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Preventing Noise-Induced Hearing Loss: Safety Measures for Field Employees

Bob Beckley, Project Leader

Ladies and gentlemen, start your chain saws, but not without your hearing protection (figure 1). Following the recommendations in this tech tip could help you save your hearing or the hearing of those you supervise.

Figure 1—Hearing protection devices, such as earplugs, must be worn while operating a chain saw. Noise from the saw will vary depending on the angle of the saw.

Highlights...

- Four common types of hearing protection devices are foam earplugs, hearing bands, earplugs, and ear muffs.
- Noise reduction ratings of hearing protection devices can help determine which device should be worn.
- Ratings are based on laboratory conditions.

Understanding Noise-Induced Hearing Loss

Loud sounds can damage the microscopic hair cells in the inner ear. Once the hair cells have been damaged, they will not grow back and cannot be repaired. Noise-induced hearing loss can be caused by a single exposure to loud sounds (such as an explosion), by prolonged exposure (such as working in a machine shop), or by repeated exposure (such as operating a chain saw).

Sound is measured in decibels (dB). Sounds softer than 75 dB are unlikely to damage hearing. Prolonged or repeated exposure to sounds louder than 85 dB can damage hearing and accelerate hearing loss.

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How Loud Is Loud?

Table 1 shows the approximate decibel levels for common pieces of equipment or activities found in the Forest Service work environment and at home. The decibel levels in this tech tip are based on testing by the Missoula Technology and Development Center (MTDC) and other Forest Service sources. Decibel levels vary depending on the type and age of equipment being tested and local conditions (figure 2).

Table 1—How loud is loud?

Equipment or activity	**Noise level** (dB)
Whisper	30
Telephone ringing	30
Normal conversation	60
Dishwasher	60
Vacuum cleaner	70
Electric shaver	80 to 84
Helicopter—light	85 to 96
Retardant plane	89 to 110
Chain saws	89 to 110
Smokejumper plane	89 to 130
Machine or wood shop	90
Gas-powered lawnmower	90
Pumper engine	94 to 97
Ponjar gas drill	95 to 105
Snowmobile	100
iPod/MP3 player	105
Loud stereo in vehicle	120
Emergency vehicle siren	120
Motorcycle	120 to 150
Small-gauge firearm	120 to 150
Blasting/explosives	135 to 159
Jet plane	140

Figure 2—Most firefighters know that noise from equipment can compromise their hearing. The noise level of a pumper engine (inset) is 94 to 97 dB. They may not know just driving to the worksite with the vehicle's windows down also can cause harm.

Driving Your Hearing Away

Driving at a high speed with your windows down can be noisy enough to damage your hearing.

Miles per hour	**Noise level** (dB)
25	78
35	80 to 83
55	84 to 92

In general, if you have average hearing and can't carry on a normal conversation without having to raise your voice, the sound around you is approaching unsafe levels. If you need to shout to be heard from 3 feet away, the sound level is probably above 85 dB. Hearing protection is recommended. Personal protective equipment (PPE) is required when unsafe conditions are identified. Table 2 compares some common sounds and their potential harmful effects.

Table 2—Sound levels and human responses. —*Courtesy of the Noise Pollution Clearinghouse <http://www.nonoise.org>.*

Common sounds	Noise level (dB)	Effect
Rocket launching pad (no ear protection)	180	Irreversible hearing loss
Carrier deck jet operation Air raid siren	140	Painfully loud
Thunderclap	130	Painfully loud
Jet takeoff (200 feet) Auto horn (3 feet)	120	Maximum vocal effort
Pile driver Rock concert	110	Extremely loud (hearing damage after 8 minutes)
Garbage truck Firecrackers	100	Very loud
Heavy truck (50 feet) City traffic	90	Very annoying (hearing damage after 8 hours)
Alarm clock (2 feet) Hair dryer	80	Annoying
Noisy restaurant Freeway traffic Business office	70	Telephone use difficult
Air conditioning unit Conversational speech	60	Intrusive
Light auto traffic (100 feet)	50	Quiet
Living room Bedroom Quiet office	40	Quiet
Library Soft whisper (15 feet)	30	Very quiet
Broadcasting studio	20	Very quiet
Leaves rustling	10	Just audible
Threshold of hearing	0	Weakest sound heard

