HEARING CONSERVATION PROGRAMMES

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AN INDEPENDENT PROJECT FOR THE FULFILLMENT OF FIRST YEAR M.SC(SPEECH AND HEARING) SUBMITTED TO THE UNIVERSITY OF aMYSORE.

ALL INDIA INSTITUTE OF SPEECH AND HEARING: MYSORE-570 006 .

1989

TO

MY PARENTS

CERTIFICATE

This is to certify that the Independent Project entitled "Hearing Conservation Programmes" is the bonafide work in part fulfilment for the degree of M.Sc, (Speech and Hearing) of the student with Reg.No.8811.

Mysore

17 May 1989

Director
All India Institute of Speech and Hearing,
Mysore-6

CERTIFICATE

This is to certify that this Independent Project entitled "Hearing Conservation Programmes" has been prepared under my supervision and guidance.

Dr.(Miss) S.Nikam,
Prof, and Head,
Audiology Department.

DECLARATION

I hereby declare that this Independent Project entitled "Hearing Conservation Programmes" is the result of my own study under the guidance of Dr. (Miss) S.Nikam, Professor and Head of the Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other diploma or degree.

Mysore. Reg.No.8811.

ACKNOWLEDGEMENTS

To Dr.Shailaja Nikam, my grateful thanks for her unceasing help, guidance and encouragements.

My sincere thanks to Dr.N.Rathna, Director, All India Institute of Speech and Hearing, Mysore-6, for giving me opportunity to do this project.

I am grateful to Mrs. Elizabeth for her help.

To Suresh T, and Ramkishan my special thanks for their invaluable assistance and constant help.

I am grateful to all my classmates especially Bijay, Maya, Vidya, Vinay and Laxmi for their encouragement and help.

I thank Sathu, Mukherjee, Jagadish for their timely help.

My thanks to Ms.Rajalakshmi R Gopal for her neat typing work.

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INTRODUCTION

Noise is defined as "unwanted sound with more or less random disturbance" (Robert and Young, 1957).

Noise is a random frequency current or voltage signal extending over a considerable frequency, spectrum and no useful purposes, unless it is intentionally generated for test purposes. (The Illustrated Dictionary of Electronics, 1980 Rutus and Turner).

Hearing loss caused by continues exposure is called occupational disease and the hearing loss due to the instantaneous impact of noise is called occupational injury. (Newell, 1987).

Hearing loss in case of noise induced hearing loss (NIHL) is usually bilateral, symmetrical, sensori-neural hearing loss, affects majorly high frequencies. It starts as a'symptomless disease. Initially losses appear as small holes in the hearing'. Such losses are difficult to detect except through professional testing. By the time even the most alert sufferer becomes consciously aware of it, hearing loss has grown quite severe, and it is already too late to do anything about it. Apart from NIHL, it also causes nonauditory effects and interference in communication.

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The problem of NIHL is severe because, there is neither recovery nor the medical line of treatment to cure the problem. Even the best hearing aid does not benefit much. Hence we should concentrate our efforts in preventing hearing loss, like the old saying goes "Prevention is better than cure"

The main purpose of hearing conservation programme is to prevent the employees from developing NIHL and nonauditory effects of noise, increase their work efficiency.

The word conservation is defined as "a careful preservation or protection of something, the planned management of a natural resource to prevent exploitation, destruction, or neglect". "Preservation" means to keep safe from injury, harm or destruction? to keep alive, intact, free from decay (Websters, 1969). The conservation of hearing is function of an audiologist.

The hearing conservation programme includes measurement of noise to find damage risk areas in the industry. The areas where the noise level is equal to or exceeds the damage risk criteria (DRC), the control of noise is brought about by the action of engineering controls and administrative controls. If however, it is not possible to control noise in this way, the control of noise can be brought about by ear protective devices (EPD). In the following chapters we will discuss on each in detail.

DEFINITION STEPS AND PURPOSE OF HEARING CONSERVATION PROGRAMMES

Definition: Once top management has approved the overall programmes and provided the funding, it becomes the responsibility of the plant physician and engineer to put it into action. The essential components of a hearing conservation programme are:

1. Measurement of plant noise and determination of which employees are exposed to levels that could produce hearing damage.
2. Hearing testing - advisable for all employees but essential for those in noisy jobs.
3. Obtaining otoscopic examination and histories of noise exposures and ear diseases on all employees, and correlating data with job noise.
4. Determining where noise control measures are feasible, and developing a good ear protection programme.
5. Disposition of individual employees with hearing problems, as well as the diagnosis of all causes of hearing loss found throughout the plant.

(Sateloff, 1975).

If it is possible to reduce plant noise to a safe level then no further attentionmay be necessary. A hearing testing programme is however, useful to protect the management from unwanted claims and legal harassment.

Initiating and maintaining a conservation of hearing programme is the responsibility of a team rather than and single individual. The plant physician, being aware of the handicaps produced by deafness, can generally be the chief motivating force in impressing management with importance of instituting the audiometric programme and noise abatement measures.

Various phases involved in a HCP can be summarized as in the table below (Templest, 1985).

Steps of hearing conservation programms.

Operation		Function
Noise Survey	:	Identification of hazardous areas/ occupations.
Noise Control	:	Reduction of noise at source enelosure of noise source/operator to reduce noise to safe levels use of sound obserbers.
Hearing protection	:	Where noise control is not possible, provision, fitting and maintenance of ear plugs, muffs for personnel at risk together with their education in the hazardous of noise.
Industrial Audiometry	:	Monitoring of the effectiveness of hearing protection. Pre-employment and serial audiometry to identify noise sensitive workers.

