrane through the tympanic cavity to the oval window (Stach, 1998, p. 151)

**Presbycusis**- Age related hearing loss (Stach, 1998, p. 166)

**Scala Media**- Middle of three channels of the cochlear duct, bordered by the basilar membrane, Reissner’s membrane, and the spiral ligament, that is filled with endolymph and contains the organ of corti (Stach, 1998, p. 181)

**Scala Tympani**- Lowermost of the two perilymph-filled channels of the cochlear duct, separated by the scala media, terminating apically at the hliotrema and basally in the vestibule at the oval window (Stach, 1998, p. 181)
**Scala Vestibuli**- Uppermost of the two perilymph-filled channels of the cochlear duct, separated by the scala media, terminating apically at the helicotrema and basally in the vestibule at the oval window (Stach, 1998, p. 181)

**Sensorineural Hearing Loss**- Cochlear or retrocochlear loss in hearing sensitivity due to disorders involving the cochlear and/or the auditory nerve fibers of the cranial nerve VIII (Stach, 1998, p. 183)

**Stapes**- Smallest and mesialmost bone of the ossicular chain, the head of which articulates to the lenticular process of the incus and the footplate of which fits into the oval window of the cochlea (Stach, 1998, p. 192)

**Threshold Limit Values**- Guidelines to assist in the control of health hazards. They are not developed for use as legal standards (American Conference of Governmental Industrial Hygienists [ACGIH], 2008a).

**Threshold Shift**- Change in hearing sensitivity, usually a decrement, expressed in dB (Stach, 1998, p. 201)

**Time-Weighted Average**- Measure of the daily noise exposure, expressed as the product of durations of exposure at particular sound levels relative to the allowable durations of exposure for those levels (Stach, 1998, p. 202)

**Tinnitus**- Sensation of ringing or other sound in the head, without an external cause (Stach, 1998, p. 202)

**Tympanic Membrane**- Thin, membranous vibrating tissue terminating at the external auditory meatus and forming the major portion of the lateral wall of the middle ear cavity, onto which the malleus is attached (Stach, 1998, p. 207)
CHAPTER II: REVIEW OF LITERATURE

Sound does not exist outside of the mind: it is the representation of physical vibrations translated into electronic impulses (Wagner, 1994). However, for clarity, “sound” will be used in this thesis to represent these vibrations.

The Hearing Mechanism

Structures and Functions of the Ear

The ear is made of three primary parts: the outer ear, the middle ear, and the inner ear. Each part is made up of several smaller components, each with its own unique function and implications for hearing loss, which can occur in any portion of the hearing mechanism (Sataloff & Sataloff, 1998). The middle and inner ear will be discussed below.

The middle ear consists of three small bones collectively called the ossicles. They are the malleus (hammer), the incus (anvil), and the stapes (stirrup). These bones, which are the smallest in the human body, collectively are smaller than a dime (HyperPhysics, 1997). The purpose of the ossicles is to transmit vibrations from the tympanic membrane to the inner ear through the oval window (Dobie, 2001). The malleus and the stapes have muscles attached to them that react to loud sounds by contracting to provide protection by keeping excessive vibrations from reaching the inner ear. This is a process known as acoustic reflex (Mullin et. al, 2003).

The inner ear, in addition to coordinating the body’s balance, is responsible for transforming the physical vibrations transmitted by the ossicles into electrical impulses (Dobie, 2001; HyperPhysics, 1997; Mullin et. al, 2003). Connecting the ossicles to the inner ear is the oval window, through which vibrations pass from the stapes to the fluid of
the inner ear. The hearing portion of the inner ear is the cochlea (Dobie, 2001). Inside the tightly coiled cochlea (unwound, it would be nearly one foot long [Mullin et. al, 2003]) are three chambers: the scala vestibuli, scala tympani, and the scala media. The scala media, or cochlear duct, contains the organ of corti, which houses the hair cells that turn physical vibrations into electrical impulses. Different areas of the organ of corti respond differently to different frequencies (Dobie, 2001).

There are four rows of hair cells in the organ of corti: three outer rows, which detect soft sounds, and one inner row, which contains most of the connections to the brain (Dobie, 2001). As vibrations pass into the cochlear fluid, the movement excites the nearly 16,000 hair cells, causing them to bend. As the hair cells bend, electrical impulses are sent through auditory nerves to the brain as neural pulse patterns (Mullin et. al, 2003).

Types and Causes of Hearing Loss

There are four classifications of hearing loss: conductive, sensorineural, central, and functional. Any of these can exist independently or simultaneously (Sataloff & Sataloff, 1998). According to Stach (1997, p. 49), conductive hearing loss is a “reduction of hearing sensitivity, despite normal cochlear function, due to impaired sound transmission through external auditory meatus, tympanic membrane, and ossicular chain.” Simply put, conductive hearing loss includes most disorders of structure of the outer ear and the bones of the middle ear. A common cause of conductive hearing loss is a middle ear dysfunction, such as fluid build-up (Sataloff & Sataloff, 1998).

Sensorineural hearing loss includes damages to the cochlea and nerves, including the hair cells (Sataloff & Sataloff, 1998; Stach, 1997). Sensorineural hearing loss often results in loss of clarity and loudness (Sataloff & Staloff, 1998). There are many causes for
sensorineural hearing loss, including heredity, disease, medications, and noise.

Unfortunately, the prognosis for recovery from a sensorineural loss is very poor, as it is usually not solved by medical treatment (Dobie, 2001; Sataloff & Sataloff, 1998).

Central hearing loss refers to a disorder occurring in the central nervous system, between the medulla oblongata and the cortex of the brain (Sataloff & Sataloff, 1998). Functional hearing loss is more psychological than physical (Stach, 1997).