Permissible Noise Exposure Limits

The National Institute for Occupational Health and Safety (NIOSH) and the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) recommend an exposure limit of 85 dBA (an 8-hour time-weighted average). Whenever noise equals or exceeds this level, OSHA requires employers to administer a continuing effective hearing conservation program. See Title 29 of the U.S. Code of Federal Regulations (29 CFR Part 1910.95 (c)).

Your distance from loud sounds also matters. As you double the distance between you and the source of a sound, the sound will be only one-fourth as loud. If you cannot move a safe distance away, you need to limit the time you are exposed to loud sounds (table 3). For every 3 decibels over 85 dB, the permissible exposure time is cut in half.

Table 3—The accepted standards for recommended permissible exposure time for continuous time-weighted average (TWA) noise according to NIOSH and the Centers for Disease Control and Prevention (CDC 2002). —*Courtesy of the Dangerous Decibels Program <http://www.dangerous decibels.org>.*

Continuous dB	Permissible exposure time
85	8 hours
88	4 hours
91	2 hours
94	1 hour
97	30 minutes
100	15 minutes
103	7.50 minutes
106	3.75 minutes (< 4 minutes)
109	1.875 minutes (< 2 minutes)
112	0.9375 minute (~ 1 minute)
115	0.46875 minute (~ 30 seconds)

Note: In this table, < means less than and ~ means approximately.

How We Hear

Ears have three anatomical parts: the outer ear, the middle ear, and the inner ear (figure 3).

The outer ear has two parts: the pinna (what we often think of as the ear) and the ear canal.

The shape, folds, and twists of the outer ear enhance sound and help us determine where sounds are coming from. Sounds in front of us are enhanced by the outer ear, while sounds coming from behind us are diminished.

The pinna captures sound and amplifies it as it travels down the ear canal. By the time the sound reaches the eardrum in the middle ear, it has been amplified as much as 15 dB (the soft rustle of leaves is about 10 to 25 dB).

The incoming sound waves vibrate the eardrum. Three tiny bones (the malleus, incus, and stapes) carry the sound waves to the inner ear.

The middle ear helps equalize air pressure with the outside air, allowing sound to be transferred effectively. You may notice a blocked or plugged feeling in your ears if you change elevation quickly, such as when you are traveling on an airplane. The Eustachian tube, a small tube in the back of the throat, is connected to the middle ear. When you yawn or swallow, the Eustachian tube opens momentarily, allowing pressure to equalize.

The inner ear has two parts: one related to balance (the vestibule and semicircular canals) and the other related to hearing (the cochlea). The vestibule and semicircular canals help maintain balance by sensing body position and movement. This system also allows you to maintain sharp visual focus when you move your head. The cochlea is a fluid-filled, coiled canal that resembles a snail shell lined with bristly structures called hair cells (figure 4). As sound waves pass through hair cells in the cochlea, they produce an electrical signal. This signal is carried by the auditory nerve to the brain, which translates the signal to the sounds we recognize and understand. If hair cells become damaged, hearing will be harmed.

