14 HEARING PROTECTION

Introduction

Many jobs produce noise. Typical construction work may involve equipment driven by large and small engines, metal fabrication, power drilling and sawing, air hammering, and blasting — all of which can produce noise at harmful levels.

Depending on the noise level, duration of exposure, and other factors, a temporary or permanent hearing loss may result. Temporary hearing losses will usually be restored by the body within a few hours after the exposure has ceased. Hearing losses which cannot be restored by the body over any length of time are termed permanent.

A person suffering a hearing loss will frequently not realize it. Noise may be harmful at levels that an exposed person does not consider irritating or annoying. Therefore, despite **individual** preferences, prevention and control procedures must be based on the **general** potential for hearing loss.

Waiting for personal discomfort before taking preventive measures may be too late to avoid a permanent noise-induced hearing loss.

Noise Measurement

Measuring sound levels can determine

- whether or not a noise hazard is present
- noise exposures of workers
- which workers require hearing protection, hearing tests, education, and training.

Measurements are performed with a sound level meter (SLM). The unit used to measure the intensity of sound is the decibel (dB). Intensity is perceived as loudness.

Noise levels can't be added directly like other numbers. For example, two noise sources producing 90 dB each would have a combined output of 93 dB, not 180 dB. The combined output of 93 dB is actually a *doubling* of intensity.

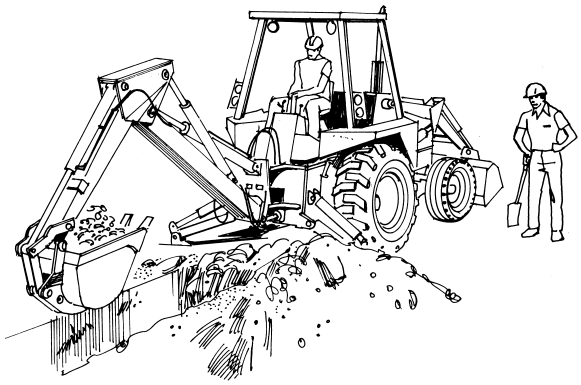
In many construction situations, several different sources each contribute to the overall noise. This means that a worker's exposure may be much higher than it would be if only one of the sources was present (Figure 22).

In addition to intensity, the SLM can detect a wide range of frequencies. Since the human ear tends to filter out the lower frequencies and slightly accentuate the higher ones, SLMs are engineered to do the same. They feature an internal mechanism called "A-weighting." The resulting noise level is expressed as decibels (dB) on the "A" scale or dBA.

Two types of noise measurements can be performed: area and personal.

An **area noise measurement** is taken in a specific work area. The measurement is generally used as a preliminary step to determine whether more detailed evaluation involving personal noise measurement is necessary. Area noise readings should not be used to determine what hearing protection is required or who needs a hearing test. Personal exposure measurement should be used for these purposes.

Figure 22



The backhoe is producing 90 dB of noise. The worker standing nearby is therefore exposed to 90 dB.

The backhoe is producing 90 dB. The compressor is also producing 90 dB. The worker standing between the two pieces of equipment is therefore exposed to their combined output. This double intensity is 93 dB.

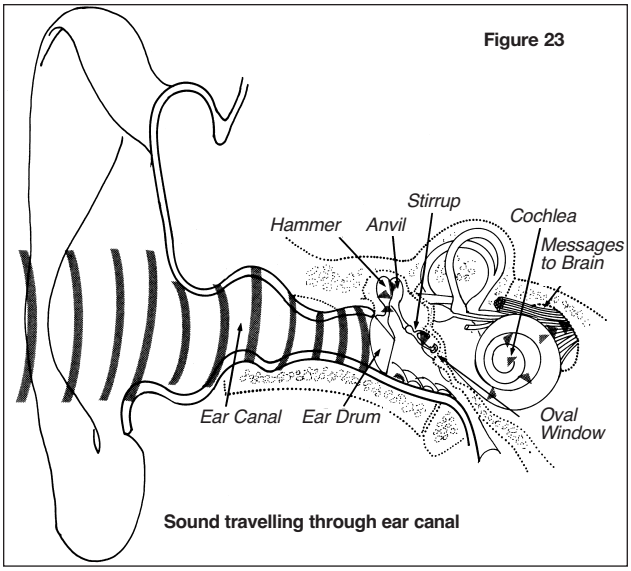
Personal noise measurement involves a small device called a noise dosimeter. Workers can wear the device to determine their average noise exposure over a whole shift. Usually worn around the waist, the dosimeter has a microphone that is placed as close to the worker's ear as possible.