Hearing loss can be attributed to a wide range of factors. It may be acquired or hereditary and, in the latter, may be present at birth or appear later on in life (Sataloff & Sataloff, 1998). According to Mills (1992, p. 237), “the most common causes of hearing loss in adults are exposure to noise, the effects of aging, the interaction of noise and aging effects, and the interaction of noise with other variables.” However, only hearing loss due to over-exposure to noise, or noise induced hearing loss (NIHL), is completely preventable (National Institute on Deafness and Other Communication Disorders [NIDCD], 2002). NIHL can occur as a result of exposure during work or recreation, and over time or suddenly. If a loss is temporary, it is referred to as a temporary threshold shift (TTS) (NIDCD, 2002), which when repeated can become a permanent threshold shift (PTS). Symptoms of a threshold shift include a ringing or “ stuffiness” in the ears (such as that after attending a loud rock concert or sporting event), as well as sounds below the normal threshold level not being heard. NIHL is characterized on an audiogram by a “notch” in the 4000 Hz, resulting in reduced hearing acuity with sounds in that frequency range, but better hearing at lower and higher frequencies (Cutietta, Klich, Royse, & Rainbolt, 1994). This differs from presbycusis, or age-related hearing loss, which typically shows a gradual decrease across higher frequency sound.
Occupational hearing loss is commonly associated with NIHL. According to Sataloff, Sataloff, and Sokolow (2006, p. 718), “occupational hearing loss is usually bilateral, fairly symmetrical, sensorineural hearing impairment caused by exposure to high-intensity workplace noise or music.” However, the same authors go on to state that music is one of the few professions that can create somewhat asymmetrical hearing loss. A greater loss on one side of the head is caused by a phenomenon known as head shadow, in which the head acts as a sound barrier. This can be seen in musicians because of placement of a musical instrument close to the ear, such as a violin. There are numerous auditory conditions that can be associated with NIHL. Tinnitus, recruitment, and hyperacusis are among the potential disorders for someone who has been over-exposed.

Tinnitus, a sensorineural hearing loss whose Latin origin means “to tinkle or ring like a bell,” is the presence of sound only perceivable by the person who suffers from the affliction (American Tinnitus Association, 2007). Often, tinnitus can function as a warning sign of NIHL (Dobie, 2001). Ringing, whooshing, pulsing, and buzzing have all been described as symptoms, but the most common complaint is a high-pitched tone, at times severe enough to disrupt sleep (American Tinnitus Association, 2007; Vernon, 1998). There are five different types of tinnitus, each of which can be classified as subjective (cannot be observed or measured by a specialist) or objective (can be observed through physical reactions by a specialist). Aurium and cerebri are both subjective forms of tinnitus associated with loud, internal pitches, both in the head and the ears. Though tinnitus is generally considered incurable, there are several treatments available.
Masking devices, which emit a tone meant to cover the internal ringing, are one of the most common forms of treatment available.

According to the *Comprehensive Dictionary of Audiology Illustrated* (Stach, 1997, p. 174), recruitment is a condition in which “loudness grows rapidly at intensity levels just above threshold but may grow normally at high intensity levels.” Hyperacusis is a similar malady. In hyperacusis, “normally tolerable sounds are perceived as excessively loud” (Stach, 1997, p. 102). Both of these conditions have serious implications for musicians, who rely on not only keen pitch discernment, but wide spectrums of dynamic volume and differential as well.

There are four key components that factor into the effects of NIHL: overall noise level, frequency spectrum, exposure duration, and temporal pattern (Bienvenue & Prout, 1990). Sataloff, Sataloff, and Sokolow (2006, p. 719) reinforce this concept when they write “The amount of hearing loss is related to the intensity of the noise, duration and intermittency of exposure, total exposure time over months and years, and other factors.”

The ear is most sensitive to frequencies between 1,000 and 4,000 Hz (Bienvenue & Prout, 1990). While this falls towards the middle and upper end of the speech frequency spectrum, it is towards the middle of music frequencies (Chasin, 1996). While it is generally believed that as exposure duration increases so do hearing problems, some researchers believe that the first 10-15 years of exposure cause the most damage (Bienvenue & Prout, 1990).
Decibel Exposure Policy

OSHA (Occupational Safety and Health Administration) and the Standards for Noise Exposure

There are several organizations that have done research into acceptable sound levels and daily exposure doses. According to the *Spark and Blaze: Personal Noise Dosimeters and Analysis Software User Manual* (Larson Davis, 2000, p. B-5), a dose is the “percentage of time that a person is exposed to noise that is potentially damaging to hearing.” These dosages are measured in decibels (dB). A decibel is the common unit of comparison of sound pressures (Sataloff & Sataloff, 1993). Since it uses a logarithmic ratio, the decibel scale does not function in typical ascending and descending fashion like regular numbers. For example, 140 dB is not twice as loud as 70 dB, as one would expect. Instead, 75 dB is twice as loud as 70 dB. The number of decibels needed before doubling occurs can also be modified by changing the exchange rate. According to the American National Standards Institute (ANSI), the exchange rate is “the change in sound level corresponding to a doubling or halving of the duration of sound level while a constant percentage of criterion exposure is maintained” (Larson Davis, 2000, p. B-2). In the above example, five is the exchange rate (75 dB is twice as loud as 70 dB). If the exchange rate were three, 73 dB would be twice as loud as 70 dB. Exchange rates of three more accurately represent experienced sound levels.

Relatively constant sounds are typically measured with sound level meters (SLM) and fluctuating sounds with noise dosimeters (Bienvenue & Prout, 1990; Raichel, 2006). These meters typically consist of a microphone, amplifier-attenuator circuitry, and a meter to read results (Michael & Michael, 2006). Sound level meters and noise
dosimeters are typically calibrated to a common reference point that correlates to the weakest sound that the human ear can recognize (Sataloff & Sataloff, 1993).

Several organizations have created user-friendly charts of common sounds and their equivalent decibel level. However, to be truly effective, these charts must include distances from the source object, which is a major factor in sound exposure. Table 1

Table 1

Decibels and their Environmental Equivalents

<table>
<thead>
<tr>
<th>Decibels</th>
<th>Environmental Equivalent</th>
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<tbody>
<tr>
<td>30</td>
<td>Whisper-quiet library</td>
</tr>
<tr>
<td>60-70</td>
<td>Normal conversation</td>
</tr>
<tr>
<td>80</td>
<td>Telephone dial tone</td>
</tr>
<tr>
<td>85</td>
<td>City traffic from inside the car</td>
</tr>
<tr>
<td>90</td>
<td>Train whistle at 500 feet</td>
</tr>
<tr>
<td>95</td>
<td>Subway train at 200 feet</td>
</tr>
<tr>
<td>100</td>
<td>Power mower</td>
</tr>
<tr>
<td>107</td>
<td>Motorcycle</td>
</tr>
<tr>
<td>110</td>
<td>Power saw at 3feet</td>
</tr>
<tr>
<td>115</td>
<td>Loud rock concert</td>
</tr>
<tr>
<td>140</td>
<td>Jet engine</td>
</tr>
</tbody>
</table>
Table 2

