HEARING PROTECTION : GENERAL REVIEW

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When noise reduction and isolation measures have failed to reduce a noise to levels acceptable in terms of damage risk, the provision of hearing protection has to be considered. The object of such protection is to reduce the amount of sound energy transmitted to the inner ear, thus protecting the auditory receptor structures in it.

BASIC TYPES OF HEARING PROTECTORS

Reduction of Transmission by Air Conduction

Earmuffs. These are rigid cups specially designed to cover completely the external ears. Two cups are held in place by an adjustable headband, best in the form of one that can swing behind the head (back-band position) and thus fit under a safety helmet, or are mounted in a helmet. Each cup has a soft cushion filled with plastic foam, or a fluid such as glycerine, to ensure a good fit between the cup and the head. The fluid-filled cushion is called a "fluid seal."

Earplugs. These are available in three general forms: (1) prefabricated earplugs, made of rubber or plastic, and usually supplied in a variety of sizes;(2) temporary earplugs in the form of a disposable material, such as wax-impregnated cotton or specially fine glass wool described as "glass-down";(3) semi-insert plugs held by a headband onto the openings of the ear canal, known sometimes as "canal caps".

Reduction of Transmission by Bone Conduction

Anything which impedes normal sound conduction causes a conductive hearing loss, although the magnitude is limited to about 60dB; after reduction of intensity by this amount the remaining sound is conducted through the bones of the skull directly to the inner ear, bypassing the ossicular chain. The maximum amount by which a hearing protector can reduce the sound reaching the ear is limited therefore by this factor.

Helmets. Helmets are commonly used to support earmuffs or earphones and cover the bony portion of the head in an attempt to reduce bone-conducted sound. They are particularly suited for use in high noise levels: also for communications and for additional safety, such as protection of the eyes and of the head against bumps or missiles, if it is required. With good design and careful fitting of the seal between the edges of the helmet and the skin of the face and neck, a further 5 to 10 dB of sound attenuation can be obtained in addition to that already provided by the earmuffs or earphones within the helmet.

REQUIREMENTS OF HEARING PROTECTORS

Noise Reduction. The protector should be chosen to reduce noise to an acceptable level. Earplugs are less effective than earmuffs, though either can be inefficient if incorrectly fitted. In general, earplugs can be used in noise levels below 100dBA, whereas earmuffs are usually sufficient in noise levels up to about 115dBA. Either can be used

for even higher noise levels if the duration of exposure is shortened appropriately.

Comfort. The acceptability of a hearing protector depends on its comfort. All protectors are uncomfortable if worn for long periods. Usually earplugs are judged less comfortable than earmuffs, despite the latter being heavier, more bulky and liable to cause perspiration. Glass-down and some "personalised" earplugs are appreciably more comfortable. Glorig's truism that 'the best ear protector is the one that is worn' should constantly be kept in mind.

Speech Communication. The use of a hearing protector does not necessarily reduce the ability to communicate; in fact, in certain circumstances it can help. Earmuffs can incorporate electronic communication aids and earplugs can be designed to have frequency-selective or amplitude-sensitive properties which help communication in certain circumstances.

Other Requirements. It should be possible to fit and remove the protectors quickly and easily. They should be durable, resistant to perspiration, and nontoxic to the epidermis. The cost of an ear protector should be judged in relation to its expected life and the protection required; the prices range from about 10p to £4, or to very much more in the case of ear defender communication head-sets. The nondisposable protector should be easy to clean, repair, or replace.

EVALUATION OF ACOUSTIC PROPERTIES

The most important consideration in the design of a hearing protector is its sound attenuation and, consequently, the sound energy it keeps out of the ear of the average person.

The U.S. Standard(1957) method of measuring the attenuation is widely accepted and involves a free-field binaural threshold shift technique. In this, the threshold of hearing for selected pure tones is measured in a free field using both ears of each of a group of subjects with normal hearing. The thresholds are also measured with each subject wearing the selected hearing protectors. The average difference between these two thresholds represents the degree of attenuation attained.

The technique has many limitations and imperfections however, and currently both the American National Standards Institution and the British Standards Institution are working on new standards. This work will be described by Dr.A.M.Martin in a later paper.

Some typical attenuation figures are tabulated below.

TABLE I. Pure-tone attenuation(and standard deviation) characteristics of hearing protectors(data from Piesse, 1962)

Hearing Protector	Measurement (dB)	Frequency(Hz/kHz) 250	500	1	2	3	4
Fluid Seal Muffs	Attenuation	28	38	39	41	44	47
	(S.D.)	(3)	(4)	(4)	(7)	(4)	(4)
V.51R Plug	Attenuation	11	13	19	27	30	25
	(S.D.)	(7)	(9)	(10)	(9)	(6)	(5)
Glass-Down	Attenuation	11	13	17	29	34	35
	(S.D.)	(5)	(4)	(7)	(6)	(7)	(7)
Waxed Cotton Wool	Attenuation	10	12	16	27	31	32
	(S.D.)	(9)	(9)	(8)	(11)	(10)	(9)
Dry Cotton Wool	Attenuation	3	4	8	12	14	12
	(S.D.)	(2)	(3)	(3)	(6)	(4)	(4)

Cotton wool earplugs are not advised on account of their inefficiency and the false sense of security which their use engenders. Although the types of cotton wool supplied more recently for medical purposes appears to have finer fibers than hitherto, they are still found to be rather unsatisfactory. The newer type has figures about 4 dB greater than that shown above.

