E·A·R·LOG® 3

Third in a comprehensive series of technical monographs covering topics related to hearing and hearing protection.

The Effects of Hearing Protectors on Auditory Communications

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In EARLogs[1] #1 and #2 we have demonstrated and discussed the fact that hearing protective devices (HPDs) reduce user sound exposures when properly worn. This means that all sounds may be attenuated, both unwanted sounds (noise) and useful sounds such as speech and warning signals. Thus wearing HPDs may affect speech discrimination, and the perception of warning signals. The magnitude and quality of these effects as a function of hearing level and hearing protector type are summarized in this, EARLog #3.

Speech Discrimination

Speech discrimination (SD) is a measure of one's ability to understand speech. It is greatly affected by such factors as a person's hearing acuity, the signal (speech) - to - noise ratio, the absolute signal levels, visual cues (lip and hand motion), and the context of the message set. SD is measured by presenting to subjects one of a number of prepared word lists (available in the literature), and determining what percentage correct responses they achieve[2]. The effects of HPDs on SD can be evaluated by establishing a set of test conditions, and measuring SD with and without HPDs on the subjects. The results of such tests conducted by many investigators may be summarized as follows:

1. HPDs have little or no effect on the ability of normal hearing listeners to understand speech in moderate background noise [3,4,5,6,7] $\approx$80 dBA, but HPDs begin to decrease SD as the background noise is reduced even further. HPDs will decrease SD for hearing impaired listeners[8] in low-to-moderate noise situations.

2. At high noise levels $\geqslant$ 85 dBA HPDs actually improve SD for normal hearing listeners[3,5,9,10,11,12] This is clearly demonstrated in Figure 1[7]. For hearing impaired listeners the effect of HPDs on SD at these high noise levels is not unequivocal, but the results seem to indicate no significant effect.[13]

3. The literature is not extensive enough to differentiate between the effects of earmuffs and earplugs on SD. Nevertheless it may be said that the higher attenuation devices, be they ear muffs or earplugs, offer greater potential for degrading SD at lower sound levels.

The beneficial effects of HPDs on SD can be partially explained by referring to Figure 2 in which the spectrum of a male voice is superimposed upon a typical industrial noise spectrum of 91 dBA. Note that although the HPD's attenuation increases with increasing frequency, at any one frequency both the speech and the noise are reduced equally. The signal to noise ratio is constant, but importantly the overall signal level is reduced. This prevents the ear itself from distorting the signal, a phenomenon which occurs even at levels well below 90 dBA.[14] Thus as long as the speech signal is maintained above audibility, intelligibility can be improved by restricting signal levels to those that will not overload the ear.

The preceeding generalizations may be modified in practice by three important factors. Typically, in real work environments, communications will be accompanied by visual cues and/or be limited in scope. Missed words can be "filled in" and intelligibility maintained. Howell and Martin [5] have shown that when the person speaking wears HPDs his speech quality is degraded and this will adversely effect communications. And finally, Acton[15] has demonstrated that employees get accustomed to listening in noise and can perform better with respect to SD than do laboratory subjects with equivalent hearing levels. The interaction of these three effects has not been fully evaluated by any one author, but Rink[3] has shown that visual cues do improve SD for hearing impaired persons wearing HPDs, especially in noise.

Localization

Another effect that HPDs can have is to confuse one's ability to locate the direction of origin of sounds.[16,17] The data indicate that earmuffs, which necessarily cover the entire ear, can interfere with this localization accuracy whereas inserts, which generally leave virtually the entire outer ear exposed, do so to a much lesser extent. Furthermore, experiments with earmuffs[18] indicate that subjects cannot adapt to this effect, i.e., they cannot learn to compensate for the adverse effects of the muff.

Amplitude Sensitive Insert Hearing Protectors

Amplitude sensitive or nonlinear inserts are designed to provide attenuation that increases with increasing sound level, so that for low level noise conditions there is little attenuation and SD can be improved. Basically these devices are insert protectors provided with a small orifice running longitudinally through the body of the plug. The orifice may contain valves or acoustical damping materials.

At sound levels below $\approx$110 dB[19] these devices simply behave as a vented earmold with almost no attenuation below 1 kHz and attenuation increasing to as much as 30 dB at higher frequencies.[20] At high sound levels ($\geqslant$140 dB), steady-state or impulsive sound waves generate turbulent air flow in the orifice which impedes the passage of sound. Measurements[19] of gunfire impulses in cadaver ears have

SPEECH DISCRIMINATION AS A FUNCTION OF NOISE LEVEL AND SPEECH LEVEL, FOR EARPLUGS vs. NO EARPLUGS

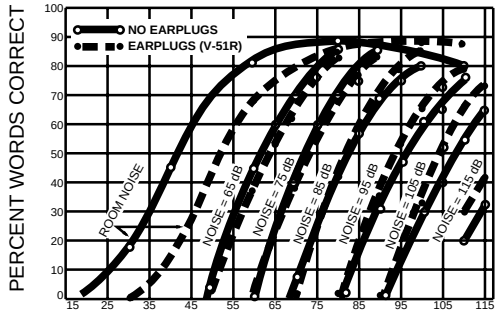

Figure 1

The relationship between speech discrimination and speech level with noise level as a parameter. Each point represents an average of the % correct responses for 8 subjects to a list of 200 words read over a PA system in a reverberant room. From Kryter.[7]

EXAMPLE OF THE REDUCTION OF SPEECH AND NOISE LEVELS THROUGH THE USE OF A PREMOLDED INSERT HEARING PROTECTOR

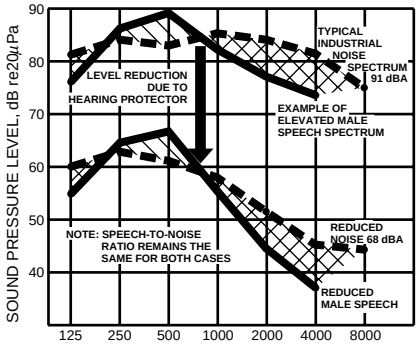

Figure 2

verified that the peak noise reduction increases from approximately 10 dB for 140 dB peaks to 20 dB for 180 dB peaks, for one particular nonlinear device. Combining this information with impulse noise damage risk criteria[10,21] indicates that these devices should be effective for limited exposures (⩽20 rounds per session) to gunfire noise up to ≈175 dB peak SPL. Measurements[19,22,23,24] of the temporary (hearing) threshold shifts of human subjects exposed to such noise, in non-reverberant spaces, verify this supposition. Unfortunately these devices are of little value for many occupational and recreational noise exposures wherein the noise levels are rarely the appropriate type or of sufficient level for these devices to become functional.[25]

Summary

The preceeding data indicate that HPDs can be effectively utilized for the preservation of hearing in high noise level environments with minimal effects on SD. For hearing impaired persons, the utilization of HPDs in lower noise level environments should be carefully considered. If localization capabilities are important then inserts should be chosen instead of earmuffs. And finally, the use of amplitude sensitive devices may be advantageous for use on firing ranges where they have been shown to provide adequate protection for limited exposures.

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