*Decibels and their Musical Equivalents*

<table>
<thead>
<tr>
<th>Decibels</th>
<th>Musical equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-70</td>
<td>Normal piano practice</td>
</tr>
<tr>
<td>70</td>
<td>Fortissimo singer at three feet</td>
</tr>
<tr>
<td>75-85</td>
<td>Chamber music in a small auditorium</td>
</tr>
<tr>
<td>82-92</td>
<td>Violin</td>
</tr>
<tr>
<td>84-103</td>
<td>Piano playing at fortissimo</td>
</tr>
<tr>
<td>85-111</td>
<td>Cello</td>
</tr>
<tr>
<td>95-112</td>
<td>Oboe</td>
</tr>
<tr>
<td>92-103</td>
<td>Flute</td>
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<tr>
<td>90-106</td>
<td>Piccolo</td>
</tr>
<tr>
<td>85-114</td>
<td>Clarinet</td>
</tr>
<tr>
<td>106</td>
<td>Tympani and bass drum</td>
</tr>
<tr>
<td>120-137</td>
<td>Symphonic music peak</td>
</tr>
</tbody>
</table>

Table 3

*Decibels and Dynamic Estimations on a Violin*

<table>
<thead>
<tr>
<th>Decibels</th>
<th>Violinist dynamics</th>
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</thead>
<tbody>
<tr>
<td>40-50</td>
<td>ppp</td>
</tr>
<tr>
<td>45-55</td>
<td>pp</td>
</tr>
<tr>
<td>50-60</td>
<td>P</td>
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</table>

*(table continues)*
Early attempts to protect workers’ hearing began in the mid-1950s by the United States military. However, it was the 1969 revisions of the Walsh-Healey Public Contracts Act of 1934 that finally established noise levels regulations, but only for governmental contract workers with contracts greater than $10,000 (National Institute for Occupational Safety and Health [NIOSH], 1998). These standards were later adopted by the Service Contract Act of 1965, which allowed for protection of contracted employees for $2,500 or more, and by the Federal Coal Mine Health and Safety Act of 1969, which protected both surface and underground coal miners (NIOSH, 1998). These early acts and standards helped lead to the creation of a governing agency within the Department of Labor. The Occupational Safety and Health Administration (OSHA) was formed in 1971 to “protect almost the entire work force from job-related death, injury and illness” as a result of the Occupational Safety and Health act of 1970 (MacLaury, 2003). Lipscomb (1988) suggested that OSHA’s responsibilities can be summarized in three
words: qualify, abate, and protect (identify a problem, fix it, and prevent it from occurring again).

The American Conference of Governmental and Industrial Hygienists (ACGIH) was formed in 1938. It began as a conference for 76 industrial hygienists, with representatives from cities, a university, the United States Public Health Service, the United State Bureau of Mines, and the Tennessee Valley Authority. After this initial meeting, a small membership of governmental workers continued the work of the conference. Current membership is extended to nearly anyone in the industrial hygiene field. There are eleven committees within the organization that deal with agricultural safety, air sampling instruments, bioaerosols, biological exposure indices, computer topics, industrial ventilation, infectious agents, international topics, small business issues, chemical substance threshold limit values, and physical agent threshold limit values. Within the physical agent threshold values are the exposure limits for daily noise exposure (American Conference of Governmental Industrial Hygienists, 2007). According to the ACGIH, a person working an eight-hour shift should not be exposed to more than an average of 85 dB a day, with the threshold of a dosimeter set for 80 dB (C. Keil, personal communication, October 16, 2007). The threshold is the lowest decibel level the dosimeter will record. This is similar to the National Institute for Occupational Safety and Health (NIOSH) standard for noise exposure, with the exception that their threshold is set for zero (NIOSH, 1998). Neither of these exposure recommendations are enforceable by United States law.

Hearing conservation programs can help protect an overexposed worker’s hearing. OSHA hearing conservation programs are put into effect when a worker is
exposed to an average of 85 dB (a dose of 50%) in an eight-hour period (Sataloff & Sataloff, 2006). A hearing conservation program consists of the monitoring of decibel levels, free audiometric testing, free hearing protectors specifically attenuated for specific jobs, and regular training in hearing protection (OSHA, n.d.). However, NIOSH and OSHA state that, whenever possible, engineering controls should be the primary means of creating a safe work environment (NIOSH, n.d.; Bruce, 2007). If the worker is exposed to an average of 90 dB or more over an eight-hour period on the OSHA permissible exposure level (PEL) scale, then engineering controls are required by law. Effective uses of engineering controls are especially challenging in instrumental rehearsal facilities, where quality and clarity of sound is especially important. The addition of noise-absorptive material is an example of an engineering control. However, absorbers must be used in conjunction with sound reflectors and diffusers to achieve an accurate, balanced sound (Geerdes, 1987, 1991; Wenger, 2003a, 2003b, 2006).

Table 4

*Decibel Levels and Exposure Time*

<table>
<thead>
<tr>
<th>Decibels</th>
<th>Daily OSHA Exposure</th>
<th>Daily NIOSH and ACGIH TLV Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>85</td>
<td>n/a</td>
<td>8 hours</td>
</tr>
<tr>
<td>87</td>
<td>n/a</td>
<td>4 hours</td>
</tr>
<tr>
<td>90</td>
<td>8 hours</td>
<td>2 hours</td>
</tr>
<tr>
<td>92</td>
<td>6 hours</td>
<td>1 hour</td>
</tr>
<tr>
<td>95</td>
<td>4 hours</td>
<td>47 minutes</td>
</tr>
</tbody>
</table>

*(table continues)*
Applications for Music and Musicians

_Acoustic Treatments for Rehearsal Facilities_

Balancing good sounding acoustics with healthy, lower decibel acoustics can be a difficult task. According to Richard Talaske in *Acoustical Design of Music Education Facilities* (1990, p. 8), “perhaps no other building type involves the intensity of acoustical planning and design as does a music education facility.” A facility designed primarily for speech has different acoustic needs than a music rehearsal hall (Geerdes, 1986, 1991; Wenger, 2003a, 2003b, 2006). Since musical sounds span a much greater range of frequencies than speech, special considerations into the design of the room must be taken into account.

