

Tips for Fitting Hearing Protectors

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This EARLog¹ is intended to assist in improving the hearing protector fitting and dispensing skills of hearing conservationists. A number of straightforward fitting techniques that can be implemented without the need for specialized measurement equipment are discussed and an overview of certain factors that should be considered when issuing hearing protection devices (HPDs) is provided.

Preliminary Considerations

When any type of hearing protector is initially dispensed, the process is best accomplished one-on-one or in small groups with a student/instructor ratio of no more than about 5/1. This is important since the compatibility and fit of protectors must be individually checked on each employee. Also to be considered is that the smaller the group, the less likely it is that the trainee(s) will become self-conscious during the fitting process. Plan on allowing about 10 min. for each employee.

HPD training in larger groups is also useful when it occurs in addition to, but not in place of, individual or small-group work. Working with larger classes is a suitable way to provide a review and reminder during the annual educational sessions that are a required part of every hearing conservation program. An excellent discussion of the fitting process may be found in reference 2.

Prior to issuing HPDs the fitter should visually examine the pinna, ear canal, and circumaural regions to identify conditions which might interfere with or be aggravated by the use of the protector in question (see EARLog 17¹). In the case of employees who are being refitted and/or retrained in the use of devices they are currently wearing, the condition of the HPDs must be checked as well.^{3,4} All resilient parts such as earplug flanges and earmuff cushions must be intact and

THE OCCLUSION EFFECT

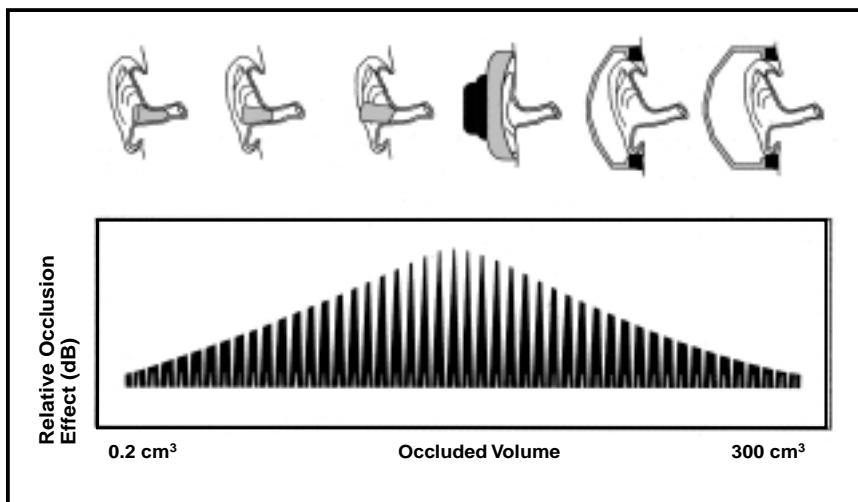


Figure 1. The **occlusion effect** and its relationship to the fit and type of hearing protector. The effect is minimized with deeply inserted plugs (left side of graph), increases in magnitude as the plugs are withdrawn, peaks when the canal is capped by a semi-aural device or the pinna is covered by a supra-aural device such as an audiometer earphone (center two drawings), diminishes as the ear is surrounded by an earmuff, and continues to reduce in magnitude as the volume of the earmuff increases (right side of graph).

flexible so that a good acoustical seal can be obtained, and the bands on earmuffs and semi-aural devices must provide sufficient force for proper fit.

Initially, hearing protectors are typically dispensed in quiet environments away from the noisy workplace. This is primarily a matter of convenience and logistics which obviously makes it easier for the fitter to communicate with the person being fitted. The disadvantage of this approach is that in low (unobjectionable) noise levels the wearer cannot appreciate the beneficial aspects of the noise reduction provided by the HPDs. It is like trying to evaluate sunglasses by wearing them at night or in a dimly lit store.

When noise is used during the fitting process the wearer can listen to it to adjust the HPDs for the lowest perceived noise level. Recordings of broadband noise or representative industrial sounds can be

presented using a portable cassette player. If a noise source is unavailable, the fitter should follow up with employees within a few days while they are in their work environment to recheck the fit and suitability of the devices that were dispensed.

The Occlusion Effect

Occluding and sealing the ear with an earmuff or earplug increases the efficiency with which bone-conducted sound is transmitted at the frequencies below 2 kHz. Called the occlusion effect³, this causes wearers of HPDs to experience a change in their perceived voice quality and other body-generated sounds/vibrations (breathing, chewing, walking, etc.). Of all the fitting tips that have been devised, listening for the occlusion effect is the most widely applicable, being suitable for use with nearly all types of hearing



Figure 2. Pulling the pinna outward and upward while inserting an earplug.

protectors. To experience the occlusion effect, plug your ears with your fingers as you read this sentence aloud and note the change in the sound of your voice - its added fullness or resonant bassiness. Other adjectives that have been used to describe the changes in voice quality are deeper, hollow, and muffled. The effect is greatest when the ear canal is covered at its entrance. It diminishes as earplugs are inserted more deeply or with the use of earmuffs with large volume earcups (see Figure 1).