Organization of hearing conservation programmes.	:	Co-ordination of work of medical safety and occupational hygiene staff involved. Education of management and work force. Referral and redeployment of workers with hearing loss/damage.
Legal aspects	:	Statute and common law, legal liability, likely legislation.

Purpose_of_HCP: The purpose is to prevent significant permanent NIHL resulting from on the job exposures.

Benefits: Implementation of HCP provide both primary and secondary benefits.

1. Primary benefits:
   a) Prevent job related NIHL.
   b) The individual protected, experiences less fatigue, less emotional stress as a result of communication difficulties on and off the job and potential benefits in communicating in noise.
2. Secondary benefits are in terms of employee employer relation. The setting up of HOP will change the attitude of employee towards the management. By HCP detection of not only NIHL, also hearing loss due to other diseases is possible The implementation of HCP for two or more years will reduce the compensation cost for NIHL, and also unjustified claims for NIHL. (Berger and Royster, 1983).

Indications of the need for hearing conservation programme may be judged by simple observation of environment. In 1982 revision of Guide for Conservation of Hearing in Noise, prepared and sub-committee on Noise of the Committee on Conservation of Hearing of the American Academy of Opthalmology and Otolaryngology the following three conditions are listed as indications of a need for such a programme.

1. Difficulty in communicating by speech while in noise.
2. Head noises or ringing in the ears after working in noise for several hours.
3. A temporary loss of hearing that has the effect of muffling speech and changing the quality of other speech sounds after several hours of exposure to noise.

NOISE SURVEY AND NOISE MEASUREMENT

Noise Survey:

In many industrial situations, the noise survey will be conducted by an industrial hygienist or safety engineer, while a detailed noise analysis and noise control require the services of an acoustical engineer. The noise survey is carried out by sound level meter (SLM), if noise level does not vary throughout the day. However, in many industries there are variations in noise throughout the day to which employee is exposed to, the use of automatic recording equipment is required.

The purpose and scope of noise survey may vary but there are four general types that may be considered (Sateloff and Michel, 1973).

1. A survey to determine damage risk.
2. A survey to determine speech interference levels.
3. A survey to determine disturbance levels.
4. A survey for noise control purposes.

Types of noise survey:

There are at least three basic types of noise surveys (Royster and Berger, 1983).

1. Priliminary noise surveys: It permits an estimation of expected employee noise dose. On the basis of this the

company will determine the need for conducting general noise survey, and to initiate the implementation of HCP.

2. General noise survey: The main objective of this survey are the identification of all areas where the employees daily noise dope exceeds the criterian level selected and determination of typically noise doses for all affected employees.
3. Engineering noise survey: The objective of this more detailed survey is the identification of major sound sources in a production areas and the dominent sound sources within each major contributor. This can be done by octave band or even narrower frequency band sound analysis. Sufficient Information should be collected during engineering survey so that a priority list for selecting the noise sources to be controlled may be established at a later date if found necessary.

Noise measurement:

Whatever national standard specification is employed, the fundamental requirement is the measurement of both sound level and the time (i.e. noise dose) of exposure for each individual. Hence careful selection of instruments for the purpose of the survey is important.

An attempt is made here, to give a list of instruments, available for any noise survey. (An instrument or a combination of them can be selected depending upon the purpose and need).

Generally, an SLM is adequate if the sound levels do not change rapidly. The characteristics of rapidly changing sound levels must be measured with an oscilloscope or peak reading instruments designed for this purpose. Frequency analyzers or filters must be used in conjunction with a SLM, if the information on sound pressure distribution over the frequency spectrum is required.

1. Sound Level Meter (SLM): Basically, it consists of a microphone, an amplifier-attenuated circuit and an indicating meter. The air borne acoustic pressure variations are converted into electrical signals by a microphone with no change in signal characteristics. This signal passes through attenuator amplifier circuit and logarthmic weighting network. The indicating meter connected to this network displays sound pressure levels with reference to 0.0002 newtons/m^2 .

The sound pressure levels indicated by a SLM can be of different values, described below:

a) RMS value - Root mean square value (RMS) most commonly employed. It is useful for hearing conservation purposes because it is related to acoustic power and it correlates with human response. It is also directly proportional to the bandwidth.

b) Peak value - As RMS value fails to express the peak pressure noise which raises above the background noise, peak value is used. But the peak value are of relatively less important for measuring sustained noises. As the waveform becomes more complex, the peak value can be as much as 25 dB above R.M.S. value.

c) Rectified average value - It is an average taken over a period of time without regard to whether the instantaneous signal values as positive or negative. It is equal to 0.636 times peak value. It may fall as much as 2 dB below the RMS value for complex waveforms.

Meter indication and response speed:

The indicating meter of a sound level meter may have ballistic characteristics that are not constant over entire dynamic range, or scale, which will result in different reading depending upon the attenuator setting and portion of the meter scale used.

When a difference in readings is noted, the reading using higher part of meter scale (the lowest attenuator setting) should be used, since the ballistics are generally more carefully controlled in this portion of the scale.