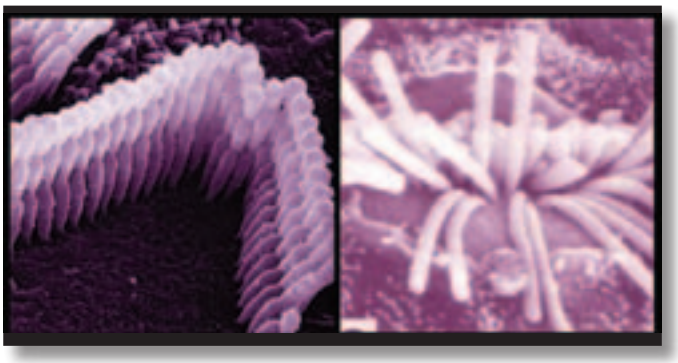


Figure 4—Healthy hair cells (left) and damaged hair cells (right). *—Courtesy of the National Institute on Deafness and Other Communication Disorders, National Institutes of Health <http://www.nidcd.nih.gov>.*

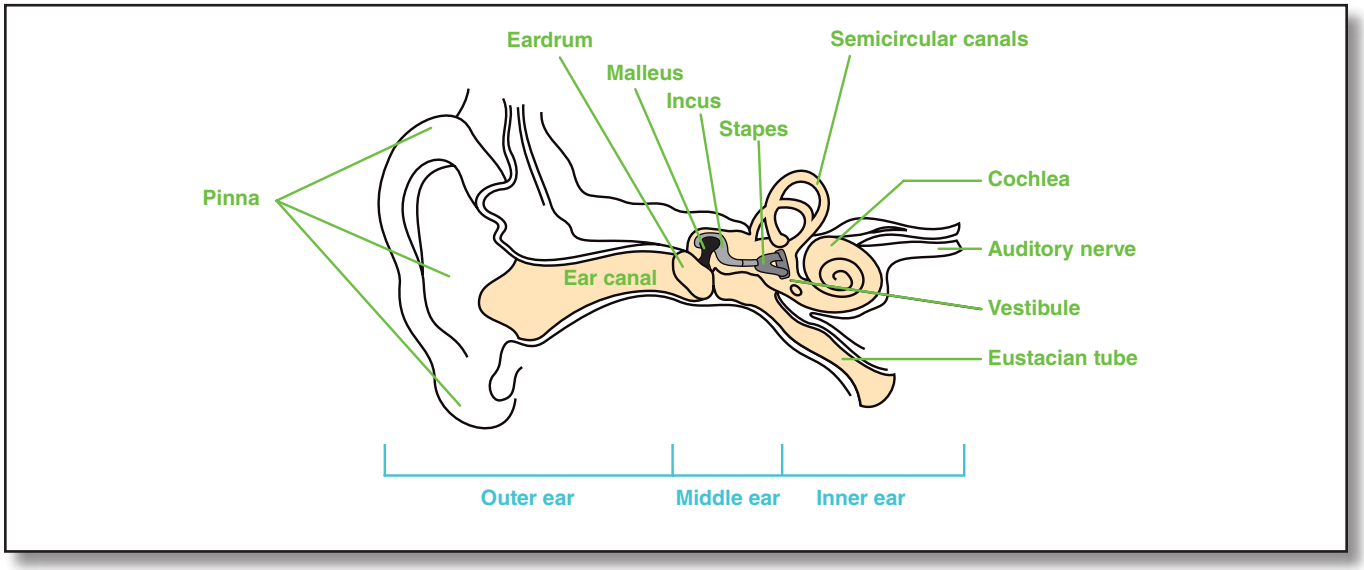


Figure 3—Diagram of an ear.

Symptoms of Hearing Loss

Hearing loss can be caused by other factors. Sound may be blocked when fluid builds up in the middle ear or when earwax builds up in the outer ear. These types of hearing loss may be treated with medicine or surgery.

Hearing may be lost because of age, disease, or injury, but loud noise is the most common cause (figure 5). Although this type of hearing loss is generally not treatable, often it can be prevented.

Figure 5—Fingers in ears may provide some noise relief but will limit the amount of work that gets done.

Hearing aids may help wearers hear some sounds, but hearing aids do not repair hearing damage, and they do not replace normal hearing. People with hearing aids should not use them as a hearing protection device by turning down the sound. If hearing protection is required for an activity, it should be used even by those with hearing loss to prevent further damage.

