OCCUPATIONAL NOISE

1.0 INTRODUCTION

Many field activities, such as drilling and heavy equipment operations, can produce considerable noise. There is evidence that exposure to noise of sufficient intensity and duration can result in hearing damage and other physical ailments. Noise-induced hearing loss can happen so gradually that it often goes unnoticed. In many instances, hearing loss can be permanent. This is why it is essential to be aware of the hazards associated with occupational noise and the steps you can take to protect your hearing.

The extent of hearing damage depends on the loudness of noise to which you are subjected and the length of time you are exposed. Exposure to loud noises can tire the inner ear and cause a temporary loss of hearing. Unprotected, continued exposure to loud noise, defined by OSHA (29 CFR 1910.95) as noise levels over 85 decibels (averaged over an 8-hour time period), can damage the hair cells of the inner ear and result in permanent hearing loss.

Learning Objective(s)
At the end of this module, you will be able to:

- Describe the basic anatomy and function of the human ear
- Recognize potentially harmful noisy environments and the effects of noise on the human body
- Explain how noise is measured
- Explain the purpose of audiometric testing
- Identify measures for controlling noise exposure (e.g., engineering controls and personal protective equipment)
- List the major components of and the need for a hearing conservation program.

2.0 THE EAR: ANATOMY, FUNCTION, AND SENSITIVITY

The ear allows humans to hear sound. Sound is defined as any pressure variation that the human ear can detect. The following sections present the basic components and functions of the ear, as well as human sensitivity to sound.

2.1 Anatomy and Function

The ear is divided into three parts: the external, middle and inner ear, each of which has a specific function.

The external portion of the ear collects sound waves from the air and funnels them into the ear canal, where they are transported to the eardrum. The external ear consists of the:

- Pinna

- External auditory canal.

The collected sound waves cause the eardrum to move back and forth in a vibrating mechanical motion that is passed on to the bones of the middle ear.

The middle ear transfers sound energy from the outer ear to the inner ear and consists of the:

- Eardrum
- Ossicular chain (hammer, anvil, and stirrup)
- Eustachian tube.

The sound vibrations transmitted from the middle to inner ear create waves in the fluid within the inner ear. This stimulates hair cells, which generate nerve impulses that then pass along the auditory nerve to the brain. The inner ear consists of the:

- Auditory nerve
- Cochlea
- Oval window and the round window
- Acoustic nerve.

2.2 Sensitivity

Sound level is measured in the units of decibels (dB). The human ear can hear sounds in the range from 0 to 140 decibels. Loudness depends not only on the sound level, but also on the frequency of sound. The human ear can detect sound waves within a frequency range of 20 to 20,000 hertz (Hz). Frequency is perceived by humans as pitch. The human ear is more sensitive to high-frequency sounds than it is to low-frequency sounds. Additionally, noise composed of narrow frequency bands can be more harmful to hearing than broad band noise.

High-frequency sounds which may be encountered during field activities include noise created by pneumatic tools and hammer mills. Some examples of low frequency sounds are the rumble associated with oil- or gas-fired burners and the noise from the exhaust of a jet engine or large gas turbine.

3.0 EFFECTS OF NOISE

Noise can have varying effects on the human body, depending on the exposure levels and the susceptibility of the worker. In addition to hearing loss, noise can alter the normal functions of the endocrine, cardiovascular, and neurological systems. There is continuing medical research on the harmful side effects of noise.

3.1 Effects of Noise on Hearing Ability

Noise may cause two different types of hearing damage:

- Acoustic trauma: The loss of hearing due to the sudden intense auditory trauma caused by a very loud, sudden sound, like an explosion. Acoustical trauma typically refers to mechanical damage, such as a ruptured eardrum.

- Sensori-neural loss: The result of continued exposure to a loud noise for a prolonged time. A sensori-neural loss can involve either an impairment of the cochlea, the auditory nerve, or both. Permanent hearing loss is normally a result of sensori-neural loss. For example, damage to the hair cells of the inner ear is classified as sensori-neural loss and may be permanent.