If the cotton is mixed with petroleum jelly or paraffin wax it becomes much more efficient. The former is rather messy and not very practical; the latter has to be preformed into earplugs and is available commercially as such. These preformed plugs have a further

disadvantage in their lack of elasticity. After awhile, the repeated alterations in the shape of the ear canal caused by jaw movements compress the relatively inelastic plug into a shape that no longer fits tightly and the plug then becomes inefficient.

PURE-TONE ATTENUATION CHARACTERISTICS AND THEIR APPLICATION

For assessing the extent of the auditory hazard when hearing protectors are worn, the usual procedure is to subtract the average attenuation from the octave-band noise levels at corresponding frequencies and to compare the noise then reaching the ear with the appropriate damage risk criteria.

It should be realised that the attenuation figures,like the criteria,apply only to a certain percentile(50% in the cases of the average attenuation and of most damage risk criteria). For more complete safety the criteria would need lowering by 5 or 10 dB,and the lower quartile of the attenuation values(approximates to mean minus two thirds of one SD) would be a more appropriate correction for use of hearing protection.

EFFECTS OF HEARING PROTECTORS ON SPEECH COMMUNICATION

In quiet, speech sounds will be heard without degradation by a normal-hearing person wearing hearing protectors if they are of sufficient intensity (e.g.,conversational voice level). On the other hand,in persons with preexisting, high-tone, perceptive hearing loss their already-reduced ability of speech discrimination, at optimum levels of amplification, is likely to be reduced somewhat further when hearing protectors are worn.

But in a background of continuous noise the situation is quite different. At noise levels of about 85 dB SPL,if the voice can be raised sufficiently loudly to be heard at all then hearing protectors make little difference to its intelligibility (in a normal-hearing person). This is because the perceived level of both the voice(signal) and the noise is lowered equally by the hearing protectors,i.e.,the signal-to-noise ratio is unaltered. Further,there is evidence that at levels above about 85 dB the use of hearing protectors may actually be beneficial to communication.

The position of persons with impaired hearing when using hearing protectors in a noisy environment does not appear to have been studied, but theoretical considerations lead to a conclusion that use of hearing protectors may have further disadvantages for these people.

One of the greatest of recent advances in communication in noisy environments has been the embodiment of telephone receivers inside noise-excluding earmuffs. This has a double benefit in practice. While the listener is dependent upon wearing the muffs for markedly improved communication, he is at the same time protected against noise. The headsets may be connected by a cord to a plug-in communication system, which may be portable. In other cases, magnetic induction-loop receivers may be incorporated and the wearer can then hear instruction anywhere within the area of the magnetic loop without the need of a trailing cord.

Finally, with occasional high intensity impulsive noises, eg from guns, and quiet intervals between, use of amplitude-sensitive earplugs such as the "Gundefender" will often provide a remarkable improvement in the communications vital for safety and efficiency (in the military or sporting activity concerned) and still give sufficient protection.

PRACTICAL PROBLEMS WITH HEARING PROTECTORS

Except in the most extreme noises or where communication facilities are embodied,dislike of wearing hearing protectors is universal, though varying in degree. Objections are in many cases very reasonable but have to be weighed against the hazard to hearing. In other cases, the objections are less well founded and depend on factors such as self-consciousness, carelessness, bravado, tradition, and unawareness of the dangers. In these cases, the resistance may largely be overcome by discipline, education, and example. Financial incentives, and the coupling of these with use of hearing protectors being a term of

employment, have also been successful and should be considered.

DIFFICULTY IN LISTENING TO MACHINERY SOUNDS OR HEARING WARNING SIGNALS

In general, the signal-to-noise ratio considerations which govern the hearing of speech against a noisy background are also relevant to the hearing of "indicator sounds." However, on some occasions, use of hearing protection may interfere with perception of these sounds, especially in persons with a preexisting, high-tone hearing loss (as may be found in many men working in noisy environments). Most engineers have learned to listen for aberrant sounds, which may indicate a hot bearing, etc., without wearing hearing protectors. If, at a later date, they are given these protectors to wear, they very naturally feel a loss of confidence in their ability to detect and interpret correctly the aberrant sounds. Another factor, affecting even normal-hearing persons, is that indicator sounds become less noticeable when wearing ear protectors. This is because, at the lower intensities then reaching the ear, the loudness of partially noise-masked signals and their ear-catching quality is reduced. Once again, explanation, encouragement, and example are the answers. It may also be helpful to arrange a practical demonstration to show that the sounds do in fact remain audible when protectors are worn.

FAILURE OF HEARING PROTECTION

Universal use of hearing protectors in any given noise-hazardous situation is seldom found, except where the protectors embody communication devices or the noise level is extremely high. Even if protectors are worn, they vary to a greater or lesser extent in efficiency according to the type used, to the degree of care in their original fitting and to education in their correct use. These factors of uncertainty, together with variations in exact amounts of noise exposure and the lack of applicability of damage risk criteria to persons who are markedly above average in susceptibility to noise-induced hearing loss, illustrate the need for monitoring audiometry in a hearing conservation programme. By means of such audiometric measurements both employer and personnel are safeguarded, because the development of noise-induced hearing loss will be detected at an early stage. In addition, by preemployment audiometric testing, the employer is protected against subsequent claims for deafness by personnel who may have had hearing impairment prior to their present employment.