Most of the general purpose SLMs have fast and slow meter response characteristics, that may be used for measuring continuous noise.

a) Fast response - This enables the meter to react within 4 dB of its calibrated reading for a 0.2 second pulse of one KHz. Hence it can be used to measure with reasonable accuracy noises whose levels do not change substantially in periods less than 0.2 second.

b) Slow response - It is intended to provide an averaging effect that will make the widely fluctuating sound levels easier to read. However it fails to provide accurate reading of sound levels changing in less than 0+5 second.

Frequency-weighting networks:

The A, B and C frequency weighting networks, which are normally available on a SLM, can be used to approximate the frequency distribution of noise over the audible spectrum.

These three networks are chosen because -

1) They approximate the ear's response characteristics at different sound levels. They can be easily produced with a few common electronic components. The comparison curve of A, B,C with flat response are given in figure.

The 'A' weighted measurement approximates the response characteristics of the human ear for low level sound is below 55 dB ref. 0.0002 n/m^2 . 'B' weighted measurement approximates the ear's response for levels between 55 and 85 dB. 'C weighting corresponds to the response for levels above 85 dB.

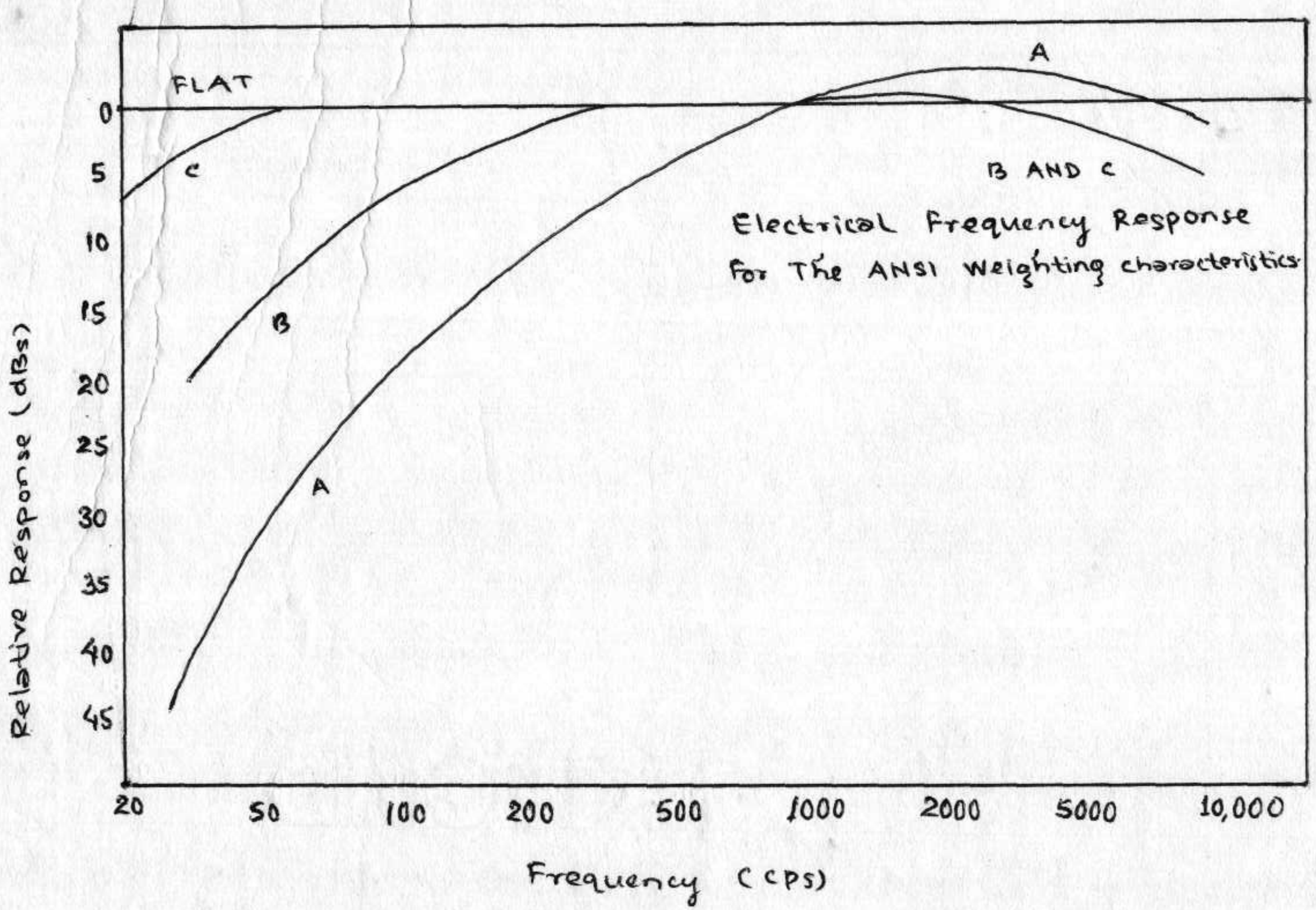

Figure - Frequency-response characteristics for sound level meters.

Using or by comparing levels measured by different networks weightings, a frequency distribution of noise energy can be approximated.

eg. If noise levels measured using 'A' and 'C networks are approximately equal, then most of noise energy is above 1KHz, as it is the only portion of the spectrum, where the weightings are similar. But if large differences are seen between the two reading, then most of the energy lies below 1 KHz.

Other use of these networks are for eg. for estimating annoyance caused by noise and for estimating the severety of NIHL (A weighting is used).