Noise-induced hearing loss may not be noticed because it develops gradually and is cumulative. Sounds become distorted or soft. People losing their hearing may need to ask others to repeat themselves or to turn up the volume on the television or stereo. Hearing tests easily detect gradual hearing loss.

A common symptom of hearing loss is tinnitus: a ringing, clicking, buzzing, or hissing in the ears. One type of tinnitus (objective tinnitus) often can be heard by a physician during an examination. Objective tinnitus may be caused by a head, neck, or blood vessel problem and may be treatable. Another type of tinnitus (subjective tinnitus) is heard only by the affected individual and can be a result of noise-induced hearing loss.

Tinnitus after exposure to a loud sound usually disappears in a matter of minutes, hours, or days. If you experience long-term tinnitus, especially if there is no obvious explanation, you should have your ears examined by a specialist.

Preventing Hearing Loss in the Workplace

In 1972, OSHA adopted a standard (29 CFR Part 1910.95) regulating occupational exposure to noise. The Hearing Conservation Amendment, added to the standard in 1983, requires a hearing conservation program for workers who are exposed to noise levels at or above 85 dB averaged over an 8-hour workday, also known as an 8-hour time-weighted average (TWA).

A hearing conservation program consists of five elements:

- Exposure monitoring
- Hearing tests
- Hearing protection
- Employee training
- Record keeping

This section focuses on three elements: hearing tests, employee training, and record keeping.

Hearing Tests

An initial baseline hearing test is a key element in a hearing conservation program (figure 6). Annual tests can be compared to the baseline, showing hearing loss even when it is so gradual that it is otherwise imperceptible. A licensed or certified audiologist—or an otolaryngologist or a qualified physician—must be responsible for the hearing conservation program, although the hearing tests can be performed by a technician. Hearing tests should be conducted annually.

Many veterans leave military service unaware of the full extent of their hearing damage. They should have a baseline hearing test if they continue to work for the Federal Government after their military duties are completed.

Figure 6—Hearing test being conducted.

Employee Training

Training, required by 29 CFR Part 1910.95(k), will help employees understand the importance of a hearing conservation program. Employees should learn about the various kinds of hearing protection devices and how to select, care for, and fit them correctly.

If employees use soft, moldable earplugs, they should work with a partner or supervisor to ensure that the earplugs are inserted properly (figure 7). Many soft, moldable earplugs have a bright line around the center of the plug or are two-toned. The line should not be visible when the plug is inserted properly (figure 8). These types of earplugs make it easy to see whether earplugs are being used properly.

Figure 7—Properly inserting an earplug requires pulling up the top part of the ear to open the ear canal.

Figure 8—When these foam earplugs are inserted properly, the earplug's orange centerline should not be visible.

Record Keeping

The final element of a hearing conservation program is record keeping. Records of hearing tests, as per 29 CFR 1910.95(m), need to be kept for the duration of an individual's employment. The records should include an employee's name, job classification, date of exam, examiner's name, date of last acoustic or exhaustive calibration of audiometers, measurements of the background sound pressure levels in the hearing test room, and the employee's most recent hearing test results (figure 9).

Figure 9—Record keeping is the final element of a hearing conservation program.

Determining Noise Levels

A sound level meter (figure 10) is the basic instrument for:

- Identifying and evaluating individual noise sources
- Evaluating hearing protection devices
- Spot checking noise dosimeter performance

A dosimeter also measures sound levels. Employees wear it throughout the workday to determine the average noise exposure. This instrument is especially helpful when locations change and sound levels vary in duration and intensity. To determine noise levels in your workplace, the hearing conservation program manager in your unit should contact an industrial hygienist or another qualified person.

For compliance with OSHA requirements, instruments must meet the standards of the American National Standards Institute. These standards set performance and accuracy tolerances for three levels of precision: type 0 (used in laboratories), type 1 (accuracy of ± 1 dBA, decibels on the A-weighting scale) and type 2 (accuracy of ± 2 dBA). For noise measurements, a type 2 sound level meter or dosimeter is the minimum required by OSHA.