Room size is one of the greatest factors in determining the acoustics of a room (Geerdes, 1986, 1991; Wenger, 2003a, 2006). According to MENC: The National Association for Music Education (1974, 1994) and the Wenger Corporation (2003a, 2003b, 2006), band rehearsal facilities should have at least 2,500 square feet of floor space (e.g., a 44x58 foot floor results in 2,552 square feet), with ceiling heights of at least

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>97</td>
<td>3 hours</td>
<td>30 minutes</td>
</tr>
<tr>
<td>100</td>
<td>2 hours</td>
<td>15 minutes</td>
</tr>
<tr>
<td>102</td>
<td>1.5 hours</td>
<td>9 minutes</td>
</tr>
<tr>
<td>105</td>
<td>1 hour</td>
<td>4 minutes</td>
</tr>
<tr>
<td>110</td>
<td>30 minutes</td>
<td>1 minute</td>
</tr>
<tr>
<td>115</td>
<td>15 minutes</td>
<td>28 seconds</td>
</tr>
</tbody>
</table>

*Note.* OSHA=Occupational Safety and Health Administration; NIOSH=National Institute for Occupational Safety and Health; ACGIH=American Conference of Governmental Industrial Hygienists; TLV=Threshold Limit Values
19 feet (this differs slightly from the 1974 MENC standards that suggested an 18 foot ceiling). The result is a cubic volume of 50,000 cubic feet (Wenger, 2003B). Built-in risers lower this volume considerably. Proper cubic volume provides an area large enough to slightly delay sounds and dissipate volume.

Rehearsal rooms that are too small may result in sound levels that are too high, as there is not enough space to dissipate and absorb the sound energy (Wenger, 2006). According to Wenger’s Planning Guide for Secondary School Music Facilities (2006, p. 10),

“Rooms that are too small result in dangerously high sound-pressure levels…Rehearsing in an excessively loud room is extremely stressful for both students and teacher and can cause permanent hearing loss over a period of time. Concert bands, marching bands, orchestras, and jazz bands generate especially high sound-pressure levels and special care should be taken to control loudness in areas where these groups rehearse and perform.”

Absorbers, diffusers, and reflectors are important in creating good room acoustics. Absorption is a “reduction of sound intensity by materials that prevent reflection” (Stach, 1997, p. 2). Absorbers are used in conjunction with diffusers and reflectors.

In general, thick, porous surfaces function as better absorbers than solid, flat surfaces (Wenger, 2003b). As sound waves hit these permeable surfaces, they loose energy as they attempt to pass through them, lowering the decibel levels and reverberation time. Because lower sounds have longer sound waves, thicker materials are needed to be effective (Wenger, 2003a).
If the material is too thin, only the upper frequencies are absorbed, leading to a dull, bass-heavy, and seemingly loud room (Wenger, 2003a, 2006). Diffusers and reflectors are shaped plastic shells that work in an opposite manner of absorbers by scattering and reflecting sound (Wenger, 2006). This makes it easier to hear individual parts and helps to promote listening to the whole ensemble. It is also easier for ensemble directors to hear balances (Wenger, 2006). “A room without reflective diffusive surfaces will almost always result in poor ensemble” (Wenger, 2003a, p. 19).

The shape of a room is also important for overall acoustics. Rooms that are perfectly square can create standing waves. Standing waves are sound waves that reflect off of themselves, causing areas where the sound seems to completely stop (Sataloff & Sataloff, 1993). Because of their physical length, lower frequencies are also exaggerated in these situations (Wenger, 2003b). The best, and unfortunately the most expensive, design for a room involves sloped, non-parallel splayed walls, much like the teeth on a saw, and an angled ceiling (Wenger, 2003a).

**Noise Exposure Research Among Selected Labor Professions and Musicians**

The health effects of prolonged exposure to noise extend far beyond NIHL. There are numerous other physiological effects as well. According to a study of steel mill workers by Pawlas, Powazka, Zahorska-Markiewicz, and Zejda (2002), there is a correlation between exposure to high levels of sound and elevated blood pressure levels. The Canadian Centre for Occupational Health and Safety (CCOHS) (2007) reports that non-auditory effects of noise include muscle tension, a change in respiratory pattern, alteration of heart beat pattern, and change in the diameter of blood vessels. Researchers disagree on the permanence of these conditions.
On the job noise exposure has been well documented for a variety of fields. Firefighters, construction workers, airport employees, and coal miners are a few of the more commonly investigated professions (Babich, Bauer, & Vipperman, 2007; Chen, Conrad, & Hong, 1998; Hessel, 2000; Hong & Samo, 2007). All of these professions have tasks that could expose workers to potentially damaging sound levels, and therefore have put hearing conservation programs and preventative measures in place to protect employees from long-term damage.

There is very little research investigating the sound exposure levels of high school band directors. Two studies by Cutietta (1989, 1994) investigated instances of NIHL and loss of hearing acuity among band directors. Hearing tests were administered to participants of a music education conference. Both studies showed that a majority of subjects displayed signs of NIHL that were potentially attributed to their chosen careers. However, neither of these studies investigated in-room decibel levels for the subjects.

Two studies were found that involved college directors’ experienced decibel levels. In Harding and Owens (2002), ensemble directors (Women’s Choir, Mixed Concert Choir, Lab Band II jazz ensemble, and Symphonic Band) from the University of Northern Colorado wore personal noise dosimeters (dosimeters are decibel measuring devices) to each of their rehearsals. Their exposures were then compared to the OSHA, NIOSH, and ACGIH standards for noise exposure. It was found that the symphonic band director had the lowest exposure, likely due to the facility, which was quite large and recently remodeled. The director of Lab Band II experienced the loudest average sounds, and therefore had the highest exposure rating. In all cases (except the Lab Band), directors would have been within the OSHA limits, but well beyond the NIOSH and
ACGIH limits. The director of Lab Band II had a projected dose of 141% under the OSHA standards, and 1,181% under the NIOSH and ACGIH standards.

