EAR PROTECTIVE DEVICES — THE STATE OF THE ART

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ABSTRACT

In this paper, an attempt is made to describe the various types of ear protective devices and to discus their merits and demerits. The methods of evaluating the effectiveness of ear protective devices are also described. Suggestions are given for moiivating the workers to use these devices.*

Industrialization has brought in its wake the spectre of noise pollution along with other hazards. The adverse effects of noise on the human system have been well documented. Less known is its subtle but far ranging impact on the hearing mechanism. Irreversible sensorineural hearing loss is the premium exacted for prolonged exposure to this pollutant.

As the long run economics of safeguarding the health of industry's power horse—the workers—became apparent, attention focussed on the problem of controlling the runaway monster. Methods of reducing generation of machinery noise as well as cutting it down in the transmission path were introduced. The notion of using devices to protect the ear took birth when, despite the above measures, noise levels continued to pose a threat to hearing health.

Ear protective devices (EPDs) of various types inundate the market today. The search continues for the perfect device—one that would provide good attenuation, comfortable wear and yet not interfere with speech communication. A review of the types of EPDs available, their merits and demerits, procedures used in the measurement of attenuation properties and the utility of EPDs under actual working conditions forms the theme of the present paper.

Types of Ear Protective Devices :

EPDs can be classed into two main categories, namely ear muffs and ear inserts.

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Ear Muffs:

They are plastic domes that encircle ears and are connected by a head-band. The band is generally adjustable so as to accommodate varying head size and ear positions. Cushions filled with air, foam or liquid are attached to the side where they contact the head.

Lining the domes with opencell foam facilitates further sound absorption and damping. It has been observed that the size of the enclosed volume within the dome is directly related to low frequency attenuation. If maximum protection is required, the domes must be formed by rigid, dense, imperforate material. The seals should have a small circumference so that acoustic seal takes place over the smallest possible irregularities in head contour. This would ensure that leaks caused by jaw and neck movements are minimal. The force applied by the connecting headband has a direct bearing on the amount of protection provided. Compromise must be made in selecting the suspension force on the basis of performance versus comfort.

The mean attenuation values for ear muffs for puretones (125-8000Hz) was, found to range from 8.2 to 29.3dB (NAL, 1979).

Advantages :

1. Protection provided is generally greater and less variable between wearers.
2. A Single size usually fits a large percentage of wearers.
3. They can be readily seen at a distance. Hence the wearing of such protectors is easily monitored.
4. They are more acceptable at the beginning of a hearing conservation program.
5. They can be used on collapsed ears or ears with minor infections.
6. They are less likely to be misplaced or lost.
7. Employees with deformed or missing digits would find them easier to use.
8. They are longer lasting if parts can be replaced.

Disadvantages :

1. In hot environments, they are uncomfortable.
2. They are not easily stored or carried.
3. They are not compatible with other personally worn items such a eyeglasses, head gear, ear rings etc.,

4. Muff suspension force may reduce with usage so that protection afforded would be curtailed.

5. Such devices would interfere where the head must be manoeuvred in close quarters.

6 They are more expensive than other EPDs.

Inserts :

Insert or plug type protectors fit directly into the ear canal. To ensure proper fit, contact must be made along the entire circumference of the canal walls.

The mean attenuation afforded by inserts for pure tones in the frequency range 100 to 10,000 Hz was found to fall between 7.3 to 21.9dB (NAL, 1979).

Inserts are generally available in four varieties.

(i) Premolded :

There are three configurations commonly used. V51-R is suitable for most canals except those that are very straight and round. On the other hand, the bullet shaped design is best suited for such ear canals. Premolded universal design is manufactured with two or more flanges on the stem. All three are available in different sizes.

(ii) Custom molded :

They are made by mixing silicone material with a fixative agent and inserting into the ear canal and outer ear. The impression is then cured to obtain a permanent custom fit for each ear. Alternatively, an ear impression is first made using special material. After processing, a product of hard plastic is obtained.

Both of thess are more expensive than the premolded variety. However, they have a longer service life.

(iii) Malleable ear plugs :

These protectors are manufactured using material such as cotton, glasswool, wax, sponge rubber, spun glass or moldable silicone. The size and shape of the ear canal does not cause problems with fitting. Such ear plugs are typically made by introducing a small cone of the material into the ear canal with sufficient force so that it takes up the shape of the ear canal and holds itself in position. The use of non-porous material for plugs provides attenuation values approximating those of the molded varieties. However, since clean hands must be employed in forming and inserting the material, they are a poor choice for use in dirty areas.

Further, they can be used only two to three times. They may therefore prove more expensive in the long run.

(iv) Superaural (Canal Caps) :

Rubber caps suspended by a spring headband are inserted into the ear canals. Sound attenuation is achieved by sealing the opening of the ear canal. Although size is not a problem here, it is difficult for inspectors to judge whether they are properly worn.