Figure 10—Sound level meter.

Hearing Protection and Noise Reduction Ratings

The best type of hearing protection device is the one that gets used! The key to getting people to use hearing protection is to make sure that it's comfortable. Employers should provide a selection of types and sizes of hearing protection devices (figure 11).

Figure 11—Hearing protection devices are available in many different types and styles. Find the type and style that best fits your ears and your needs. Remember, you can always use earplugs and ear muffs together for added hearing protection. Inset: Noise Reduction Ratings (NRR) are listed on the package.

Warning Signs

The NIOSH recommends that a warning sign (figure 12) be visible at the entrance to areas where noise exposure is equal to or exceeds 85 dBA (TWA).

Figure 12—Warning sign.

Figure 13—Ear muffs are often the preferred type of hearing protection in shop settings.

Hearing protection devices range from inexpensive foam earplugs to custom devices. More expensive devices may not provide better protection. Flight helmets and headsets offer protection similar to ear muffs but also allow radio communication. This tech tip focuses on four hearing protection devices commonly used in the workplace: foam earplugs, hearing bands, reusable earplugs, and ear muffs (figure 13).

To determine the effectiveness of hearing protection devices, manufacturers provide noise reduction ratings (NRR). Noise reduction ratings are based on laboratory conditions. Only a small percentage of individuals will receive the full benefit of the NRR rating. Because the NRR overstates the actual protection, the NRR should be reduced (derated) to more accurately reflect the benefit. NIOSH recommends reducing the NRR (table 4) for ear muffs by 25 percent, foam earplugs by 50 percent, and all other earplugs by 70 percent. More information is available at <http://www.cdc.gov/niosh/docs/98-126/>.

Table 4—Comparing four hearing protection devices.

Type	Advantages	Disadvantages	Noise Reduction Rating (NRR)
Foam earplugs	Cooler, more comfortable under hot conditions Easy to dispose of Lightweight Inexpensive	May irritate the outer ear May be difficult to fit	Deduct 50 percent from the manufacturer's listed NRR
Hearing bands	Cooler, more comfortable under hot conditions Can be worn over the head, under the chin, or behind the neck Can be worn around the neck when not in use Lightweight	May irritate the outer ear May be difficult to fit	Deduct 70 percent from the manufacturer's listed NRR
Reusable earplugs	Cooler, more comfortable under hot conditions Can be reused if cleaned properly Lightweight	May irritate the outer ear May be difficult to fit	Deduct 70 percent from the manufacturer's listed NRR
Ear muffs	Easy to use, fewer problems with fit	Less effective if anything (even the temples of eyeglasses) breaks the seal Heavier/warmer than earplugs	Deduct 25 percent from the manufacturer's listed NRR

Manufacturers of sound level meters use different response curves referred to as A-, B-, and C-weighting scales:

- A-weighting follows the frequency sensitivity of the human ear at low levels. Sound level meters set to this scale filter out high- and low-frequency noise that the average person cannot hear; measurements are designated dBA and are used to identify hearing risk.
- B-weighting follows the frequency sensitivity of the human ear at moderate sound levels and is not applicable for industrial noise.
- C-weighting follows the frequency sensitivity of the human ear at very high sound levels. Sound level meters set to this scale include low-frequency noise; measurements are designated dBC and are used (with a correction for C- and A-weighting differences) to rate the effectiveness of hearing protection devices.

In some cases, such as when using a chain saw, it's wise to double-up hearing protection with a combination of earplugs and ear muffs. Swampers are adequately protected with earplugs.

Table 5 shows how to use sound level information to choose hearing protection devices that will prevent hearing loss.

Table 5–Hearing loss prevention sound survey for use of a Stihl 044 chain saw. The sound level meter was set to high range, slow response, A-weighting.