Occupational hearing loss in the high frequency ranges seriously affects the understanding of speech, since hearing at these higher frequencies is necessary to discriminate the consonants of speech that carry information. For example, a worker may be able to hear speech, but not be able to understand what is being said (e.g., the ability to differentiate between "fish" and "fist"). Workers in noisy areas are at higher risk of having an accident because they do not understand verbal warnings.

3.2 Other Effects of Noise

Excessive noise levels can affect the body in many different ways. Some of the known effects of noise on the body are:

- Quickened pulse rate, increased blood pressure, and narrowing of blood vessels, which tend to put an additional strain on the heart
- Abnormal secretion of hormones (e.g., thyroid, adrenaline), which causes early fatigue and possible illness
- Nervousness, sleeplessness, and general fatigue
- Pupil dilation
- Heart palpitations
- Digestive problems.

In the workplace, loud noises can startle workers, make them nervous and irritable, and also contribute to increased accidents and mistakes.

4.0 EXAMPLES OF NOISY ENVIRONMENTS, ACTIVITIES, AND EQUIPMENT

With normal hearing, the range of audible sound falls within 0-140 decibels. Sound levels ranging from 0 to 70 decibels offer no cause for concern. Whispering and conversational speech fall into this range.

When you move into the 80 to 135 decibel range, you may need to use protective equipment, such as ear plugs. Depending on the duration of exposure, noise at this level

can be damaging. Examples of sounds in this range include noise from a factory, a passing truck, or a riveter.

Sound levels above 135 decibels are considered hazardous. The threshold of pain begins at 140 decibels for most individuals. You should avoid entering areas with noise at or above these levels unless you have the proper protective equipment.

The table below provides examples of noisy environments, activities, and equipment and corresponding sound levels for each.

SOUND LEVEL (DB)	SOUND SOURCE
194	Saturn rocket
180	
170	
160	Ram jet
150	Turbo jet
140	Threshold of pain
135	
130	Pipe organ
120	Riveter, chipper
110	Punch press
100	Passing truck
90	Factory
80	Noisy office
70	
60	Conversational speech
50	Private office
40	Average residence
30	Recording studio
20	Whisper
10	Threshold of good hearing
0	Threshold of excellent youthful hearing

Source: National Safety Council's Fundamentals of Industrial Hygiene: Industrial Noise

5.0 HEARING LOSS PREVENTION

Because hearing loss can be permanent, the only way to protect your hearing is through loss prevention. Your facility can do the following to prevent hazards:

- Install or use mufflers or muffling devices on engines, machines, and work processes to help reduce noise levels

- Use equipment shrouds or covers to help eliminate noise and protect workers from moving parts
- Whenever possible, select work sites in remote areas or in areas away from noisy equipment or processes
- Properly maintain and operate equipment in accordance with specifications to keep operations from being noisier than needed
- Shut down equipment when not in use and establish a work procedure which limits exposure time.

The health, safety, and engineering personnel should take every step possible to limit or reduce noise hazards. If they have taken all preventative measures possible and a hazard still exists, workers may be required to wear personal protective devices. The following sections discuss the hearing conservation program and the steps employers are required to take to protect you from the hazards of occupational noise.

6.0 HEARING CONSERVATION PROGRAM

When noise exposures equal or exceed the action level, employers must implement a hearing conservation program. The following areas must be covered in a hearing conservation program:

- Noise exposure monitoring
- Audiometric testing
- Hearing protectors
- Employee training and information
- Recordkeeping system.

6.1 Monitoring

According to OSHA regulations, employers must implement a noise monitoring program when information indicates that exposure may equal or exceed the action level, defined as an 8-hour time weighted average (TWA) of 85 decibels (dBA). A rule of thumb to use is that if you have to raise your voice in order to be heard over the noise a few feet away, you are probably close to the 85 decibel level. Noise exposure monitoring should be conducted to:

- Identify employees for inclusion in the hearing conservation program
- Allow for proper selection of hearing protectors.