2. Microphones: Microphone commonly used for noise measurement are piezo electric, dynamic and condensor. Each of these have their own disadvantages and advantages depending upon measurement condition. All 3 can be made to meet American standard specification for general purpose SLM. The dynamic and piezo electric microphone designed are normally less expensive than condensor type and are provided as standard equipment with most low and medium priced sound measuring instruments.

The comparison of three types are given in a table.

TABLE

	Frequency response.	Frequency range.	Dynamic range	Temperature	Humidity
1.Piezo electric microphone	Flat response for low and middle audible frequency.	Less than the other two types (15 Hz to 8 KHz)	—	Older with Rochelle salt are damaged by heat/humidity and with barium tartrate may only give temporarily erroneous reading on condensation.	
2.Bynamic microphone	It is uniform even above 12000 Hz		-	It is not affected by temperature change	It is not affected by humidity change.
3.Condensor microphone	Uniform/flat frequency response	Various sizes may be employed to extend the range from few Hz to 100,000 Hz.	It has a dynamic range of 20 to 145 dB. Standard microphones have range of 30 to 160 dB? 50 to 175 dB? 60 to 185 dB.	No change	High humidity maycause temporarily erroneous readings.

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Microphone directional properties:

In a normal industrial setting, the noise falling on the diaphragm of a microphone, will be coming from all directions because of reflected energies. Here microphone is calibrated for random incidence of sound. Microphone can also be calibrated for grazing incidence, perpendicular incidence, for use in couplers, depending upon design and the purpose of the microphone. Hence for higher accuracy, the correct microphone should be chosen.

Microphone commonly used with sound measuring equipment are nearly omnidirectional for frequency below 1 KHz and hence directional characteristics are important for frequencies above 1 KHz. Therefore, for measurements of high frequency noise produced by a directional noise source, the orientation of microphone is important. A microphone calibrated with random incidence, should be pointed at an angle of 70* from the axis or as directed by the manufacturer.

Free-field microphone is calibrated to measure sounds which have perpendicular incidence to microphone diaphragm. Hence it should be pointed directly at the source.

Pressure type microphone are designed for coupler measurement. They can be used for measurement of noise of audible range at grazing incidence to the diaphragm.With this a calibration curve is used.

The directional property can also be used to advantage in noise measurement, e.g: improved S-N ratio can be obtained by placing the microphone at 0^o incidence to the source, when high level noise is produced by other sound sources. Reflected high frequency sounds of other sources can be checked by rotating the microphone axis, as this would cause a remarkable change in reading of Reflected energy.

Microphone orientation corresponding to the lowest reading should be chosen since the reflected error would be minimum at this position.

Special sharp microphone are helpful in locating high frequency sound source in the background of other sources.

Microphone cable:

Standard microphone cables with shielded and twisted wires should be used to minimized the Electrical noise pick up. No correction is needed for such adjustment with a dynamic microphone, if the length of the cable is below 100 ft. When condenso microphone is used, depending upon the preamplifier design, correction may or may not be applied. When piezo electric microphone is used either a correction or impedance matching is applied.

3. **Frequency Analyzer:** When the information provided by the frequency weighted networks of an SLM is insufficient, for more specific measurement a frequency analyzer is connected to SLM.

a) Octave band analyzer: The octave band analyzer is the most common type of filter used for most noise measurements related to HCP. Octave bands are the widest of the common bandwidths used for analyzers. Hence they provide information about spectral distribution of pressure with a minimum number of measurements.

The old instruments usually have a series of octave bands from 37.5 to 75, 75 to 150, 150 to 300 . . . . . 4600 to 9600Hz. Newer, octave bands analyzers have octave bands centered at, 31.5, 63, 125, 250, 500, 8000 Hz according to American standard Frequencies for acoustical measurements.

b) Half octave and third-octave analyzers: It is used when even more specific information of pressure spectral distribution is designed than that provided by octave bands. (A half-octave is a bandwidth with an upper edge frequency equal to the 2 times its lower edge frequency).

c) Adjustable bandwidth broad band analyzers: The design permits a selection of bandwidth in octaves, multiples of octaves, or a fraction of aa octave. These analyzers permit the selection of an octave hand, rather than a preselected series of octaves, for a particular job.

d) Narrow band analyzers: Analyzers with bandwidth narrower than octaves are referred to as narrow band analyzers.

They are usually continuously adjustable. Hence are referred to as constant percentage bandwidth or as constant bandwidth types.

4. Tape recorders: It is sometimes convenient to record noise so that an analysis may be made at a later date, for eg. when lengthy narrow band analysis are to be made, or when very short-transient type noises are to be analyzed.

   Care must be taken in the calibration and use of recorders to avoid errors. Microphone should also have the same characteristics as that of tape recorders. Any of professional or broad casting quality tape recorders are sufficient. Also, direct sound pressure level measurement and analysis should be made during the recording procedures, so that operator will be aware when additional measurements or data are necessary.

5. Graphic level recorder: This can be coupled to the output of a SLM, or analyzer, to provide continuous written record of the output level. Recent GLRs give records in the conventional RMS logarthmic form used by SLMs. Hence the data can be read directly in dBs.

Magnetic field and vibration effects:

The response of SLM and analyzers may be affected by strong alternating magnetic fields found around some electrical equipment. Dynamic microphones, loops and transformers are susceptible to hum pick-up from these fields. Some of dynamic microphones have hum-breaking circuits that minimize the pick-up, but caution should be executed in all cases. To test for hum pick up, disconnect the suspected component and check for a drop in level on the indicating meter or follow the manufacturer's procedure. Dynamic miscrophones are not useful in metal shop areas.