Activity	**Distance from source** (feet)	**Operation description**	**Noise** (dB)	**Mitigation** (effective NRR required)	**Minimum PPE** (with NIOSH derating)	**Minimum PPE** (without NIOSH derating)
Idle	3	From right side	80	None	None	None
Idle	3	From front	81	None	None	None
Idle	0	At operator's ear	77	None	None	None
Cutting (vertical angle)	8	Full throttle from right side	95	10 dB	Earplugs	Earplugs or ear muffs
Cutting (vertical angle)	0	Full throttle at operator's ear	103	18 dB	Earplugs or ear muffs	Earplugs or ear muffs
Cutting (horizontal angle)	0	Full throttle at operator's ear	110	25 dB	Ear muffs or ear muffs and earplugs	Earplugs or ear muffs
Gunning the engine, not cutting (horizontal angle)	0	Full throttle at operator's ear	116	31 dB	Ear muffs and earplugs	Earplugs

Determining Exposure

If a noise measurement is in dBC, subtract the NRR of the hearing protection device (ear muffs in this example) to determine the exposure:

Noise level	105 dBC
NRR	– 25 NRR
	80 dB

If a noise measurement is in dBA, subtract 7 dB from the NRR of the hearing protection device as a correction for C- and A-weighting differences, then subtract the resulting lower NRR from the dBA noise measurement to determine the exposure:

Noise level	105 dBA
25 NRR – 7 dB =	– 18 NRR
	87 dB

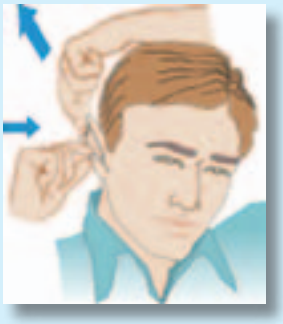
Why Hearing Protection Fails

For hearing protection devices to be effective, they must be worn properly and be maintained or replaced regularly. Training is required—29 CFR 1910.132(d) (2)—to ensure that employees are aware of the importance of wearing hearing protection devices and know how to use the devices properly. When hearing protection devices fail, it's usually because of:

- **Discomfort—**If your hearing protection device is uncomfortable, you are less likely to use it properly. Unfortunately, the better the hearing protection, the more uncomfortable it is likely to be. This is why training is important.
- **Improper fit—**All heads and ears are different. Ear canals aren't necessarily the same size, even in an individual's left and right ears. Eyeglasses, beards, long hair, or a hardhat could keep ear muffs from making a tight seal. This problem helps explain why it's important for employers to offer employees different types and sizes of hearing protection devices.
- **Movement—**Earplugs may work their way loose and ear muffs may shift because of simple head movements, talking, or perspiration. It's important to check and readjust your hearing protection device regularly (figure 14).
- **Deterioration—**Most hearing protection devices are inexpensive; replace them at the first sign of excessive wear or deterioration. Disposable foam earplugs should be replaced frequently. Earplugs can dry out and harden, ear muff cushions can dry out and crack, and headbands may become loose. Inspect your hearing protection devices frequently and replace them as needed. Ensure that users do not modify their hearing protection devices to make them more comfortable. The modified devices will probably not be as effective.
- **Hygiene—**Keep your hearing protection device clean. Dirt, oil, or other foreign substances could interfere with the device's hearing protection and might contribute to ear infections. Clean or replace your hearing protection devices regularly.
- **Lack of training—**Foam earplugs are the least expensive type of hearing protection and one of the best. When foam earplugs are not worn correctly, their effectiveness is reduced (figure 15).

Figure 14—Earplugs (left) that do not fit properly provide little or no protection. Properly inserted earplugs (right) barely protrude from the ear.

1. **Roll** the earplug into a small, thin "snake" with your fingers. You can use one or both hands.



2. **Pull** the top of your ear up and back with your opposite hand to straighten out your ear canal. The rolled-up earplug should slide right in.