Mace (2005) asked performance instructors at a university to wear a noise dosimeter over the course of their typical workday. The results showed that 35% of those investigated experienced sound levels that were above the NIOSH standard, and 14% were above the OSHA standard. It was noted, however, that 22% of those studied wore earplugs while performing, practicing, or teaching.
CHAPTER III: PROCEDURE

Subjects for this study were four band directors from northwest Ohio and east central Illinois. Selections were made based upon directors’ availability to participate and quality of rehearsal facility. Two directors from treated facilities and two directors from untreated facilities participated. A treated facility contained three or more of the following four characteristics: (a) they were designed specifically for band usage, (b) they employed effective professional acoustical treatments designed to reflect and diffuse sound, (c) the room was of proper shape and dimensions for size of ensemble, and (d) the usage of flat floors. Untreated facilities contained three or more of the following four characteristics: (a) they were designed as a “music” room, or as another non-music space, (b) they included usage of non-effective amateur acoustical treatments, such as drapes and carpet squares, (c) the room size and shape were not adequate for the ensembles using it, and (d) they used built in concrete risers. Subjects who worked in untreated facilities will be referred to as Director A and Director B, while directors who worked in treated facilities will be referred to as Director C and Director D.

The facilities of Directors A and B were considered untreated. Both featured built in concrete risers, little to no professional acoustic treatment, and an abundance of hard, reflective surfaces with very little absorptive material. Director A’s facility had panels at the front of the room made of an unknown material, but their placement did little for acoustics. The facility of Director A also had made attempts at sound absorption by simply hanging carpet sample squares from the ceiling rafters. Director B’s facility was designed to accommodate both instrumental and vocal ensembles, which require different
acoustic considerations. Both rooms had walls that were primarily painted concrete block.

The risers in Director A’s facility were built seven feet from the front of the room and rose six inches each step. There were four steps in this configuration. Director B’s facility used a similar set-up, with four risers each expanding six inches closer to the ceiling, except for the top step, which rose seven inches. The facility of Director A had bare concrete floors, while Director B’s had tile.

The facilities of Director C and D were considered treated. Both rooms had professional acoustic treatments applied, including the addition of noise absorbers. Both facilities also had flat floors, with Director D’s facility using a mix of carpet and tile instead of all tile, as seen in Director C’s. Director D’s facility also had a large amount of in-room storage, with a mix of solid and grille doors on the cabinets. This allowed the storage units to act as absorbers and reflectors.

Data were collected in the fall and early spring semesters of the 2007-2008 school year using Larson Davis Spark 706RC Personal Noise Dosimeters, devices used to measure and calculate decibel exposure. These devices were worn with the microphone on the subject’s shoulder from the time the subject arrived at school until their last musical event for the day. Measurement times and ensemble samples varied depending on the subject’s schedule. Most samples lasted between five and seven hours. Two dose parameters on the dosimeters were set to correlate to the OSHA (Occupational Safety and Health Administration) standards for permissible exposure limits (PEL) and hearing conservation (HC) limits, and a third to the ACGIH (American Conference of
Governmental Industrial Hygienists) threshold limit value (TLV) standard for noise exposure.

Each standard has specific parameters for settings on the dosimeter. The settings include the threshold, the criteria, and the exchange rate. The threshold is the lowest decibel level that the dosimeter will record. The criteria is what decibel level would create a 100% dose over an eight-hour day. The exchange rate is the amount it would take to double the decibel level.

The average amount of decibel exposure over the duration of the sample was the time-weighted average (TWA). When calculated to reflect an average workday, this figure is expressed as the TWA-8. The “8” references the hours in the average workday.

Table 5

Dosimeter Settings

<table>
<thead>
<tr>
<th></th>
<th>Threshold</th>
<th>Exchange</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DOSE 1</strong></td>
<td>90db</td>
<td>5</td>
<td>90db</td>
</tr>
<tr>
<td>(OSHA PEL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DOSE 2</strong></td>
<td>80db</td>
<td>5</td>
<td>90db</td>
</tr>
<tr>
<td>(OSHA HC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DOSE 3</strong></td>
<td>80db</td>
<td>3</td>
<td>85db</td>
</tr>
<tr>
<td>(ACGIH TLV)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* OSHA PEL=Occupational Safety and Health Administration permissible exposure level; OSHA HC= Occupational Safety and Health Administration hearing conservation; ACGIH TLV=American Conference of Governmental Industrial Hygienists threshold limit values.
The daily exposure levels were calculated in percentages, with n% representing the amount of the recommended daily sound exposure level reached. These levels were referred to as the “dose.” When calculated to estimate the exposure over an eight-hour workday, they were referred to as the “projected dose.”

Subjects were also asked to complete a researcher-designed “Hearing Activity Log” to correlate exposure data to particular events and rehearsals and to take note of any painful or unusual exposure instances, as well as to denote times of audio events (e.g. 11-12 pm band rehearsal, loud trumpets, etc.). Initial data interpretation was done with Blaze Software, while further refinement was done with the assistance of a Bowling Green State University Associate Professor of Environmental Health who specializes in noise exposure research.
CHAPTER IV: RESULTS

Decibel exposure measurements for four selected high school band directors were taken in December 2007 and January 2008. These exposure levels were then compared to the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PEL), hearing conservation limits (HC) and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLV). Exposure durations lasted the duration of the workday, which varied with each subject’s daily schedule (between 5 hr 16 min and 7 hr 36 min).

Each exposure limit has specific parameters for settings on the dosimeter. A dosimeter is an electronic device used to monitor and record decibel levels. The settings include the threshold, the criteria, and the exchange rate. The threshold is the lowest decibel level that the dosimeter will record. The criteria is what level would create a 100% dose over an eight-hour day. The exchange rate is the amount it would take to double the decibel level.

The average amount of decibel exposure over the duration of the sample was the time-weighted average (TWA). When calculated to reflect an average workday, this figure is expressed as the TWA-8. The “8” references the hours in the average workday.

The daily exposure levels were calculated in percentages, with n% representing the amount of the recommended daily sound exposure level reached. These levels were referred to as the “dose.” When calculated to estimate the exposure over an eight-hour workday, they were referred to as the “projected dose.”

The OSHA PEL sets the dosimeter to 90/5/90 (Threshold=90, Exchange rate=5, Criteria=90). Under the OSHA PEL, if a worker is exposed to TWA-8 of 90 dB, then
engineering controls must be put into place. Engineering controls are modifications made to existing structures to reduce noise exposure, such as the addition of noise-absorptive material. If employees are exposed to more than 90 db, then the employer could be fined for over-exposing them to excessive noise.