This could be accomplished by performing a complete sound level survey of the entire site and recording the results on a site plot plan. When the sound level survey indicates portions of the site may exceed 85 dBA, additional area or personal dosimetry can then be used to identify employees and their levels of noise exposure.

Appendix A contains a table of sound levels and acceptable durations of exposure at each level.

6.1.1 Sound Measuring Instruments

There are three basic types of sound measuring instruments:

- Sound level meters (SLMs)
- Noise dosimeters
- Octave band analyzers.

SLMs measure the noise at a given point in time, while dosimeters log noise over a designated sampling period. Many dosimeters give results as percentages of the allowable 8-hour time-weighted average.

Octave-band analyzers are used to determine where the noise energy lies in the frequency spectrum. This is especially useful when developing engineering controls for noise problems.

As mentioned earlier, the human ear is more sensitive to high-frequency sounds. To account for this fact, weighting networks ("A", "B", and "C") were developed so that the sensitivity of sound measuring instruments would vary with frequency in the same manner the human ear does. The ACGIH has adopted the A-weighted sound level for assessing noise exposure.

6.2 Audiometric Testing

An audiometric testing program must be available at no cost to all employees exposed at or above the action level. Within 6 months of an employee's first exposure at or above the action level, a valid baseline audiogram must be obtained. If mobile test vans are used to meet the audiometric testing requirement, a valid basline audiogram must be obtained within 1 year of an employee's first exposure at or above the action level. At least annually thereafter, a new audiogram must be obtained as long as the employee is exposed at or above the action level.

6.2.1 Standard Threshold Shifts

A standard threshold shift is defined as a change in hearing threshold relative to the baseline audiogram of an average of 10 dB or more at frequencies of 2000, 3000, and 4000 Hz in either ear.

If a standard threshold shift has occurred, the employee must be informed of this fact in writing, within 21 days of the determination and additional steps must be taken to ensure that employees are protected from further overexposure (consult OSHA's 29 CFR 1910.95 for details).

6.3 Hearing Protection

Hearing protection may be necessary during some field activities if noise exposures cannot be controlled through engineering or other work practice controls.

Earplugs or earmuffs are the most common protective devices. Many brands and types of these devices exist, each with its good and bad points.

6.3.1 Earplugs

These types of earplugs and their relative advantages/disadvantages include:

Formable: Formable plugs are generally of the disposable expanding foam type. This type of earplug has the dual advantage of being able to expand to fit all sizes of ears, are inexpensive, and can be disposed of after each use. This can reduce the risk of ear infection provided hands are cleaned before handling the earplugs. Some of these foam plugs come with a cord.

Custom molded: Each person's auditory canal is a different size and shape. Thus there are earplugs which can be custom made and fitted for the individual. Since your ear canal can change shape-size at different times, fitting this type of earplug can be difficult. Drawbacks associated with this type of plug are the expense and the requirement to keep plugs clean at all times. They also have a tendency to shrink over a period of time

Premolded: These plugs come in general sizes (small, medium, and large) and do not fit as well as individual plugs. Preformed plugs can be disposable or non-disposable, and must be cleaned before each reuse to prevent ear infections. Shapes include cones, "Christmas trees", flanged, etc. Many come with a cord.

6.3.2 Earmuffs

Earmuffs, also known as circumaural hearing-protective devices, consist essentially of two cup or dome-shaped devices that fit over the entire external ear, including the lobe, and then seal against the side of the head with a suitable cushion or pad. In general, the ear cups are made of a molded rigid plastic and are lined with a cell-type foam material.

The size and shape of the ear cup vary from one manufacturer to another.

When selecting earmuffs, choose the cup with the smallest possible circumference to accommodate the largest ear lobe. A slight pressure on the lobe can become painful in time, so it is very important to select a muff dome that is large enough.