The occlusion effect can be used as a fit test for either plugs or muffs by asking the wearer to count loudly from 1 to 5 while listening for the change in voice quality which indicates an acoustical seal and the presence of the effect. With earplugs, an alternative approach is to count aloud with only one ear correctly fitted. The voice should be more strongly heard or felt in the occluded ear⁵. If this does not occur, the plug should be resealed or resized. When the second ear has been fitted correctly, the effect should be the same in both ears, causing the voice to be heard as though it were emanating from the center of the head.

Some listeners are unable to hear differences in the occlusion effect between their two ears, but most can hear a change in the overall sound of their voice when both ears are sealed. An alternative means of generating a "test signal," and one which some find easier to detect, is to hum. It is a good way to create sounds of varying pitch and constant

level that can be used when listening for the occlusion effect while adjusting the HPD.

A caveat with respect to the occlusion effect is that although it is a fine way to test the fit of HPDs, its presence is often cited as an objectionable characteristic of wearing hearing protection. As is shown in Figure 1, semi-aural HPDs will create the most noticeable occlusion effect. The amplification can be minimized by wearing earplugs that are inserted more deeply or earmuffs with larger volume earcups.

Earplug Fitting Tips

When initially dispensing earplugs the fitter should insert at least one plug into the employee's ear so that s/he can experience the feel of a properly seated device. This is especially important because of the reluctance most novice users have of placing anything deeply into their ear canals. With one earplug properly inserted, the person then has an example to try to match. Ask the wearer to insert the other plug until both of their ears feel the same and sound equally occluded. Once the two plugs have been properly inserted ask the person to remove them both and then insert them one more time for review and additional practice.

For all types of earplugs, with the possible exception of custom earmolds, insertion is easier and more effective if the outer ear (pinna) is pulled outward and upward as illustrated in Figure 2. Plugs should be inserted into the right ear using the right hand and into the left ear with the left hand. The pinna is pulled with the opposite hand by reaching behind or over the head. This allows the hand inserting the plug to have the best line of approach for proper fitting.

The fitter should determine the best direction in which to pull the pinna to access and enlarge the canal as much as possible. Merely pressing the pinna back along the side of the skull is usually not effective. Demonstrate the correct technique by guiding the user's hand to help pull his or her pinna in the proper manner. All wearers should initially use the pinna-pull technique as they learn how to best fit their earplugs, although

with time and experience some may find it no longer necessary.

Employees may also require assistance in finding the best direction in which to "aim" the plugs into their canals. Although this will usually be forward and slightly upward, it can vary substantially for different individuals, in some instances even being directed towards the back of the skull.

Once fitted, the noise reduction of earplugs can be tested subjectively by pressing firmly cupped hands over the ears while listening to a steady noise. With properly fitted plugs the noise levels should seem nearly the same whether or not the ears are covered.

When dispensing earplugs, fitters will soon learn that people are very conscious of the cleanliness of their ear canals. If cerumen (ear wax) adheres to or coats trial earplugs, wearers may be embarrassed. Assure them that earplugs penetrate more deeply into their ear canals than they can or should normally reach when cleaning their ears. Furthermore, a certain amount of cerumen is necessary to provide a protective barrier for the ear (EARLog 17), and it can in fact furnish lubrication to ease and improve the fitting of earplugs.

Foam Earplugs: Foam earplugs are prepared for insertion by rolling them into a very thin crease-free cylinder. The cylinder should be as small in diameter as possible, that is, as tightly compressed as can be achieved. Crease-free rolling is accomplished by squeezing lightly as one begins rolling, and then applying progressively greater pressure as the plug becomes more tightly compressed. Be sure to roll the plug into a cylinder rather than other shapes such as a cone or a ball.

After insertion, it may be necessary to hold foam earplugs in place with a fingertip for a few moments until they begin to expand and block the noise. This is not intended to keep them from backing out of the ear canal, since properly in-

sented foam earplugs do not in fact exhibit such a tendency, but rather is to assure that the plugs do not move and dislodge prior to reexpanding enough to hold in place.

Unlike other types of earplugs, foam earplugs should not be readjusted while in the ear. If the initial fit is unacceptable, they should be removed, re-rolled, and reinserted. Furthermore, a large occlusion effect does not usually signify a best fit for foam earplugs since the effect is maximized when they barely enter or cap the canal, rather than when they are well inserted (see Figure 1). In fact the deeper the insertion (which for foam earplugs is usually associated with improved comfort), the better will be the fit and the attenuation, and the less noticeable and annoying will be the occlusion effect.