Advantages :

1. They are better accepted for use in hot, humid workshops.

2. Storing and carrying them around is not cumbersome.

3. Less expensive when compared to earmuffs.

4. They donot interfere with the wearing of glasses, hats etc.

5. Keeping them clean is not a problem.

6. Wearing them would not hinder work where the head must be manoeuvred at close quarters.

Disadvantages :

1. Premolded plugs require a tight seal of ear canal, in order to be effective.

2. Use of these devices is difficult to monitor by safety personnel.

3. Some amount of manual dexterity is required for insertion.

4. Sizing of each ear is required.

5. If not replaced regularly, they become hard or may shrink.

6. They need to be reseated frequently.

The selection of EPDs is influenced by several parameters. Prime consideration, however, is directed to the aspect of attenuation characteristics. Some of the measurement and rating procedures are discussed here.

Measuring Hearing Protector Attenuation :

Absolute threshold shift procedure : This is the most commonly used method for measuring the attenuation offered by ear protectors. Almost all manufacturers data on such devices is derived by this method. Essentially, the procedure; involves determination of the minimum level of a sound that a listener can hear

TABLE 1
Comparision of various ear protective devices.

	CIRCUM AURAL	PREMOLDED	SELF MOLDED	CUSTOM MOLDED	CANAL CAPS
Attenuation	Good	Fair	Good for nonporous material	Good	Good
Economy	Expensive	Not Expensive	Expensive in the long run	Expensive	Expensive
Operation	Easy to use	Requires dexterity	Requires dexterity	Easy to insert	Easy to use
Durability	Long lasting as parts can be replaced	Hardens & Shrinks	Hardens	May harden	
Monitoring	Easy	Difficult	Difficult	Difficult	Easy
Best spot for use	Where movement of head in close quarters is not required	Any	Steady noise environment	Any	Intermittent low noise levels
Poor choice in	Hot, humid environment		Dirty environment		
Compatibility with other personally worn items	Poor	Good	Good	Good	Fair
Reseating required	No	Yes	No	No	Yes

Without an EPD (Open threshold) and with an EPD in place (Occluded threshold). The difference between the two thresholds is an index of the attenuation provided *by* the protector.

Description of the threshold shift techniques of evaluating EPDs is provided by two American National Standards. Testing of ten subjects, three times each, at nine different frequencies is required by both.

The ANSI (1957) technique was discarded as the impropriety of using pure tone in a directional field was recognized. The later ANSI standard (S3. 19-1974) specified the use of rd octave bands of noise, presented in a uniform diffuse sound field. Such testing was thought to more closely approximate typical industrial noise environment.

Single Number Ratings : Laboratory reports on the attenuation afforded by an EPD provided information pertaining to the mean attenuation and standard deviations at each frequency. While such data does allow comparison between protectors at each frequency, they do not facilitate direct determination of the total effectiveness of one device as compared to another. Reduction of this data to a single number rating therefore could provide a simple and effective means of choosing EPDs and assessing their utility for particular applications.

Many single number descriptors have been proposed over the last decade. The Noise Reduction Rating (NRR) is the current single number rating proposed by the Environmental protection Agency. The NRR is the difference between the overall C-weighted sound level of a pink noise spectrum and the resulting A-weighted noise levels under the protectors. Using data provided by Zwislocki (1957 cited by Berger 1979) on bone conduction thresholds, it was possible to determine that the maximum theoretical NRR possible is 45. The highest NRR ever measured on an EPD is 35.

A laboratory round robin experiment on EPDs organized by the Environmental Protection Agency (cited by Berger 1979) demonstrated significant interlaboratory variation in results of NRR tests of hearing protectors. It was there fore suggested that rank ordering performances of EPDs should not be attempted unless all the data are collected from one laboratory.

Indian Standards :

The Indian Standards (1979) specify that the material used in constructing EPDs should not cause irritation and should be resistant to heat, skin oil and wax. They should be both moisture and cold proof. Further, certain tests are necessary

including damp heat, rapid change of temperature test, low air pressure test, low temperature impact test, cleanability test, salt mist test and headband extension test. The acceptable minimum sound attenuation for earmuffs are 25 dB at 500Hz and 35 dB at 1000, 2000, 3000 and 4000 Hz. For plugs, a minimum sound attenuation of 20 dB at 500 Hz and 25 dB at 1000, 2000, 3000 and 4000 Hz is specified. Manufacturers are required to supply information with regard to sound attenuation, test tension, overall mass, temperature range, low pressure sensitivity and instruction for use and cleaning.

The measurement procedure for EPDs as specified by Indian Standards is similar to the ANSI standard described earlier.