Vibration of the microphone or measuring instrument, may cause erroneous reading and in some cases may permanently damage the equipment. Hence it is good practice to mechanically isolate sound measuring equipment from any vibrating surface. Holding the equipment in your hands or placing it on a foam rubber pad is satisfactory in most cases.

Impulse or impact noise measurement:

The inertia of indicating meters of general purpose sound level meters prevents accurate, direct measurements of single impulse noises which have significant level changes is less than 0.2 second. Typical noises with short time constants are those produced by hammers, explosives, and others with short, sharp changing characteristics. A low inertia device such as an oscilloscope must be used to measure these impulse type noises if detailed information is required.

Measurement of impulse noise characteristics may be taken directly from calibrated oscilloscope with a long persistence screen, or photographic accessories may be used to obtain permanent records. The oscilloscope is usually connected to the output of sound level meter having a wide frequency response and calibrated with a known sound level of sinusodial characteristics.

Instrument calibration:

If valid data are to be obtained, it is essential that all sound measuring and analyzing equipment be in calibration.

Most general purpose sound measuring instruments have built in calibration circuits that may be used for checking electrical gain. Most sound level meters have built in, or accessory, acoustical calibrators that may be used to check the overall acoustical and electrical performance at one or more frequencies. The calibration should be made according to the manufacturer's instructions at the beginning and at the end of each days measurements. A battery check should also be made at these times.

Periodically, sound measuring instruments should be sent back to the manufacturer, or to a competent acoustical laboratory, for a complete overall calibration at several frequencies throughout the instrument range. In any case, a complete calibration should be made if any unusual change (more than 2dB) is seen in the daily calibration.

Dosimetry:

Noise dosimeters are becoming widely used for monitoring noise environments that may be hazardous to hearing. Basically the dosimeter integrates a weighted function of sound pressure or sound pressure level over a time period, and their determines the noise dose as a percentage of permissible exposure criteria. Most often these instruments are worn on the person, with microphone located on the chest or shoulder. They may also be used as an area monitor if not worn by a person.

The instrument can be broken down into these components.

1. A sound level meter
2. An integrator
3. A read out device.

The overall response and quality of sound level meter is controlled by standard, and tolerances are usually specified by ANSI S.4-1971 for a type-2 meter. The integrator section electrically integrates a power function of the mean-square signal over time. A rather general expression which describes the operation mathematically is

$$D = \frac{100}{T_c} \int_0^T \text{antilog} \left(\frac{L - L_c}{q} \right) dt.$$

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where

D = Percentage exposure (%)

T_C = Criterian sound duration(vsually 8 hours)

T = Measurement duration (h)

t = time (h)

L = weighted sound level (a function of time)(usually dBA)

L_C = Criterian threshold sound level(dBA)

q = Criterian exchange parameter (dB)

The exchange rate parameter is generally related to exposure accumulation factor of the criteria. For example, the OSHA exposure criteria reduce permissible exposure by one-half when the noise level increases by 5 dBA. Other international criteria reduce exposure by one-half when the noise level increases by 3 dBA, which is little more plausible from an energy stand point.

According to the formula, a dosimeter worn by the operator for 8 hour at 90 dB&and 100 dBA would indeed register 100% and 400% exposure accordingly.

With respect to read out, some dosimeters are self contained,in that the percentage exposure is given as a digital read out on the face of the instrument. Others require additional and separate read out indicating equipment.

Finally, because most exposure criteria do not accumulate below a specified threshold level, the dosimeters must respond accordingly. This simply means that the integrator is idle below a present level say 90 dBA, and no exposure accumulated.

The instrument is calibrated by placing a pistonphone or diaphragm calibrator over the microphone. Here as for the SLM, the dosimeter indicator is adjusted to an exposure accumulation rate based on the precise calibration sound level.

In summary for dosimeters there are numerous major variations in calibration read out, threshold level selection, etc. However the response and operation are controlled by standard and two most relevant are ANSI SI.25-1978 (American National Standards specifications for personnel noise dosimeters) and ISO R 1999 (Assessment of occupational noise exposure for hearing conservation purposes).

Microprocessor based noise measurement:

With the help of microprocessor based noise measurement instrumentation we can find out noise dosages for those employees whose noise dosages change on a daily and some times hourly basis due to their movement from location to location.

With the help of recently developed noise-logging dosimeter we can have direct read out of many exposure level measurement

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and can store 1 minute histograms to 40 hours, can print out 1, 3, 5 or 10 minute histograms, or can project 8 hour % noise dosages and statistical distributions, so hearing conservationist will be haying over abundance of information.

There are hearing conservation computer programs which eliminate lot of paper work. Acquisition of more information and analysis of the same is going to define our role as a good hearing conservationist. Ultimately microprocessor computer will have the greatest impact on how we administer our programs. (Dietz, 1987).

DAMAGE RISK CRITERIA

The relation of noise exposure to hearing loss is not precisely defined.

From the data available from laboratory investigations of TTS and observations of permanent hearing loss in industrial populations, four major faetors contribute to noise hazards emerge (American Academy of Ophthalmology and Otolaryngology, 1982). These factors are -

1. Sound level measured in dB
2. Spectral distribution (distribution of sound energy with frequency)
3. Duration and distribution of noise (sound) exposure during a typical work day and
4. Cumulative noise exposure in days, weeks or years.