Noise measurements should be carried out in accordance with acceptable standards. Canadian Standards Association (CSA) Standard Z107, *Procedures for the Measurements of Occupational Noise Exposure*, provides guidance on the type of equipment to use, which workers to test, and how to test.

Noise evaluation must be done by a knowledgeable person trained and experienced in conducting noise surveys.

Hearing Process

The hearing process begins when the outer ear directs sound waves into the ear canal (Figure 23). The eardrum vibrates as sound waves strike it. This vibration is then transmitted through the middle ear where it is amplified on a membrane called the oval window. The oval window separates the middle ear from the inner



ear where the sensitive hearing organs are located. Attached to the other side of the oval window is a tiny, snail-shaped structure called the cochlea. The cochlea contains fluid and hair cells. These thousands of small but highly sensitive hair cells feel the vibration. Responding to the cells are microscopic nerve endings that send messages to the brain, where the signals are interpreted as varieties of sound.

Hearing Loss

Any reduction in the normal ability to hear is referred to as a loss of hearing. A hearing loss can be either temporary or permanent.

Temporary Threshold Shift

With a temporary hearing loss, normal hearing will usually return after a rest period away from all sources of intense or loud noise. The recovery period may be minutes, hours, a day or perhaps even longer. It is believed that a temporary hearing loss occurs when hair cells in the inner ear have been bent by vibrations and need time to bounce back.

Most of the temporary hearing loss occurs during the first two hours of exposure and recovery takes place usually within the first two hours after exposure stops. However, the length of time needed for recovery depends primarily on how great the initial loss was. The greater the initial loss the longer the time needed to recuperate. This temporary decrease in hearing ability is called a temporary threshold shift (TTS) because the threshold or level at which sound can be heard has been raised.

For instance, to listen to your favourite music at the volume you like, you would have to turn it up a few more notches than usual. This phenomenon explains why some people, particularly those who suffer from some form of hearing loss, claim that they "get used to the noise."

If these previous exposures are allowed to continue under the same conditions and without the proper interval of rest, then a certain degree of permanent hearing loss is possible.

Permanent Threshold Shift

Permanent hearing loss is the result of hair cell or nerve destruction within the cochlea. Once these important parts of the hearing process are destroyed, they can never be restored or regenerated. The resulting permanent hearing loss, also referred to as permanent threshold shift (PTS), can range from slight impairment to nearly total deafness.

A symptom of PTS is the inability to pick up sounds with higher frequencies. As damage increases, the reception of speech becomes more difficult.

Unfortunately, the damage builds up gradually. Workers may not notice changes from one day to another. But once the damage is done there is no cure. Effects may include the following.

- Sounds and speech become muffled so that it's hard to tell similar-sounding words apart or to pick out a voice in a crowd.
- Sufferers ask people to speak up, then complain that they are shouting.
- There's a permanent ringing in the ears (tinnitus).
- Sufferers need to turn the volume on the radio or television way up or find it hard to use the telephone.

Determining Factors

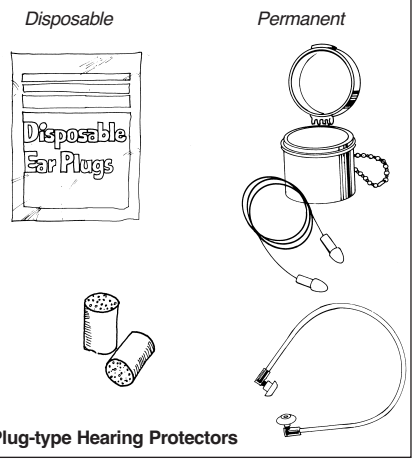
The following factors determine the degree and extent of hearing loss:

- **Type of Noise**
  (continuous, intermittent, impact, high or low frequency)
- **Intensity of Noise**
  (level of loudness)
- **Duration of Exposure**
  (length of time worker subjected to noise — for example, during day, on specific shifts)
- **Employment Duration**
  (years worker subjected to noise)
- **Type of Noise Environment**
  (character of surroundings – for example, enclosed, open, reflective surfaces)
- **Source Distance(s)**
  (distance of worker from noise source)
- **Worker's Position**
  (position of worker relative to noise source)
- **Worker's Age**
  (for instance, a 20-year-old apprentice versus a 50-year-old journeyperson)
- **Individual Susceptibility**
  (sensitivity difference, physical impairments)
- **Worker's Present Health**
  (whether a worker has any detectable losses or ear diseases)
- **Worker's Home and Leisure Activities**
  (exposures to noise other than occupational, such as hunting, skeet shooting, earphone music, snowmobiling, etc.)

Other prime causes of permanent hearing loss are age, traumatic injuries (such as from explosions or gunfire), and infection.

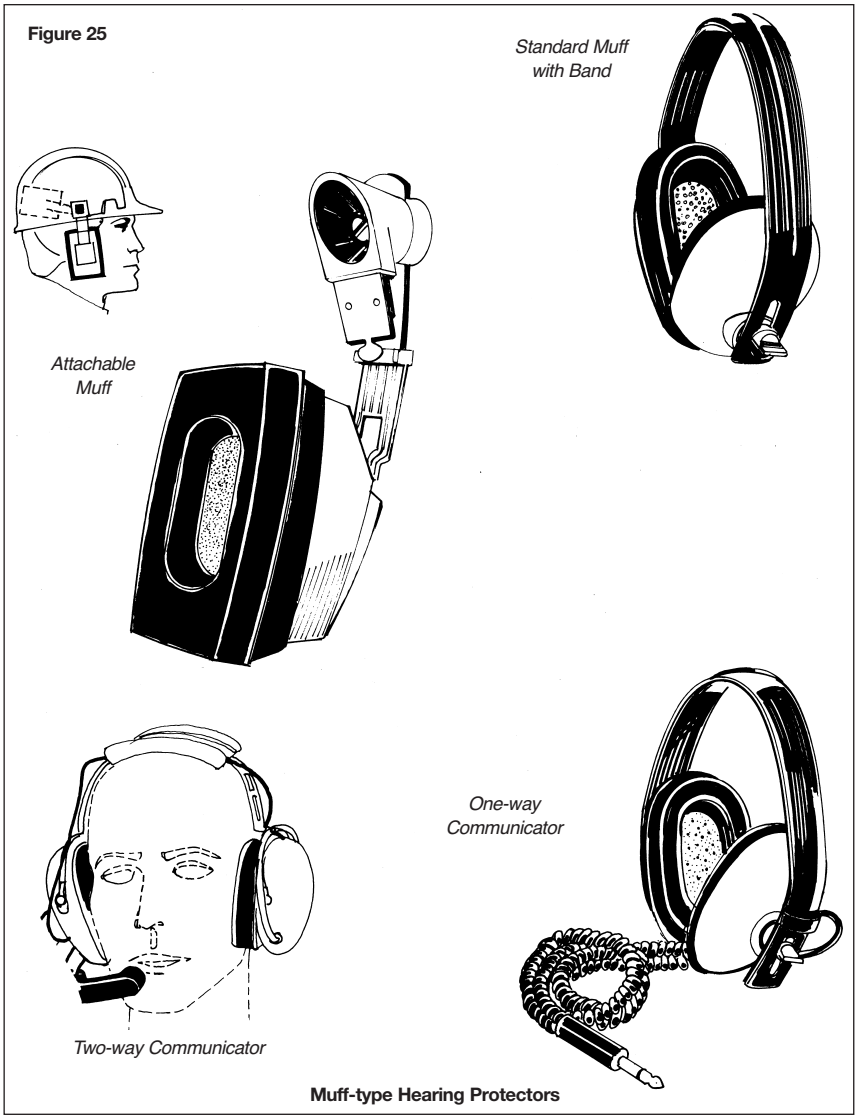
Noise, however, is the major identifiable cause of hearing loss. Therefore, it is important that controls are exercised wherever possible so that such losses can be prevented.