3. **Hold** the earplug in with your finger. Count to 20 or 30 out loud while waiting for the plug to expand and fill the ear canal. Your voice will sound muffled when the plug has made a good seal.

Figure 15—How to wear foam earplugs. —*Courtesy of the Centers for Disease Control and Prevention.*

To get the best protection from foam earplugs, remember to roll, pull, and hold when putting them in. Your hands need to be clean to keep dirt and germs out of your ears!

When you're finished, check to make sure that most of the foam body of the earplug is within the ear canal. Try cupping your hands tightly over your ears. If sounds are much more muffled with your hands in place, the earplug may not be sealing properly. Take the earplug out and try again.

The proper procedure is shown in a short video at the NIOSH Web site <http://www.cdc.gov/niosh/mining/products/product88.htm>.

Conclusions

Noise-induced hearing loss can occur anytime in your life (figure 16). Hearing loss may not be painful. If loud sounds don't bother you as much as they used to, you may be losing some of your hearing.

In the workplace, personal protective equipment is often required when employees work near loud noises. Forest Service field crews, as well as employees in machine and fabrication shops, may be exposed to sounds louder than 85 dB that require the use of hearing protection.

Loud sounds are not limited to work. Protect your hearing at home when you run a lawnmower, leaf blower, or other loud device.

Some of life's greatest pleasures are the conversations and laughter we share with friends and family (figure 17). Don't risk losing your hearing because of loud noise. Block the noise, avoid the noise, or turn down the sound.