In addition to the above factors, the following factors should also be considered.

5. Type of noise (steady state or intermittent)
6. Susceptibility of people to NIPTS.

A criterian must be established which specifies the risk which is considered acceptable and serve as basis for establishing prediction noise contours (Burns, 1973). In general, noise specifications or noise contours have became known as damage risk criteria, with actual criteria being unknown or or ignored by users, several specifications have been developed since the mid 1950s. Most of these noise specifications have made concessions in the amount of protection offered to industrial employees from NIPTS.

The starting point, then, for development of noise such specifications is the degree of deterioration of hearing which is regarded as acceptable. If all people reacted in the same way, then a limit could be established which would separate the damaging noise from safe noise. However, it is not true.

The most familiar, detailed, and elaborate noise specifications published thus far are the recommendations made by National Research Council Committee on Hearing, Bioacoustics and Biomechanics (CHABA) (Kryter et al. 1966). The criterion of acceptability underlying the CHABA proposal regards noise conditions as acceptable, if after 10 years or more of daily noise exposure, a hearing loss of not more than 10 dB at 1000 Hz and below, or 15 dB at 2000 Hz or 20 dB at 3000 Hz and above is produced. The CHABA cover a frequency range between 100 to 7000 Hz and have been published in the form of noise curves or damage risk contours. A distinct feature of these contours that not only are maximum allowable sound pressures for bands of noise indicated, but also the duration to which a person might be exposed to any given level is specified. The contours show that 8- and 4- hours exposures are almost the same. This recommendation is questionable in view of information from studies using noise exposure longer than 8 hours (Mills, et al 1970; Melnick, 1974; Melnick and Maves, 1974). The CHABA specifications predict that continuous noises having tonal components are more hazardous. The recommendation did not provide specifications for impulse noise.

Permissible sound levels for an 8 hours work day that give an L_{eq} for this period of 90 dB(A).

Sound level (<3BA)	Permissible daily exposure, hours
90	8
92	6
95	4
97	3
100	2
102	1½
105	1
110	½
115	¼ or less

(Occupational safety and health act).

Botstord (1970) recommended the use of a single index of noise magnitude, the 'A' weighted sound level to over come the octave band analysis of noise. The A-weighting network in a sound level meter makes the meter less sensitive to low frequency sounds in much the same way that the ear is less sensitive to these same low frequency sounds. It has been

incorporate

concerning

The American conference of Governmental, industrial hygienists developed recommendations for limits of permissible noise exposure (Botsford, 1970). These recommendations were incorporated in the Walsh-Healey public contracts act and in the occupational safety and health act. These values shown in table and incorporated the so called "5dB rule". The rule assumes that time intensity trades will maintain equal noxiousness of noise exposures. If the intensity of noise is increased by 5 dB, then the permissible duration must be reduced by one half. When the noise levels are determined by octave band analysis the equivalent A-weighted sound level may be determined to determine the exposure limits from the table. (When the employees are subjected to sound exceeding those listed in table, then HCP should be implemented to reduce the levels of noise ia order to prevent the employees from NIHL. The 90 dBA for 8 hours applies to continuous noise. Information on impact noise and intermittent noise is less available.) In the inter-society report certain guidelines have been proposed for intermittent and part time exposure to noise.

When daily noise exposure is composed of two or more periods of noises at different levels, their combined effect should be considered. This kind of exposure is expressed as a noise exposure rating. which is defined as a ratio of observed duration of the dangerous noise to that duration allowable under the specifications for regulatory limits. Noise exposure is considered acceptable for all values of exposure if the combined ratios do not exceed unity (one). The hazard to hearing increases as the noise exposure ratios becomes progressively greater than one. The hazardous noise rating may be calculated by using the following equation.

$$\frac{C1}{T1} + \frac{C2}{T2} + \frac{Cn}{Tn} = \text{noise rating}$$

C indicates the total time of exposure at a specified noise level, where T_n indicates the total time of an exposure permitted at that level (W.S.Department of Labor, 1974).

Noise exposure can also be described in terms of daily noise dose or the 8 hour time weighted average sound level (TWA) (U.S. Department of Labor, 1981). The noise dose simply requires multiplying the noise rating ratio by 100. The TWA is the sound level which if constant over an 8 hour exposure period would result in the same measured noise dose and can be calculated in dB, from the noise dose by the formula.

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$$TWA = 16.61 \ Log_{10} \ (D/100)+90$$

For impulse noise, a recommendation has been made that impact noise should not exceed 140 dB peak SPL.

With impulsive noises, there is usually a trade-off between intensities of pulse and number of pulses that can be experienced. A current recommendation is that with a 10 dB decrease in peak sound pressure level there would be corresponding increase in the number of allowable pulses in a work day by a factor of 10. The base is assumed to be 100 pulses per day. If the peak level increases to 150 dB, then only 10 pulses per day would be permissible (W.B. Department of Labor, 1974).

Many European standards allow a permissible 3 dB increase in sound level for each halving of exposure duration, whereas in U.S., there is a support for a 5 dB increase per halving of exposure duration.