Figure 24



Plug-type Hearing Protectors

Figure 25



Muff-type Hearing Protectors

Hearing Protection

One form of controlling noise hazards is through the proper use of hearing protection devices (HPDs). Hearing protectors should be provided when engineering controls cannot be implemented or while such controls are being initiated.

Hearing protective devices are barriers that reduce the amount of noise reaching the sensitive inner ear. Fit, comfort, and sound reduction or "attenuation" are important considerations in choosing HPDs.

Commonly used hearing protection devices are either earplugs or earmuffs. Earplugs attenuate noise by plugging the ear canal (Figure 24). The muff-type protector is designed to cover the external part of the ear providing an "acoustical seal" (Figure 25). Table 1 describes some of the characteristics of these different types of hearing protectors.

Effectiveness

Obviously, the effectiveness of an HPD depends on the amount of time it is worn. What is not obvious to most wearers is the drastic reduction in protection if HPDs are not worn in noisy environments even for short periods of time.

The reduction in effectiveness can be as great as 95% or more if the protectors are not worn for as little as three or four minutes. It is therefore important to wear HPDs during the entire noise exposure period in order to achieve the maximum protection available.

The effectiveness of HPDs also depends on the manner in which noise is transmitted through or around the protector. The following points should be noted.

- Even relatively small openings or air leaks in the seal between the hearing protector and the skin can typically reduce attenuation by 5 to 15 dB or more.
- Constant movement of the head or body vibration can lead to air leaks, therefore making periodic adjustments necessary to ensure a proper seal.
- Hair, especially long hair and facial hair, can cause a poor fit.
- Proper fitting is crucial to obtaining a reasonable degree of protection from an HPD.
- Earmuff effectiveness is greatly influenced by headband tension. If tension decreases through routine usage or alteration by the user, earmuff effectiveness is reduced.
- Modifying the earmuff by drilling holes in the earcups renders the protection useless.
- Anatomical differences such as ear canal size, jaw size, and heads of different shape and size may affect the fit of earmuffs and earplugs. To accommodate these differences, HPDs should be made available to users in various shapes and sizes.
- Recreational headsets such as those used with radios and CD players are **not** to be used as hearing protection.

Table 3: Types of Hearing Protectors

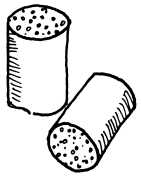
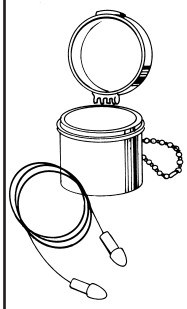
	FOAM EARPLUGS	PREMOULDED EARPLUGS	EARMUFFS	FORMABLE EARPLUGS	CUSTOM-MOULDED EARPLUGS	SEMI-INSERT EARPLUGS
						