The OSHA HC sets the dosimeter to 80/5/90 (Threshold=80, Exchange rate=5, Criteria=90). According to the OSHA HC, if a subject is exposed to an eight-hour time-weighted average (TWA-8) of more than 85 dB (a 50% dose), they should be enrolled in a hearing-conservation program (C. Keil, personal communication, October 16, 2007). A hearing conservation program includes the monitoring of decibel levels, free audiometric testing, free hearing protectors specifically attenuated for specific jobs, and regular training in hearing protection, all of which are provided by the employer (OSHA, n.d.).

The ACGIH TLV sets the dosimeter to 80/3/85 (Threshold=80, Exchange rate=3, Criteria=85). There are no legal implications associated with the ACGIH TLV. However, these standards are based on current research, and offer the greatest protection to an exposed worker’s hearing. A worker should not be exposed to a TWA-8 of 85 dB or greater in a day.

All four directors in this study returned three sets of data measurements, with the exception of Director B, who returned two, as seen in Table 6. All TWA-8 and percent value referred to before Table 6 are presented in the table in bold format. Subjects were also asked to complete a researcher-designed “Hearing Activity Log” to correlate exposure data to particular events and rehearsals and to take note of any painful or unusual exposure instances, as well as to denote times and occurrences of “noticeable audio incidents” (e.g., 11-12 pm band rehearsal and loud trumpets, etc.). The hearing
activity log sheets were largely inconsistent, with six instances of a class schedule being turned in, six instances of a blank form being returned, and only one instance of a “noticeable audio incident”. Because of these inconsistencies, the hearing activity log sheets were disregarded for this study.

According to the data, each director experienced decibel levels that would either make them eligible, or very close to eligible, for a hearing conservation program. A subject is eligible if he or she is exposed to a TWA-8 of 85 dB or more, or a projected dose of 50% under the OSHA HC. The directors in all four facilities had exposures over this amount. While none of the directors had three samples over the 50% dose, Directors A and D had two of the three samples 50% or above. This would be an indicator that they were being consistently over exposed, but further sampling would be needed. All of the measurements fell within the acceptable limits of the OSHA PEL. None of the measurements met the requirements of the ACGIH TLV, with the lowest projected dose being 130%.

Under the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PEL), if a worker is exposed to TWA-8 (Time weighted average, 8 hours) of 90 dB, then engineering controls must be put into place. If they are exposed to more than 90 db, then the employer could be fined for over-exposing employees. According to the data, no samples met these criteria. The closest Director A came was 82.8 dBA on Day 1. Director B came the closest of all the subjects to reaching the 90 dBA criterion (87.1 dBA on Day 2). Directors C and Ds’ highest exposures were Day 1 (75.1 dBA) and Day 2 (83.5 dBA), respectively.
According to the Occupational Safety and Health Administration (OSHA) hearing conservation limits (HC), if a subject is exposed to an eight-hour time-weighted average (TWA-8) of more than 85 dB (a 50% dose), they should be enrolled in a hearing-conservation program (C. Keil, personal communication, October 16, 2007). A hearing conservation program includes the monitoring of decibel levels, free audiometric testing, free hearing protectors specifically attenuated for specific jobs, and regular training in hearing protection provided by the employer (OSHA, n.d.). As shown in Table 6, Director A experienced levels high enough to qualify her for hearing conservation program two of the three days sampled, with the highest projected dose (148%) occurring on day 1. As shown in Table 6, Director B had one sample that would qualify them for a hearing conservation program (268%), and one that was less than 2% under the allowable amount (48.2%). As shown in Table 6, Director C had only one exposure above 50% (50.9% on Day 1). As shown in Table 6, Director D had two exposures that would make him eligible for a hearing conservation program (72.3% on Day 1 and 54.7% on Day 2).

There are no legal implications associated with the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values ACGIH TLV. However, these standards are based on current research, and offer the greatest protection to an exposed worker’s hearing. A worker should not be exposed to a TWA-8 of 85 dB or greater in a day (a 100% dose). As shown in Table 6, each director far exceeded the daily dose allowable by the ACGIH TLV. Exposure amount ranged from 125% (Director D, Day 3) to 1,526% (Director 2, Day 2). Director A had a high exposure of 969% (Day 1), while Director C’s highest exposure was 488% (Day 1).
### Table 6

**Band Directors’ Exposure Levels**

<table>
<thead>
<tr>
<th>Director</th>
<th>Day</th>
<th>Sample Duration (In hours)</th>
<th>OSHA PEL</th>
<th>OSHA HC</th>
<th>ACGIH TLV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>TWA-8</td>
<td>Dose</td>
<td>Projected Dose</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>7:33</td>
<td>82.8</td>
<td>35%</td>
<td>37%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5:40</td>
<td>78.4</td>
<td>14.3%</td>
<td>20.1%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>5:28</td>
<td>73.6</td>
<td>7%</td>
<td>10.3%</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>7:36</td>
<td>74.7</td>
<td>11.5%</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6:56</td>
<td>87.1</td>
<td>58.1%</td>
<td>67%</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>6:01</td>
<td>75.1</td>
<td>9.6%</td>
<td>12.7%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6:44</td>
<td>73.5</td>
<td>8.5%</td>
<td>10.2%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6:52</td>
<td>67.8</td>
<td>4.6%</td>
<td>5.4%</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>5:59</td>
<td>77.7</td>
<td>13.5%</td>
<td>18.1%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5:16</td>
<td>83.5</td>
<td>26.9%</td>
<td>40.9%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>7:32</td>
<td>76.2</td>
<td>14.8%</td>
<td>15.7%</td>
</tr>
</tbody>
</table>

*Note.* Values in **bold** were referred to in the text on the proceeding pages.
CHAPTER V: DISCUSSION

The OSHA (Occupational Safety and Health Administration) standards are not legally enforceable in Ohio public schools. However, in 1994, the State of Ohio adopted the OSHA standards into the Public Employee Risk Reduction Act (PERRA), covering all state employees, including those employed by public schools. This means that all state employers, including the school districts of three of the band directors in this study, must meet OSHA standards for sound exposure or face potential reprimands. In Illinois, educators are covered by the Health and Safety Act of 1986, which uses the OSHA standards as a criteria.