The EPA identifies an equivalent sound level of L_{eq} =70 dBA as the maximum permissible when measured on 24 hours/day and everyday of the year basis. Level is modified to 71.4 dBA to provide margin of safety. But, on basis of 8 hours/day, 5 days/week for 50 week/year, which is reasonable for many life style, then the exposure at work may rise to an L_{eq} over then hours to 76.4 dBA (Say 76 dB), or, adding margin of safety to 77.8 dBA(Say 78 dBA).

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The criterion is based on the noise level which protects 96% of the population against noise induced permanent hearing loss of greater than 5 dB at 4000 Hz. It is argued that, people beyond 96th percentile, who are those with already impaired hearing, are also protected at the criterion level because their hearing is too impaired to be damaged by sounds, which at this level, they cannot hear.

At present there is not complete agreement in the U.S. that, EPA criterion is correct one point of disagreement being energy based trading relationship with time.

Much of the impetus for establishment of equal energy principle for assessing hearing hazard in Britain derived from Medical Research Council and National Physical Laboratory study. The report of this work is by Burns and Robinson(has since formed the basis for a method of assessing potential hazard to hearing. A number of European national bodies have also based their standard methods of assessment on this type of information.

Equal energy principle:

Burns and Robinson (1970) showed that for steady state noise a relationship exists between A-weighted sound energy and persistent hearing loss.

A-weighted sound energy received during noise exposure may be deduced from the product of A-weighted sound and the duration of exposure. A doubling of energy represents an increase in noise level of 3 dBA. That is for example exposure of 90 dBA for a given period is equivalent in terms of sound energy and therefore a hazard, to an exposure to 93 dBA for half that period. This is equal energy principle. Subsequent research by other by and Martin (1971) and Rice and Martin (1973) has shown that this principle may also be extended to the assessment of risk of hearing from industrial impact noise and from high-level transients such as gunfire.

Table-C gives examples of values of sound level and exposure duration which, when considered together, represent an L_{eq} of 90 dBA for 8 hours. This noise dose is considered at present in criterion to be safe maximum. An L_{eq} of 90 dBA over 8 hours is equivalent to an L ^3 of 85 dBA over 24 hours which/is higher than the EPA proposed value.

The British Occupational Hygiene Society (BOHS) document refers solely to steady state noise and is intended to restrict occupational exposure to noise&o that handicap does not occur in more than 1 percent of persons exposed during their working life time. This objective is to be considered to be achieved if the noise induced impairment to hearing at the end of 30 year working life does not exceed levels of 40 dB calculated as the average loss at the audiometric frequencies 0.5, 1, 2, 3 and 6 KHz in 1 percent of persons exposed. To meet this criteria noise levels should not exceed an L_{eq} of 90 dBA. The standard must not be used for impulse noise or if these are significant pure tones.

The international organization for standardization(ISO) recommendations R 1999 does not quantify absolute levels which must not be exceeded. Rather it gives practical relationship between occupational noise exposure, expressed in terms of noise level and duration within a normal working week of 40 hours, and the risk of increase in percentage of persons in specified age groups that may be expected to show during impairment as a result of specified exposures. Hearing is considered to be impaired for conversation of speech if the arithmetic average of hearing loss for the frequencies 0.5, 1, and 2 KHz is 25 dB or more. The recommendations does not set down limits but points to levels of 90 dBA legislated in some countries. Impulse noise of less than 1 second duration for a single level transient such as gun fire are excluded.

The table (b) will give the comparison of exposure times permitted by BOHS (1971) and ISO (1981) document.

BOHS permitted duration hours per day	Maximum per-missible sound level dBA	ISO permitted documents hours
12	88	
11		
10		
9		
8	90	40
7	90.5	35
6	91	30
§	92	25
4	93	20
3	94	15
2	96	10
1	99	5
0.5	102	150 minutes
	105	75 minutes
	108	40 minutes
	111	20 minutes
	114	1.0 minutes.

Table (c) Permissible exposure under occupational safety and Health Act.

Sound level (dBA)	Permissible daily exposure (hours)
90	8
92	6
95	4
97	
100	2
102	1½
105	1
110	½
115	¼ or less

The damage risk criteria is a statistical concept and must be interpreted as such without discrimination, and without application to individual situations. Further most, it is very complex concept involving variables that are incompletely understood, such as individual susceptibility to noise, its cumulative effect, and the relation of auditory fatigue to permanent deafness.

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TEAM MEMBERS

The hearing conservation programme requires interaction and cooperation among various professionals and administrators. Setting up a conservation of hearing programme costs the industry both time and money. The decision to invest that time and money is management decisiopand is based upon a determination whether or not noise problem exists. Once it has been established that noise problem exists management is next concerned with the question "What are the economic consequences of claims, for industrial hearing loss".

How to sell management hearing conservation:

Sateloff and Michel (1973) indicated that the large companies become aware of the problem either through the safety engineer, plant physician or the nurse. The small industries, as they do not have medical director, are not aware of the problem or the need of HCP. Either a warning from the state inspector of claim for compensation by an employee make them aware of need for HCP.

Until the OSHA was passed most plants did little about hearing conservation even after being appraised of their noise problem. But on the whole there has been more discu-ssion rather than action in practice of hearing conservation programme.

The progrmme must be sold first to top management and have its complete approval and cooperation. To achieve this, many plants have to bring in an outside consultant who can impress top management with the important advantages of the programme. In describing the need for hearing conservation programme and how and who will run it, an estimate cost must be presented. Very few companies have enough competent personnel to implement the entire programme by themselves. Most plants have to seek the help of an acoustics consultant, safety engineer and especially audiologist familiar with this work. The cost proposal should also include expenses for equipment and ear protectors. The possible cost noise control measures should also be presented. Now we will look into the role played by different members of team, separately.