STYLE and COMFORT	Consist of compressible plastic foam. Come in many shapes. Often described as "disposable plugs." Elasticity lets them adapt easily to changes in ear canal.	Usually made of plastic or silicone rubber attached to a flexible stem for handling and insertion. Come in many shapes and sizes to suit different ear canals.	Consist of two insulated plastic cups attached to metal or plastic band. Cups equipped with soft cushions for seal and comfort. Head band tension ensures good seal.	Made from pliable material such as cotton/wax mixture, silicone putty, and mineral wool.	Custom made to fit a particular ear by taking an impression of the ear, making a mould, and casting a plug.	Commonly known as banded earplugs or canal caps. They consist of small caps or pods that are held in place over the ear canal by spring-loaded bands.
INTENDED USE	Most brands can be reused a few times before being discarded.	To be used more than once.	To be used regularly. Can be worn with or without plugs. Easily attached to hard hats.	• Single-use for mineral wool products. • Multi-use for cotton/wax products. • Semi-permanent for silicone putty products.	Permanent use	To be used more than once.
HYGIENE PRACTICES	Clean hands required each time fresh plugs inserted.	Plugs should be cleaned regularly with warm soapy water, preferably after each removal from ear.	General maintenance required. Head band must be maintained. Cushions must be replaced when soiled or brittle.	Clean hands required for shaping and insertion.	Wash with hot water and soap, preferably after removal.	Wash with hot water and soap, preferably after removal.
ADVANTAGES	Low risk of irritation. One size fits most workers.	Reusable.	Less likely to cause irritation. When attached to hard hat, always available for use.	Relatively cheap	Good fit only if a proper impression of the ear is taken.	Good for when frequent removal is required.
DISADVANTAGES	Use requires clean hands. Large supply required for frequent removals and usage.	Plugs must be kept clean to prevent irritation. May produce some discomfort with pressure. Though reusable, plugs degrade over time. Inspect and replace as necessary.	Bands may wear out and tension decrease. Eyewear and hair may interfere with fit and reduce protection.	Not recommended for the noise levels found on construction projects.	If the wearer's weight changes drastically, new plugs should be made. Plugs can be lost, shrink, harden, or crack over time, and must be replaced.	Proper seal is necessary for good attenuation.

Table 4

Level of Noise Exposure L_{EX} (dBA)	Grade	Class
< 90	1	C
< 95	2	B
< 100	3	A
< 105	4	A
< 110	Dual*	
> 110	Dual†	

Based on an 8-hour exposure to noise levels in dBA. Adapted from CSA Z94.2-2002

* Dual hearing protection required. Use a minimum of a Grade 2 or Class B earmuff and a Grade 3 or Class A earplug.

† Dual hearing protection required. Also, it is recommended that exposure durations be limited, octave-band analyses be conducted for attenuation predictions, and twice-annual audiometry be provided to the affected individuals.

Selection Criteria

In addition to attenuation characteristics, the following factors should be considered when selecting hearing protectors:

- noise exposure levels and standards
- comfort
- appearance
- communication requirements
- work environment or work procedures
- overprotection.

Noise Exposure Levels and Standards

Identifying the noise level(s) to which an individual may be exposed throughout an entire working day determines the class or grade of hearing protector needed.

Evaluation is based on eight-hour noise exposure, not a spot or area measurement. For example, a quick-cut saw operated by a mason may produce a noise level of 110 dBA. But the mason may only be exposed to an average of 92 dBA over the full eight-hour shift. The reason is that the saw is not operated continuously during that period. There will be times when the worker is laying brick, taking a coffee break, or eating lunch.

CSA Standard Z94.2-2002 *Hearing Protectors*, classifies hearing protectors as A, B, and C or Grades 1, 2, 3, or 4 based on the level of protection they provide.

Grade 4 or Class A protectors offer higher protection than Grade 1 or Class C protectors if worn properly.

Table 4 provides guidelines for proper selection. Table 5 lists typical noise levels for various kinds of construction equipment. The upper limits of the noise levels can be used as a guide in selecting a specific class or grade of hearing protectors.

Comfort

Comfort is an important consideration in selection. An HPD that isn't comfortable will simply not be worn or will be worn improperly.

Table 5

Typical Noise Level Measurements for Construction

EQUIPMENT*	NOISE LEVEL (dBA) AT OPERATOR'S POSITION
Cranes	78 – 103
Backhoes	85 – 104
Loaders	77 – 106
Dozers	86 – 106
Scrapers	97 – 112
Trenchers	95 – 99
Pile drivers†	119 – 125
Compactors	90 – 112
Grinders	106 – 110
Chainsaws	100 – 115
Concrete saw	97 – 103
Sand blasting nozzle	111 – 117
Jackhammers	100 – 115
Compressors	85 – 104

* Generally, newer equipment is quieter than older equipment. (For noise levels of specific equipment, contact IHSA.)

† Pile drivers and explosive-actuated tools generate intermittent or "impulse" sound.