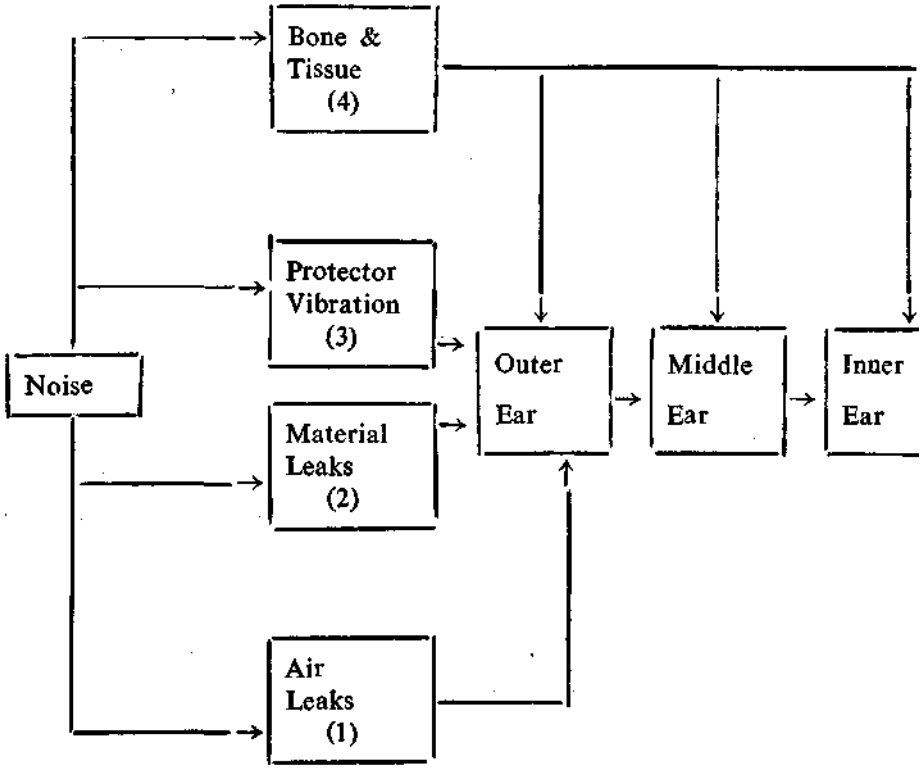

Fig. 1
Noise Pathways to the inner ear (Ref. : Sataloff & Michael, 1973)

Performance of Protective Device in Real World :

Most of the data on EPDs emerged from laboratory studies on well motivated trained subjects using optimal fitting protectors. However, such data obviously do not hold good for individuals working at industrial sites unless modelled after

actual usage conditions. An attempt along these lines was made by NAL (cited by Berger 1979a). Their subjects were only provided with the manufacturer's data and very little supervision. The absolute threshold shift procedure (ANSI-24-22) was adopted. Results indicated lower means attenuation values and higher standard deviations than the data supplied by the manufacturers. This contention is further supported by other studies (Edwards et. al., 1978 ; Regan, 1975 ; Padilla, 1976 cited by Berger 1980b) which show that in-field attenuation is only 40-60% of dB values provided by the manufacturers.

When an EPD is carefully fitted and adjusted on a laboratory subject, air leaks will be substantially reduced. Paths 2, 3 and would constitute the primary sound transmitting paths (Fig. 1). In contrast, under actual conditions Path-1 transmission through air leaks, often takes precedence. Air leaks result when plugs do not fit properly or muffs do not seal properly against the head.

Some of the causes of poor EPD sealing are :

1. Comfort and Fit:

Inserts must fit snugly in ear canals and muffs in tight contact with the side of the head. In general, the better the fit, the poorer the comfort. While some individuals adapt, other do not. Therefore, it is important to select several EPDs from the more comfortable ones and to allow the employees to make the final choice.

2. **Utilization** :

User problems such as discomfort, poor motivation or inadequate training may lead to earplugs not being properly inserted or muffs not being well adjusted.

3. Readjustments :

Ear protectors that work loose or are jarred out of position during work are commonly encountered problems. Employees typically talk, eat and move about actively resulting in jaw motion and perspiration.

4. Compatibility :

The suitability of EPDs vary across different ear canal and head shapes. Some ear canals and head contours defy all attempts to be fitted with EPDs.

5. Deterioration :

EPDs wear out with use. Some may shrink or harden ; flanges can break off and plugs may crack. It must be borne in mind that ear canals too gradually change in shape with time, leading to poor seal. Earmuffs headbands may lose

Research & Development:

Research must be directed to several areas. EPDs suited to specific set ups need to be devised. Manufacturers should be encouraged to develop a variety of EPDs that would cater to the needs of the Indian population. Managements must be made aware of the importance of trying different sizes of inserts for the two ears and of using a combination of EPDs. in certain workspots and of periodic-reissue of EPDs.

To conclude, ear protectors play a pivotal role in hearing conservation.

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