The simplest, but least accurate method to assess the fit of a foam earplug, is to visually (for the fitter) or with the fingertips (for the wearer), check the position of the end of the plug relative to the tragus and concha (see Figure 3). If the outer end of the plug is flush with or slightly inside the tragus, this generally indicates that at least half of the plug is in the canal and the fit is proper. If most of the plug projects beyond the tragus and into the concha, the insertion is probably too shallow. Since tragus-to-ear canal dimensions vary significantly, this check is not a foolproof indicator.

Another test that either the wearer or the fitter can perform is to remove an earplug after it has expanded in the ear for about a minute. If it was well fitted, it should appear free of creases and wrinkles, and the still partially-compressed portion of the plug will indicate that at least one-half of its length had extended beyond the entrance of the ear canal and formed a seal within the canal itself.

A comprehensive guide to all aspects of foam earplug utilization, as well as a Roll Model training aid, are available from Aearo Company.⁶

Premolded Earplugs: When initially inserting premolded earplugs the fitter should be able to easily detect gross errors in sizing.

Ear gauges are available from some manufacturers of premolded earplugs to aid in this process. Plugs that are much too small will tend to slide into the canal without any resistance, their depth of insertion being limited only by the fitter's finger and not the plug itself. Overly large plugs either will not enter the canal at all or will not penetrate far enough to allow contact of their largest (outermost) flanges with the concha (see Figure 3). With certain premolded multiple-flanged earplugs, however, it is unnecessary for the outermost flange(s) to seal the ear to obtain a proper insertion and fit for those with small to extra-small ear canals.

A plug that is well seated and appears to make contact with the interior wall of the canal without appreciably stretching the tissues is a good size to begin wearing.⁷ When a canal falls between two sizes the larger size plug is not necessarily the best one to choose. Even though it may provide more attenuation, if the plug is not worn or not used correctly due to discomfort, the resultant effective protection may be less than would have been achieved had the smaller more comfortable size been selected.

Experience suggests that in about 2 to 10% of the population different sizes of premolded earplugs will be required for the left and right ears. As a general rule, the more sizes in which a particular plug is manufactured, the greater will be the likelihood of this occurring.

A properly inserted premolded earplug will generally create a plugged or blocked-up feeling due to the requisite airtight seal.

When a seal is present, resistance should be felt if an attempt is made to withdraw the plug from the canal, much like pulling a rubber stopper from a glass bottle. The seal can be further tested by gently pumping the plug in and out of the ear canal. When a proper acoustic/pneumatic seal is present, the pumping motion will cause pressure changes in the ear which the wearer should be able to detect.

Because of the pneumatic seal created by properly inserted premolded earplugs, suction is created if they are rapidly removed. This can be uncomfortable, painful, and/or potentially harmful to the ear. Teach wearers to remove plugs slowly, or even to use a slight twisting or rocking motion to gradually break the seals as the plugs are withdrawn.

Custom Molded Earplugs: One of the most important steps in making a custom earmold impression is the use of a cotton or foam block or eardam inside the canal. Use of eardams prevents the impression material from being forced too deeply into the canal where it could contact the eardrum or be difficult to remove.

Of equal and perhaps greater importance, an eardam helps to ensure that a better fitting impression is obtained. If the dam is absent, the impression material is permitted to flow along the canal without ever properly filling it. However, when the dam is present the flow of the impression material is locked, which forces it radially outwards to better fill the canal, thereby providing a tighter fit and a more effective seal.

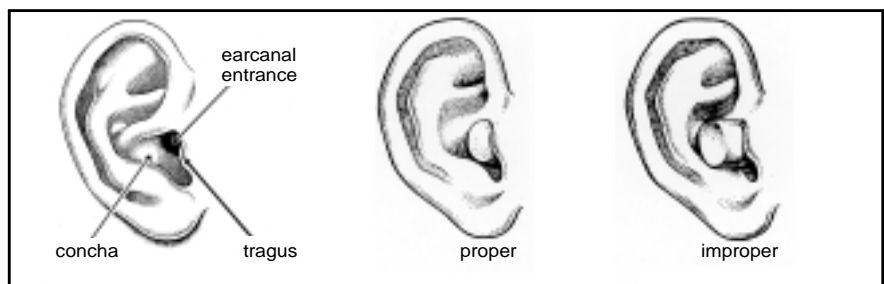


Figure 3. Key features of the external ear (pinna and earcanal) along with demonstration of a proper and improper fit of a foam earplug.