The earmuffs currently on the market are supplied with replaceable ear seals or cushions that may be filled with foam, liquid, or air - the foam-filled type is the most common. The outer covering of these seals is vinyl or a similar thermoplastic material. Human perspiration tends to extract the plasticizer from the seal material, eventually stiffening the seals. For this reason, the seals need to be repaired periodically, depending on the condition of exposure.

Ear muffs are relatively expensive, tend to be warm, can be difficult to use when wearing head and respiratory devices, and must be cleaned between uses. However, when constructed properly, ear muffs can afford the best protection. The fit must not be obstructed by long hair, glasses, or any device or piece of clothing, such as a hat or hood.

6.3.3 Selection of Hearing Protectors

The type of hearing protector to be used should be chosen with the specific job in mind. For example, if the protector must be removed frequently, earplugs may not be practical, and ear muffs should be used instead. However, if glasses or long hair prevent effective use of muff type protectors, earplugs should be used. Personal preference, comfort, and duration of use are also factors to consider when selecting hearing protection.

Hearing protective devices are typically given a Noise Reduction Rating (NRR) per EPA testing guidelines. This rating is used as a guide to estimate how much noise (dB) the protective device will reduce when properly worn. For example, a protection device with a NRR 30 will supposedly make a noise of 90 dB sound like 60 dB to the ear.

Hearing protectors must be **available** to all employees exposed at or above the action level (85 dBA, 8-hr. TWA), at no cost. Hearing protectors must be **worn** by:

- Any employee exposed to noise above the permissible limits (90 dBA 8-hr. TWA), in order to reduce sound levels below the permissible noise exposures when feasible administrative or engineering controls have failed

- Any employee who is exposed at or above the action level and has not yet had a baseline audiogram within six months of first exposure, or who has experienced a standard threshold shift.

Although personnel exposed to noise between 85-89 dBA are not required to wear hearing protection, it is highly recommended.

Employees must be given the opportunity to select their hearing protection from a variety of suitable protectors provided by project leaders.

6.4 Employee Training and Information

All employees exposed at or above the action level must participate in a training program including, but not limited to, the following topics:

- The effects of noise on hearing
- The purpose of hearing protectors
- The advantages, disadvantages, and attenuation of various types of hearing protectors
- Instructions on selection, fitting, use and care of hearing protectors
- The purpose of audiometric testing, and an explanation of testing procedures.

The training program must be offered annually to each employee in the hearing conservation program. Information must be updated to be consistent with changes in protective equipment and work practices.

6.5 Recordkeeping System

Employers must keep an accurate record of all employee noise exposure measurements for a minimum of two years. All employee audiometric test records obtained must be retained for the duration of the affected worker's employment, including the following information:

- Name and job classification of the employee
- Date of the audiogram
- The examiner's name
- Date of the last acoustic or exhaustive calibration of the audiometer
- Employee's most recent noise exposure assessment
- Measurements of the background sound pressure levels in audiometric test rooms.

7.0 CONTROL MEASURES

A straightforward method of controlling noise exposure is to examine the problem in terms of its three basic elements:

- Sound arises from a source
- Sound travels over a path
- Sound affects a receiver.

Solution of a given noise problem might require alteration or modification of any or all of these three basic elements. For example, you could:

- Modify the source to reduce its noise output. For example, impact or impulse noise can be decreased by reducing weight, size, or height of fall of the impact mass.

  Noise output can also be decreased by reducing speed in machines and flow velocities and pressures in the fluid systems and by controlling the frictional resistance and vibration of parts.

- Alter or control the transmission path and the environment to reduce the noise level reaching the receiver. Separate the noise source and receiver as much as possible and use sound barriers, deflectors, mufflers, or silencers where appropriate.

- Provide the receiver with personal protective equipment (but only if the noise source or path cannot be controlled).

8.0 SUMMARY

Noise is an occupational hazard which, if not properly controlled, can lead to temporary or permanent hearing loss and other physical ailments, as well as increased accidents in the workplace. The primary factors in the analysis of noise exposure are:

- Sound level
- Frequency of sound
- Duration of exposure.

