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Technical Data Bulletin
3M Personal Safety Division

#234 Hearing Protection for Impulse Noise Published July 2015

Impulse noises are generally defined as sounds with short duration (less than 1 second) such as gunfire, explosions or the "pop" of a pneumatic nail gun. These sounds typically have an extremely fast onset and often reach very high sound pressure levels (SPL). In figure 1, for example, the sound of gunfire reaches a peak SPL of 164 decibels (dB) in the first few tenths of a millisecond then decays rapidly.

By comparison, *continuous* noises are generally defined as sounds that have a longer duration (more than 1 second) such as most typical industrial noises, noises from vehicles and aircraft, and noise from operating power tools at work or at home.

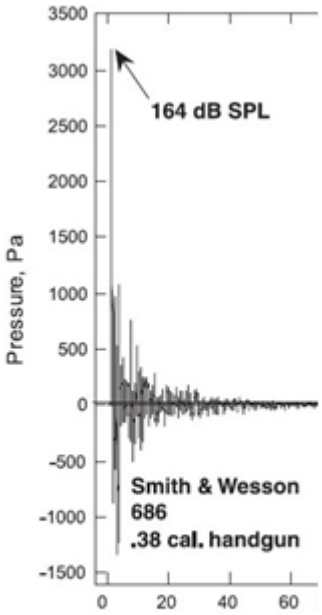

Figure 1. Example of impulse waveform from handgun. Flamme, et al 2009.

What are the Risks Associated with Impulse Noise?

One commonly accepted approach to assessing the health risks for people exposed to impulse noise is to measure the instantaneous *peak* sound pressure level (L_{pk}) rather than the *average* sound pressure level (L_{avg}). When peak sound levels exceed 135 dB, the risk of damage to the auditory system and other adverse health effects increases significantly. Common health effects associated with impulse noise include hearing loss, tinnitus, hyperacusis (abnormal sensitivity to loud sounds) as well as non-auditory effects such as hypertension, fatigue and other conditions related to stress.

Are Hearing Protectors Effective Against Impulse Noise?

When properly selected and worn according to the user instructions, hearing protection devices (HPDs) help reduce exposure to both continuous noises as well as impulse noises. However, it is difficult to predict the required and/or actual hearing protection obtained during exposure to impulse noises. For gunfire, the weapon type, number of rounds fired, proper selection, fit and use of hearing protection, the proper care and condition of the hearing protectors, and other variables will impact hearing protector performance.

Traditional Passive Hearing Protectors

Passive hearing protectors are devices without electronic components. Traditional passive HPDs, such as roll-down foam earplugs, push-to-fit foam earplugs and earmuffs, create a physical barrier that reduces (attenuates) the sound level that reaches the wearers' ears by a certain amount regardless of the sound level to which the wearer is exposed. For example, someone who selects and wears 3M™ E-A-Rsoft™ FX™ Earplugs correctly and obtains 33 dB of noise reduction overall would be expected to

obtain that amount of noise reduction for an 85-dB SPL exposure and at least that much or more noise reduction for a 150-dB SPL exposure. These devices are sometimes referred to as “conventional” or “non-level-dependent” hearing protectors.

Passive Level-Dependent Hearing Protectors

HPDs that incorporate specialized acoustic filters are often referred to as “level-dependent” or “nonlinear.” Unlike traditional passive hearing protectors, these devices create a relatively transparent barrier at low sound levels, using a tiny orifice or a thin diaphragm. The intention is for the amount of noise reduction to increase in proportion to the sound level to which the wearer is exposed.

At low sound levels, below 110 dB SPL for example, these devices provide little or no attenuation, allowing the wearer to maintain better hearing ability*. However, when the wearer is exposed to very high level, short-duration impulse noises, the acoustic filters instantaneously restrict the transmission of sound into the ear by a greater amount that increases as sound level increases, to help boost the attenuation of the peak sound pressure wave, L_{pk}, and reduce the exposure of the wearer.

Some level-dependent HPDs, such as the 3M™ Combat Arms™ Earplugs, allow the wearer to switch from the impulse noise protection mode to a continuous noise protection mode by sealing the acoustic filter, thus causing the device to function as a traditional hearing protector. This can be useful when the wearer is exposed to impulse noise at certain times and continuous noise at other times.

Electronic Level-Dependent Hearing Protectors

These HPDs use electronic technology to maintain, and in some cases enhance, hearing ability when sound levels are low. They are often referred to as “active” hearing protectors. Environmental microphones (also referred to as tactical, surround, or situational-awareness microphones) on the device pick up the low-level (non-hazardous) sounds in the area around the wearer and reproduce them inside the hearing protector. Typically the wearer can control the loudness using a volume control on the device. The amount of sound that is electronically reproduced inside the HPD decreases proportionally as the sound level outside the device increases. Electronic compression is used to limit the level of the reproduced sound inside the headset to non-hazardous levels.

Since the maximum attenuation provided (in the absence of electronic reproduction) is based on the physical properties of the earmuff cups or earplugs that create the acoustic seal around the ear or in the ear, these devices provide protection against both impulse and continuous noises in the same way as traditional HPDs. The big difference is the ability of electronic level-dependent HPDs to allow the wearer to hear more effectively during periods of low noise without the need to remove the device.