According to the data, all four directors may be eligible for a hearing conservation program, which includes the monitoring of decibel levels, free audiometric testing, free hearing protectors specifically attenuated for specific jobs, and regular training in hearing protection, all of which are provided by the employer (OSHA, n.d.). In Ohio, these would be enforced by PERRA, while in Illinois, it would be the Health and Safety Act of 1986. In all cases, further data would need to be collected.

One of the most important findings of this study was the disparity between the OSHA standards and the ACGIH TLV (American Conference of Governmental Industrial Hygienists threshold limit values) for sound exposure. According to Sataloff and Sataloff (2006), the OSHA standards were created in the 1970s, when audiometric data and research was still in its infancy. The ACGIH TLV was much more recently created and updated regularly to reflect current research (the TLV standards for noise are scheduled to be reviewed in 2008 [ACGIH, 2008b]).
OSHA also allows for an acceptable degree of hearing loss in their standards. According to NIOSH (National Institute of Occupational Safety and Health) (1998), there is only an 8% risk of hearing damage over a 40-year span under the 85 db criteria, as compared to OSHA’s 90 db, which has shown a 40% risk of hearing damage. While this loss is small enough to generally affect only the high-frequency range of the hearing spectrum, it can be a major hindrance to musicians, who rely on the full spectrum of audible sound to do their musical activities. Figure 1 shows the typical frequency ranges of human hearing, music, and speech. A comparison of exposure data can be seen in Figure 2.

![Frequency Spectrum for Selected Sounds](image)

While exposure levels may be falling well within the OSHA-enforceable limits for exposure, the potential for hearing damage still exists. As noted, there is a significant difference in the daily exposure levels of OSHA and the ACGIH. Due to the need for hearing acuity beyond that of typical speech frequencies, musicians should make personal efforts to follow the more stringent ACGIH TLV standards for exposure.

When analyzing the data, it was interesting to note the tremendous impact that marching band had on exposure levels. The only sample involving marching band came from Director A. On that day, she experienced an ACGIH dose of 969.2%, nearly ten times what she should have received. It is important to note that she taught marching
band less than two hours on this day, a fraction of her total workday (7 hours, 33 minutes).

Figure 2

Comparison of OSHA Exposure Levels to ACGIH Exposure Levels

![Comparison of OSHA Exposure Levels to ACGIH Exposure Levels](image)

*Note.* OSHA PEL=Occupational Safety and Health Administration permissible exposure level; OSHA HC=Occupational Safety and Health Administration hearing conservation; ACGIH TLV=American Conference of Governmental Industrial Hygienists threshold limit values.

Another major exposure took place on the second day for Director B. On this day, she received an ACGIH dose of 1,325%, over thirteen times the acceptable amount. It was noted that she was teaching beginning percussion lessons on this day, in a very small room (not the facility included in this thesis). This massive dose of sound most likely resulted from the instruments simply being too loud for the room they were in.

There are acoustical treatments that can be used to alleviate excessive decibels yet retain quality acoustics. Thick, porous absorbers have the mass needed to absorb the greatest amounts of sound energy from a wide frequency spectrum. However, using
only absorbers can create a room in which it is very difficult to “hear” (i.e., the full range of instruments and overtones). To alleviate this problem, absorbers should almost always be used in conjunction with diffusers and reflectors, such as plastic panels, which redirect sounds across the ensemble. This will help prevent the musicians from overplaying their instruments, trying to compensate to be heard. This procedure should, however, only be undertaken by a professional acoustician. Directors should not undertake their own acoustical treatments.

“Do-it-yourself” remedies rarely work. As observed in Facility A (Figure 3),

Figure 3

*Non-professional Acoustic Treatments of Facility A*

carpet squares were hung from the metal ceiling in the hopes of reducing excessive loudness. In actuality, this may have compounded existing problems. Thin materials, such as carpet squares, act as absorbers, but only for higher frequency sounds. They do
not have the density and mass needed to absorb low frequency sounds, such as those generated by a tuba or bass drum. By stripping away the higher frequencies, the ensemble is out of balance, and higher-voiced instrumentalists are forced to play louder in an attempt to “fix” the balance. This can also lead to poor playing technique. As noted, the most damaging types of sounds to the ear are loud and higher frequency sounds.

There are very few solutions for a room that is too small. If a band is too large for the size of the rehearsal room, one solution may be found in scheduling. A possible modification would be to split or reduce the ensemble into groups small enough to bring the decibel levels down. Another possibility is to alter the schedule so that directors allow time for their ears to rest (not be exposed to loud sounds). By building in rest time into the schedule, the hair cells in the ear have a greater chance to recover from a heavy exposure. However, even this solution could eventually pose problems as the hair cells lose their rigidity and ability to recover, potentially leading to a hearing loss.

Realistically, these solutions may pose as many potential problems as they alleviate, as scheduling can be challenging. While they may not be the most practical solutions, they are much more economical than building a new rehearsal facility. To avoid this problem, band rehearsal rooms should be built with the proper dimensions (a cubic volume of at least 50,000 cubic feet [Wenger, 2003B]) to begin with.

If room or schedule modifications are not an option, a director should consider musicians’ earplugs. These are special earplugs designed to reduce decibels without distorting sounds. Different filters are available to lower different levels of decibels, depending on the application. These filters commonly reduce nine, 15, and 25 decibels.
A common misconception among directors is that with earplugs in, they will not be able to have an accurate aural perception of the ensemble. Cost may be another reason why more directors have not started using hearing protection. A pair of custom-molded earplugs costs approximately $200 (US). While foam earplugs or even a quality pair of earplugs designed for gun shooting may be much less expensive, they are not attenuated, or designed, for musical performance. Because of the amount of sound generated by marching bands, earplugs should always be worn in these rehearsal situations, regardless of whether the room has been acoustically treated. Student musicians should also consider using musicians’ earplugs.

Because high school ensembles typically play with a relatively small dynamic variance, and usually at consistently louder levels, directors should work on expanding the dynamic range of their ensembles. It is believed one potential reason professional orchestra directors have less exposure danger is because of the wider dynamic range of their ensembles (Millin, as cited in Cutietta, 1994). Professional orchestras typically have a 13db dynamic range, while high school bands have only a 3db range (Millin, as cited in Cutietta, 1994). The benefits of expanding the dynamic range are twofold. First, directors will experience a wider variety of dynamics, particularly softer dynamics, giving their ears much needed rest. Secondly, expanding the dynamic range will help their students to become better musicians.