With earplugs, several factors affect comfort. Since some plugs are relatively non-porous, they can often create a pressure buildup within the ear and cause discomfort. Dirty plugs may irritate the ear canal. The shape of an individual's ear canals may not allow certain plugs to fit properly.

Earmuffs should be made of materials which do not absorb sweat and which are easy to maintain and clean. The earmuff cup should be adjustable to conform to various head sizes and shapes. Headband tension and earcup pressure should be adjusted so that they are effective without being uncomfortable. Weight may also be a factor.

Workers should be allowed to try out various HPDs to determine which are most comfortable.

Appearance

HPD appearance may influence selection. Those that look bulky or uncomfortable may discourage potential users. Allowing workers to select from various HPDs, or various makes of the same HPD, can help overcome this problem.

Speech Requirements

Consider the level of the noise hazard and the risks of impaired communication (Table 6). The potential for speech interference is greatest when background noise — meaning all noises generated in the surrounding area — is low. In this case, HPD wearers with impaired hearing may have difficulty understanding speech because they must contend not only with their hearing loss but also with the attenuation of their protector as well. In other cases, the use of HPDs by workers with normal hearing may

Table 6

Effects of Hearing Protectors on Understanding Speech

Hearing Ability of Wearer	Background / Surrounding Noise Levels in dBA		
	Less than 75	75 to 85	Greater than 85
Normal hearing	Little effect	No effect	Improves communication
Impaired hearing	Moderate effect	Little effect	No effect

actually *improve* their understanding of speech in noisy environments.

In other words, wearing HPDs doesn't always reduce the ability to communicate. Factors to consider include the user's hearing ability, noise levels, and the type of HPD. Where two-way communication is vital, radio-equipped hearing protectors can be worn (Figure 25).

Work Environment/Procedures

Choosing an HPD is sometimes dictated by the constraints of the work area or work procedures. For example, large volume earmuffs may not be practical in confined work situations with little head room or clearance.

In this case, flat-cup muffs or earplugs may be more practical. Where work is necessary near electrical hazards, it may be desirable to use non-conductive suspension-type muffs. The type of protector may also be determined by the nature of work, as in welding where certain types of earmuffs may interfere with the welder's helmet.

The attenuation of the muff-type hearing protector may be considerably reduced when worn with spectacle-type safety glasses. (The head configuration of the wearer and the type of glasses worn will determine the reduction in attenuation.) Where safety glasses must be worn, cable-type temples should be used in order to allow the smallest possible opening between the seal of the protector and the head. Otherwise earplugs should be worn, provided they are adequate.

Consideration should be given to hearing protectors which can be attached to hard hats where exposures to noise may be high but intermittent and where hard hats must be worn at all times. Periodic adjustments may be necessary because movement of the hard hat may break the seal of the HPD.

Consideration should also be given to work involving oils, grease, and other products which may soil hands. Ear infections may occur when earplugs are inserted by soiled hands.

Overprotection

Workers wearing HPDs that provide too much attenuation may feel isolated from their surroundings. Sounds may be heard as muffled. Speech or warning sounds may be unrecognizable. Overprotection can lead workers to resist wearing HPDs. Protectors should be chosen to provide sufficient, but not excessive, attenuation. The objective should be to reduce noise levels to or below the recommended maximum eight-hour exposure of 85 dBA, but not below 70 dBA.

Fit, Care, and Use

Workers should be instructed in the proper fitting of HPDs as recommended by the manufacturer. Training should include a demonstration. Workers should then practice using the HPDs under close supervision. Checks are needed to ensure the best possible protection. Many of these checks relate to fit.