All 3M™ PELTOR™ electronic level-dependent hearing protectors limit the sound reproduced from the environmental microphones to 82 dB SPL. In the absence of the reproduced signal (even if the active circuitry is powered off), some sound will continue to be transmitted into the ear since the barrier created by the earmuff cups or earplugs themselves has the same limitations as does a traditional HPD. In other words, even electronic level-dependent hearing protectors eventually depend on the non-electronic components to help protect the wearer’s hearing.

**Hearing ability is a general term to describe various factors related to auditory situational awareness such as sound detection, recognition, identification, localization and communication.*

Hearing Protector Guidance

A variety of factors affect the hazardousness of the impulse noises and the degree of hearing protection required, especially the number of exposures and overall peak level, L_{pk}, of each impulse. For example, the sound made by a weapon fired in an indoor firing range may have a greater intensity due to reverberation than the same weapon fired at an outdoor range where there is rapid sound decay. The caliber and type of weapon (handgun versus rifle) can also have a significant effect on L_{pk} .

The following guidance is to be considered general in nature since the actual hazard associated with exposure to gunfire and other impulse noises and the protection obtained when hearing protectors are worn is influenced by the variables described above.

Regardless of the hearing protector being worn, the user should be alert to his or her own hearing. If during or after an exposure, tinnitus (ringing or buzzing in the ears) is heard or the user's hearing seems muffled or dulled, or for any other reason the user suspects a hearing problem, the fit, condition or adequacy of the protector should be carefully checked and/or a more protective device or combination of devices (such as earmuffs and earplugs together) should be worn. For those exposed to weapons fire on a regular basis, periodic hearing evaluations are advised.

For highest noise reduction: wear dual protection (earmuffs worn over high attenuation earplugs fit deeply in the ear). This configuration will significantly boost the noise reduction but will reduce the user's hearing ability.

For high noise reduction: wear a good quality single hearing protector, such as foam earplugs fit deeply in the ear or high attenuation earmuffs. This approach may also reduce hearing ability.

For better hearing ability: consider level-dependent hearing protectors, either passive or active. Possible configurations include the following, with the dual-protection option being the more protective.

- Single hearing protection
    - Electronic level-dependent earplugs such as the 3M™ PELTOR™ Tactical 100, or
    - Electronic level-dependent earmuffs such as 3M™ PELTOR™ Tactical Sport, or
    - Passive level-dependent earplugs such as the 3M™ Combat Arms™ Earplugs
- Dual hearing protection
    - Passive level-dependent earplugs worn together with electronic level-dependent earmuffs, or
    - Electronic level-dependent earplugs worn together with traditional passive earmuffs, or
    - Traditional passive earplugs worn together with electronic level-dependent earmuffs, or
    - Electronic level-dependent earplugs worn together with electronic level-dependent earmuffs.

Hunters may choose level-dependent HPDs to balance the need for protection with the ability to detect and locate nearby game animals. Likewise, target shooters may opt to combine electronic level-dependent devices with passive HPDs (dual protection) to allow better audibility of range commands without sacrificing hearing protection.

For more information on hearing protection for indoor firing ranges and other shooting sports, read:

- Preventing Occupational Exposures To Lead and Noise At Indoor Firing Ranges. NIOSH publication 2009-136. Available online at http://www.cdc.gov/niosh/docs/2009-136/
- Hearing Protection & the Shooting Sports. Published by the National Hearing Conservation Association (NHCA) and the National Shooting Sports Foundation (NSSF). Available online at https://nhca.site-ym.com/store/ViewProduct.aspx?id=1945533

The importance of proper fit

The noise reduction of earmuff-style hearing protectors may be lower when eyeglasses, goggles or respirator straps are worn between the sealing surface of the earmuff cushions and the sides of the wearer's head. For best noise reduction, select eyeglasses or goggles that have thin, flat temples or straps that will minimize interference with the seal of the earmuff cushions. Pull long hair back to the extent possible and remove other items that may degrade the earmuff seal such as pencils, hats, jewelry or earbuds. Do not bend and reshape the headband as this will cause a loose fit and allow sound leakage.

Earplugs should be used in accordance with the manufacturer's instructions with special emphasis on selection of proper size and proper depth of insertion. If using disposable foam earplugs such as the 3M™ E-A-R™ Classic™ Earplugs, it's important to ensure that the proper technique for rolling and compressing the plug is used to avoid creating a crease along the length of the earplug that can degrade the noise reduction properties of the plug.

3M recommends fit testing of hearing protectors to provide a better estimate of the noise reduction obtained by the wearer. Proper care and maintenance of hearing protectors is critical in ensuring the device's protective capabilities can be maximized. To learn more about fitting, care and use of hearing protectors visit 3M online at www.3M.com/Hearing.

Flamme GA, Wong A, Liebe K, Lynd J. (2009) Estimates of auditory risk from outdoor impulse noise II: Civilian firearms. *Noise Health* 11: 231-42.

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