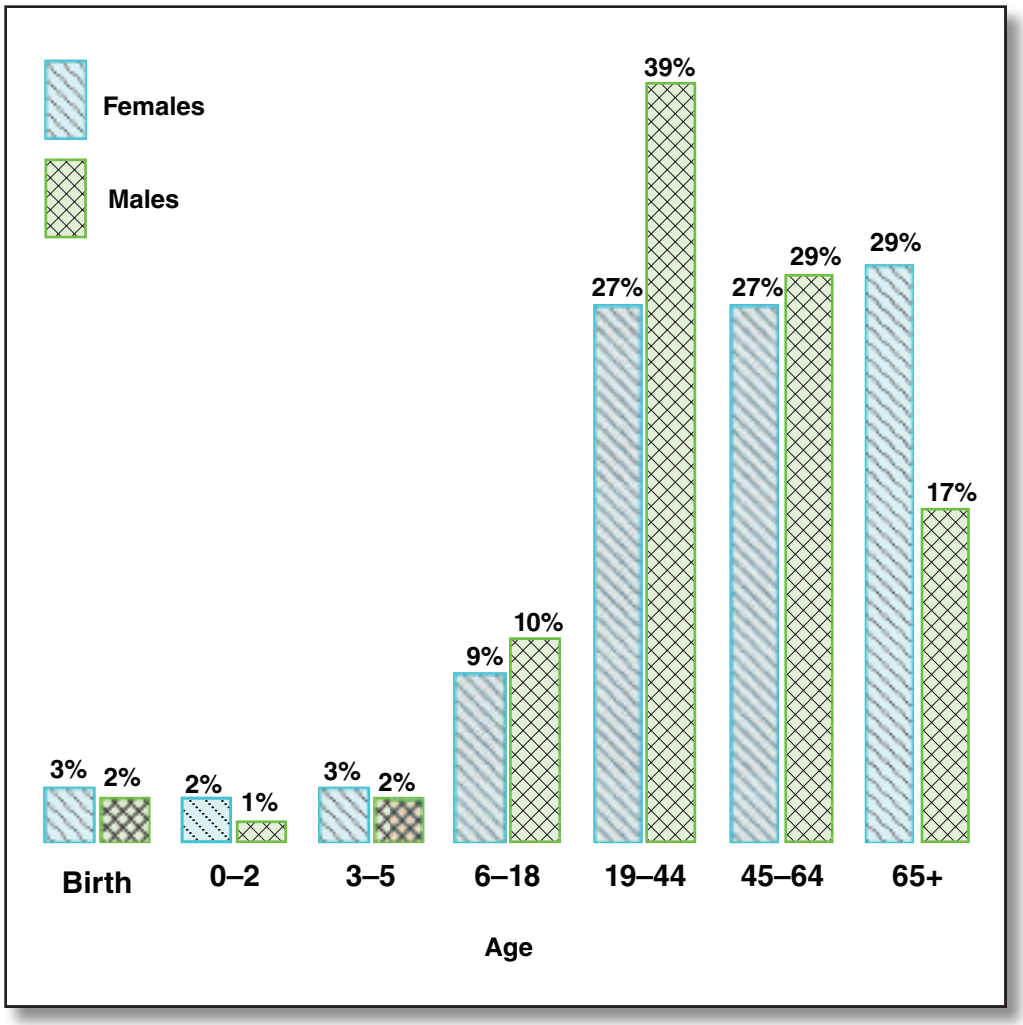


Figure 16—Age at Which Hearing Loss Begins: National Health Interview Survey, 2002. —*Courtesy of National Institute on Deafness and Other Communication Disorders, National Institutes of Health <http://www.nidcd.nih.gov/health/statistics/begins.htm>.*

Figure 17—Protect your hearing so you can enjoy the sounds of family and life.

Useful Links

American Speech-Language-Hearing Association
http://www.asha.org/publications/

Council for Accreditation in Occupational Hearing Conservation
http://www.caohc.org/publications/meter.php

Elvex Corporation Safety Articles on Noise and Hearing Loss Prevention
http://www.elvex.com/articles.htm

National Institute on Deafness and Other Communication Disorders
http://www.nidcd.nih.gov/health/statistics/quick.htm

National Institute for Occupational Safety and Health
http://www.cdc.gov/niosh/topics/noise/
http://www.cdc.gov/niosh/topics/noise/noisemeter.html
http://www.cdc.gov/niosh/topics/noise/noisemeter_html/hp0.html

U.S. Department of Labor, Occupational Safety and Health Administration
http://www.osha.gov/Publications/osha3074.pdf
http://www.osha.gov/SLTC/noisehearingconservation/standards.html

U.S. Department of Defense Hearing Conservation
http://militaryaudiology.org/site/resources/

Project Proposal

Thanks to...

Michael Cobbold, the safety and occupational health officer for the Shasta-Trinity and Mendocino National Forests, submitted the project proposal for this hearing protection tech tip.

The Missoula Technology and Development Center thanks Michael Cobbald for his proposal and welcomes additional proposals for projects to help Forest Service employees do their jobs more safely, easily, and efficiently. Proposals can be submitted online at http://fsweb.mtdc.wo.fs.fed.us/proposal/ or to wo_mtdc_pubs@fs.fed.us.

About the Author

Bob Beckley received a bachelor's degree in political science from the University of Montana in 1982. He began his Forest Service career as a timber technician on the Nez Perce National Forest. Bob Beckley was a smokejumper when he came to the Missoula Technology and Development Center in 1990. He assists in the explosives program and works as a project leader and public affairs specialist.

Library Card

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Noise-induced hearing loss is almost always preventable. Forest Service employees can be exposed to loud noises for varying lengths of time in the workplace. OSHA requires employers to provide personal protective equipment and training on how to use it correctly. This tech tip includes information about hearing conservation programs and hearing protection devices.

Keywords: audiology, decibels, earplugs, Eustachian tubes, NIOSH, OSHA, otology, safety at work, tinnitus

Additional single copies of this document may be ordered from:

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Electronic copies of MTDC's documents are available on the Internet at:

http://www.fs.fed.us/eng/pubs

For additional information about noise-induced hearing loss, contact Bob Beckley at MTDC:

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Forest Service and Bureau of Land Management employees can search MTDC's documents, CDs, DVDs, and videos on their internal computer networks at:

http://fsweb.mtdc.wo.fs.fed.us/search/