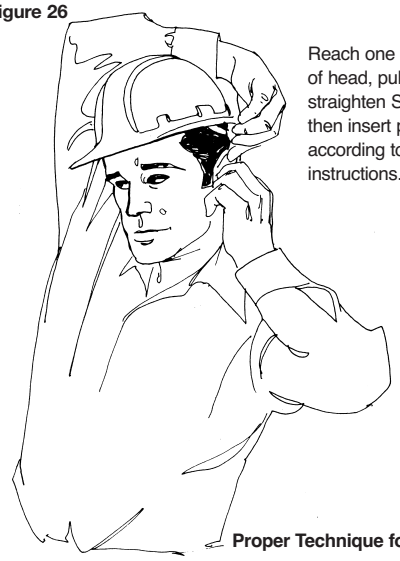
Earmuffs

1) Earmuffs should conform to the latest issue of CSA Standard Z94.2.
2) The cup part of the earmuff should fit snugly over the entire ear and be held firmly in place by a tension band.
3) The cup and band should not be so tight as to cause discomfort.
4) Cup, cushion, and band should be checked for possible defects such as cracks, holes, or leaking seals before each use of the HPD.
5) Because band tension can be reduced over a period of time, the band may require repair or replacement.
6) Defective or damaged parts should be repaired or replaced as needed. Tension band, cushions, and cups are readily replaceable.

Earplugs

1) Earplugs should conform to the latest issue of CSA Standard Z94.2.
2) For maximum attenuation, the method of insertion illustrated in Figure 26 should be used. Because the ear canal is slightly S-shaped, the ear must be pulled back to straighten the canal for the plug to fit properly.
3) Earplugs must be fitted snugly in the ear canal. This will cause some discomfort initially. However, in time (usually a period of two weeks) the discomfort vanishes. Should there be severe discomfort initially or mild discomfort for more than a few weeks, seek professional advice. In most instances it will only be a matter of re-sizing, although some ear canals cannot be fitted with plugs because of obstructions, unique shapes, or deformities. In fact, the shape of one ear canal may be entirely different from the other.

Figure 26



Reach one hand around back of head, pull ear upwards to straighten S-shaped ear canal, then insert plug with other hand according to manufacturer's instructions.

Proper Technique for Inserting Earplugs

4) Reusable earplugs should be washed daily with warm soapy water to prevent the remote possibility of infection or other discomfort. When not in use, they should be kept in a clean container.
5) Earplugs with torn or otherwise damaged flanges should be replaced.

WARNING: Cotton batten does not provide adequate protection from construction noise.

Training

Workers who wear HPDs should be trained to fit, use, and maintain the protectors properly. Workers should understand that

- there is risk of hearing loss if HPDs are not worn in noisy environments (eight-hour exposure of 85 dBA)
- wearing HPDs is required in all situations where noise exposure may damage hearing
- to be effective an HPD must not be removed even for short periods
- various HPDs are available to accommodate differences in ear canal size, jaw size, head size and shape, comfort level, compatibility with other forms of PPE, etc.
- proper fit is essential to achieve maximum protection.

Audiometry

Anyone who works with noisy equipment on a regular basis should take a periodic audiometric or hearing capability test for the following reasons:

1) **To determine whether or not a hearing loss exists.** Even if no hearing loss is detected, workers exposed to noise levels in excess of 85 dBA should wear hearing protectors. Workers who have some hearing loss should wear HPDs to minimize any further loss.
2) **To determine the type of hearing loss.** Certain hearing losses can be reversed. Some individuals have suffered for years only to find out that their hearing problem could have been corrected surgically. These situations usually occur as a result of birth defects and are known as “conductive losses.”
3) **To determine the effectiveness of programs for noise control and hearing protection.** Early identification is important so that prevention practices can be implemented, maintained, and revised when necessary.

Summary

Control of noise in workplaces is of growing importance as a result of increasing hearing loss claims.

Most noise problems can be analyzed in terms of source, transmission path, and receiver. This allows a convenient understanding of the overall problem and a useful approach to remedial measures. The three components can usually be treated in isolation, although sometimes all three must be considered together in order to control unacceptable noise levels.

At the source, remedial measures are aimed at reducing the noise being generated.

Along the transmission path, barriers can be introduced to reduce or eliminate noise reaching the ears.

At the worker, remedial measures involve personal protective equipment being properly selected, fitted, and worn. The equipment must be used in high noise environments **all the time.**

Failure to provide preventive or control measures will result in temporary and ultimately permanent hearing losses.

The Infrastructure Health & Safety Association can assist management and labour in the industry by providing useful information, research, and training. For more information, visit the hearing protection page on our website.