Potentially, the most important finding of this research is that it is nearly impossible to issue a broad-reaching explanation or solution for band directors’ sound exposure. Each situation presents its own unique circumstances. This may be one reason why so little research has been done specifically on this topic. If possible, each director
should seek out the resources, such as decibel meters or noise dosimeters, to determine their own decibel exposures. With this knowledge, a modified hearing conservation program could be put into effect, potentially preserving hearing acuity and prolonging the inevitable decline brought about by the aging process.

Implications for Music Education

Based upon the results of this study, the following points may be useful for band directors to consider:

1. Band directors should strongly consider wearing musicians’ earplugs during rehearsals.
2. Band directors should try to determine their own decibel exposure levels through the use of noise dosimeters or decibel meters to determine their need or eligibility for a hearing conservation program.
3. The advice of a professional acoustician should be sought out before construction or modification of a rehearsal facility.
4. Directors should be made aware early on in their career that there is a potential for substantial hearing loss attributed to their profession so they can take the appropriate preventative measures.

Suggestions for Further Research

Based upon the results of this study, the following suggestions for further research seem warranted:

1. It may be helpful to include more marching and athletic bands, which produce much greater decibel levels than high school concert bands, in future studies.
2. It may be beneficial to take a greater number of samples, as well as include a greater number of high school band directors.

3. It may be useful to investigate other music educators’ decibel exposure levels, including general music, choir, orchestra, and band at all grade levels.

4. It may be helpful to compare how well directors hear various aspects of musical ensembles both with and without musicians’ earplugs.
REFERENCES


*Acoustical design of music education facilities.* (pp. 8-15). Syracuse, NY:

Acoustical Society of America.


Contemporary.


Owatonna, MN: Author.

BIBLIOGRAPHY


APPENDIX A:

COVER LETTER SENT TO DIRECTORS
Dear (Insert Subject Name),

My name is Andy Messerli, and I am currently completing my second year of masters’ studies in music education at Bowling Green State University. As part of my degree program, I am conducting a thesis research project. The purpose of this study will be to determine high school band directors' sound exposure levels relative to the Occupational Safety and Health Administration (OSHA) workplace standards. By determining these exposure levels, it can be better determined what, if any, precautions should be in place for band directors, such as room modifications or hearing protection. It is my hope that you will be willing to participate in this study.

Your participation is completely voluntary, and at any time, you may withdraw from this study. If you agree to participate, you will be asked to wear a noise dosimeter (a device used to record audio exposure levels) for three non-consecutive days (approximately once a month). The dosimeter is roughly the size of a large cell phone and can be worn comfortably on a belt or in a pocket. There is also a small microphone that is worn on the shoulder. No actual sound will be recorded, only the sound levels. None of the equipment should interfere with conducting or normal instructional activities. Data collected from these dosimeters will be downloaded via infrared transmission to a computer with analysis software. In addition, you will be asked to complete a brief hearing activity log on a form provided for you. This will allow a better understanding of what high school directors are exposed to. There are no risks associated with this study other than what your ears would on a typical day of work. The data gathered will remain confidential; your identity will not be revealed in any published results unless you specifically request identification. You will be referred to only by numbers (Subject 1, Subject 2, etc.) in the study. The dosimeters used to record data are numbered, and only I will know which director they are assigned to. The hearing logs will be labeled only with the assigned dosimeter number. This information will be kept on a single-user, password-protected computer.

Feel free to contact me with any questions. Please let me know by September 20th if you are able and willing to participate. You may also contact the Chair, Human Subjects Review Board, Bowling Green State University, (419) 372-7716 (hsrb@bgsu.edu), with questions or if any problems or concerns arise during the course of the study.

Thank you in advance for your time,

Andy Messerli
1-618-567-4019
messera@bgsu.edu

cc: Project Advisor
Dr. Bruce Moss
1-419-372-2186
bbmoss@bgsu.edu
APPENDIX B:

DOSIMETER OPERATING INSTRUCTIONS
To turn the dosimeter ON:
1. Press the ON/OFF button (1)
2. After the screen has finished loading, press the RUN button (2)

To turn the dosimeter OFF:
1. Press the RUN (1) button, followed by the ON/OFF button (2).

*If the screen appears with the message shown at the left, you must first press the (*), then follow the steps above.

If you have any other problems operating the device, please contact me at 1-618-567-4019. It is very important that the recording takes place only during the hours that you are wearing the dosimeter!
APPENDIX C:

HEARING ACTIVITY LOG SHEET
Hearing Activity Log Sheet

Please complete one of these sheets each time you wear a dosimeter. Under “Class or Activity,” please list what class, rehearsal, or other activity you are involved with. For “Noticeable Audio Incidents,” please list any observations about particularly loud noises, if you experience any pain, or other comments. An example can be seen in the first row of the table.

<table>
<thead>
<tr>
<th>Time</th>
<th>Class or Activity</th>
<th>Noticeable Audio Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00</td>
<td>Jazz Band</td>
<td>Ringing in ears after loud</td>
</tr>
<tr>
<td></td>
<td>Main rehearsal</td>
<td>trumpet sections</td>
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<tr>
<td>7:00</td>
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<td>8:00</td>
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<td>9:00</td>
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<td>9:00</td>
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</tbody>
</table>
APPENDIX D:

PHOTOS OF FACILITY FOR DIRECTOR A
Rear of Facility for Director A

Front of Facility for Director A
Absorptive Material in Facility for Director A
APPENDIX E:

PHOTOS OF FACILITY FOR DIRECTOR B
Left Rear of Facility for Director B

Right Rear of Facility for Director B
Front of Facility for Director B
APPENDIX F:

PHOTOS OF FACILITY OF DIRECTOR C
Rear of Facility for Director C

Loft storage of Facility for Director C
Absorptive Material in Facility of Director C

Diffusers in Facility of Director C
APPENDIX G:

PHOTOS OF FACILITY OF DIRECTOR D
Front of Facility for Director D

In-Room Storage in Facility of Director D
Rear of Facility for Director D (A banner identifying the school has been blacked out)

Absorptive Material in Facility of Director D