Since hearing loss may be permanent, loss prevention is the key to protecting your hearing ability. Workplaces with noise levels above the action level (85 decibels, 8 hour TWA) must institute a hearing conservation program which includes measures for:

- Noise measurement and analysis
- Control of noise exceeding permissible exposure limits (through engineering and work practice controls)
- Hearing protection for employees working in areas where noise cannot be feasibly controlled
- Audiometric testing for all employees covered under the hearing conservation program
- Employee information and training
- Recordkeeping.

In addition to the hearing conservation program, employers can take the following measures to protect employee hearing:

- Use engineering controls, such as installing muffling devices or equipment shrouds, to reduce noise from machinery and equipment.
- Select work sites in areas away from noise equipment whenever possible.
- Properly maintain equipment.

- Shut down equipment when not in use.

Measures you can take to protect your hearing include:

- Obtain a baseline and an annual audiogram if you are eligible for the Hearing Conservation Program or if you feel you need one.
- Participate in employee training programs offered as part of the Hearing Conservation Program.
- Use personal protective equipment such as earplugs or ear muffs, if needed.

EXERCISE

Fill in the blank with the appropriate response.

1. Collected sound waves cause the _____ to move back and forth in a vibrational mechanical motion that is passed on to the bones of the middle ear.

2. The human ear can hear sounds in the range of ____ to ____ decibels, and the human ear can detect sound waves within a range of _____ to _____ hertz.

3. Noise can cause two different types of hearing damage: _____ and _____.

4. A monitoring program must be implemented when noise exposures equal or exceed the _____, which is _____ dBA.

5. A _____ is a change in hearing threshold relative to the baseline audiogram of an average of _____ dB or more at frequencies of 2000, 3000, and 4000 hertz, in either ear. This can be detected by an _____ testing program.

6. Control measures may be implemented for any of the three basic elements of a given noise problem: at the _____; over the noise pathway; or at the _____.

7. The key factors in noise exposure analysis are _____; _____; _____.

EXERCISE KEY

Fill in the blank with the appropriate response.

1. Collected sound waves cause the ***eardrum*** to move back and forth in a vibrational mechanical motion that is passed on to the bones of the middle ear.

2. The human ear can hear sounds in the range of ***0 to 140*** decibels, and the human ear can detect sound waves within a range of ***20 to 20,000*** hertz.

3. Noise can cause two different types of hearing damage: ***acoustic trauma and sensori-neural loss.***

4. A monitoring program must be implemented when noise exposures equal or exceed the ***action level***, which is ***85*** dBA.

5. A ***standard threshold shift*** is a change in hearing threshold relative to the baseline audiogram of an average of ***10*** dB or more at frequencies of 2000, 3000, and 4000 hertz, in either ear. This can be detected by an ***audiometric*** testing program.

6. Control measures may be implemented for any of the three basic elements of a given noise problem: at the ***source***; over the noise pathway; or at the ***receiver***.

7. The key factors in noise exposure analysis are ***sound level; frequency; duration.***

APPENDIX A:

SOUND LEVEL (dBA)	DURATION (HOURS)
80	32
81	27.9
82	24.3
83	21.1
84	16.4
85	16
86	13.9
87	12.1
88	10.6
89	9.2
90	8
91	7.0
92	6.1
93	5.3
94	4.6
95	4
96	3.5
97	3.0
98	2.6
99	2.3
100	2
101	1.7
102	1.5
103	1.3
104	1.1
105	1
106	0.87
107	0.76
108	0.66
109	0.57
110	0.5
111	0.44
112	0.38
113	0.33
114	0.29
115	0.25
116	0.22
117	0.19
118	0.16
119	0.14
120	0.125
121	0.11

122	0.095
123	0.082
124	0.072
125	0.063
126	0.054
127	0.047
128	0.041
129	0.036
130	0.031