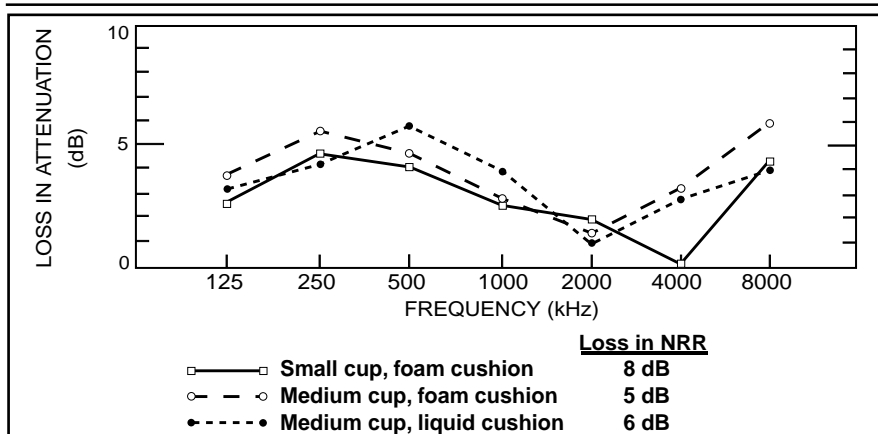


Figure 4. Effects of correctly sized and fitted eyeglasses on the attenuation of three different earmuffs.⁸ 10-subject data re ANSI S3.19-1974

Earmuff Fitting Tips

Contrary to popular belief, earmuffs are not one-size-fits-all devices. The headband may not extend or collapse enough to fit all head sizes, and cup openings may not properly accommodate the largest ears. The contours in the circumaural areas of the wearer's head may be so irregular that the cushions cannot properly seal against them. Like an earplug, an earmuff must be individually dispensed and checked for fit to acquaint wearers with its features and make sure it is compatible with their anatomy.

Place the muff on the wearer's head and be sure the cups fully enclose, and are centered about the pinnae, without resting on them. Adjust the headband so that it sits comfortably on the head and the cushions feel to the wearer as though they exert evenly distributed pressure around the ears. Instruct users about the importance of achieving the best possible seal between the earmuff cushions and the side of the head. Caps and other head-worn gear must not interfere with this seal, and excess hair should be pulled back and out from beneath the cushions.

Eyeglass temples should fit close to the side of the head and be as thin as practical in order to reduce their effect on the ability of cushions to seal around the ear. The loss in attenuation that temples create, with cushions in good condition, is normally 3 to 7 dB. The effect varies widely among earmuffs and also depends upon the fit and style of the eyeglasses. Representative data are plotted in Figure 4.

Wearing eyeglasses in combination with earmuffs may be uncomfortable for some wearers since earmuff cushions press the eyeglass temples against the skull. The pressure can be relieved by fitting foam pads over the temple pieces, but the increase in comfort may be at the expense of attenuation as has been demonstrated for one commercially available pad product.⁸ Also, pads do nothing to reduce acoustic leaks caused by overlength temples which break the cushion-to-skull seal behind the ear. However, temple pads should still be considered for use, since the improved comfort they can provide may be crucial in motivating certain employees to wear their HPDs.

Earmuff protection can be roughly checked by asking wearers to listen with earmuffs on while in the noisy environment in which they work. They should be able to detect a considerable difference in the overall apparent noise level if they lift both earmuff cups, or between their two ears if they lift only one cup. If not, the earmuffs were either grossly misfitted, are in very poor condition, or the noise in which the persons work is predominated by the lower frequency sounds for which earmuffs generally give less protection. Most listeners will not be able to detect small to modest degrees of misfit with this test since earmuffs will usually provide enough noise reduction, even when moderately misfitted, to be clearly distinguishable from the no-attenuation (i.e. the lifted-cup) condition.

Final Comments

Years of hearing conservation experience have shown that hearing protectors are often misused, and that in general their real-world performance falls far short of the protection that properly-worn and maintained HPDs can provide. To improve the situation, employers must develop effective group and individual training sessions in which employees are provided clear and accurate guidance in the fitting and use of their HPDs. The tips described herein will be useful in that regard; training and motivational concepts have been elaborated elsewhere.^{1,3,5,7,9}

Remember, it takes time to get used to wearing protectors, both how they feel and how they sound. A break-in period is advisable for new wearers, especially in the case of earplugs. It may take a week or two for some persons to fully adapt to the feeling of wearing hearing protectors and to begin to recognize and appreciate the auditory as well as the non-auditory benefits that their use provides.

Fitting hearing protectors is largely a common-sense affair. With time, commitment, and the experience gained from careful observation, nearly all ears can be successfully fitted and real world problems overcome.

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