The role of the safety engineer and industrial hygienist:

The role played by the safety engineer and industrial hygienist can be summarized as below:

1. The safety engineer brings the awareness among the management and employees, about the HCP.
2. He helps to decide how extensive a HCP should be
3. He performs the noise surveys and recommends the noise control measures.
4. He should evaluate EPD and decide which EPD suits which noise area.

In addition to the above, he has other responsibilities also such as

1) He supervises the EPD usage by employees.

2) He takes over the responsibility of the overall programme in the absence of plant physician.
3) He selects the room for hearing testing.
4) He also has a role in scheduling employees for hearing testing.
5) Any modification made in the Industrial noise control set up should be evaluated by safety engineer.

Role of the industrial noise:

The plant nurse is probably the most important person in a HCP. Most important, the nurse creates the image of the HCP.

She has to not only conduct the audiometric tests, but also explains the results to the employer, fits the ear protectors (Sachin, 1963). She also checks the employee's EPDs and demonstrates the correct use of it. She keeps records, and takes case histories. She should be taught to uncover important information and also to examine the ear canal and ear drum with an otoscope.

The role of industrial physician and otologist:

The role of the industrial physician is summarized below:

1. The physician has to supervise the noise surveys carried out by the safety engineer.
2. The decision whether the noise is sufficient to cause damage to the employees' hearing is taken by the plant physician.

3. The physician with the management decides the various steps to be implemented in order to carry out effective HCP.
4. The plant physician has to decide the susceptibility of an individual to noise, and also to whether to employ or not.
5. He also has the responsibility to schedule the employees for audiograms.

The consultant otologist:

The role of consultant otologist can be summarized in the following points.

1. He should diagnose the employees on the basis of history and different audiological tests.
2. The otologist should be able to testify as an expert witness in medico legal situations.
3. If plant physician is not available, the otologist may be involved in HCP.
4. The report of consultant otologist should include results of all tests performed, as the report may be the focal point of claim for compensation.
5. He should treat the hearing loss due to others problems such as ASOM, CSOM, reaction to EPD. etc.

Role of an Radiologist:

While discussing the role of Audiologist it is best to quote the hearing conservation amendment published by OSHA (1982). It states that "for compliance purposes, the audiologist, Otolaryngologist, and other Physicians are on equal footing. While the agency believes that audiologist and otolaryngologist will be in the best position to make judgements about testing procedures and the validity and interpretation of audiograms, physicians with specialities other than otolaryngology may be quite capable of making these judgements".

The audiologist should interpret the audiograms, carried out by audiometric technicians or industrial nurse. He should involve himself in motivating, educating the purpose usage and case of EPD, to the employees (sateloff and Michel, 1973).

Role of audiometric technicians:

Audiometry generally is done by audiometric technicians specifically trained for this purpose. They carry out the audiometric testing under the supervision of an audiologist or an otologist, since the audiometric technicians come in contact regularly with employees, they can educate and motivate the employees regarding benefit and usage of EPD.

Role of purchase section:

The purchase department has a responsibility to make sure that only equipment approved by engineering, industrial hygiene, safety medical and other department is purchased for use in the industry.

The purchase section should include specific noise limits or other requirements on order. (BHEL, Course material, 1984).

Role of the supervisors:

The Supervisor's responsibility in HCP are -

1. To instruct his employees periodically on precautions and practices to be followed in noisy area.
2. To make sure of warning signals.
3. To inform authorities on conditions which appear noisy.
4. To consult other sections whenever necessary.
5. To assist the safety engineers during noise survey. (BHEL, Course Material, 1984).

Role of the employees:

Employees has equal responsibilities in HCP to control exposure limits. Their responsibilities are mainly -

1. To notify their supervisor of conditions, that result in increased noise levels.
2. To Observe all safety rales. (BHEL, Course Material, 1984)

INDUSTRIAL AUDIOMETRY

The main interest of an Audiologist in industrial hearing conservation, because of his association, training and experience will be in the area of hearing measurement. The hearing testing being mainly done by an industrial nurse or any other well trained individual.

The hearing testing programme or industrial audiometry involves purpose of testing, site of testing, different types of audiometers used, types of tests used, calibration of audiometers, record keeping, history of industrial audiometry test personnel, test environment.

History of industrial audiometry:

The first reliable automatic self recording audiometer for industry introduced by Rudmose in 1955 was described in literature (McMurray and Rudmose, 1956). The original Rudmose audiometer presented a continuous tone which was adjusted by responses of subject to increase and decrease signal intensity around his threshold. The Rudmose audiometer is commonly referred to as a descrete frequency Bekesy type audiometer.

Soon after, Borgan (1956) described computer assisted automatic audiometer which simulated manual audiometry in that successive discrete intensity steps were presented whose level depended upon response or lack of response of the subject. If the subject responded, the next time was less intense and vice-versa.

Recently computer based audiometers and hearing conservation vans are used for hearing testing.

Benefit of hearing testing:

Sataloff and Michel (1973) suggested the following benefits provided by hearing testing or industrial audiometry.

1. To ensure or protect the employees of company against unjustified claims of hearing loss.
2. To make a truely preventive medical program that can protect the worker against ever sustaining an occupational hearing loss.
3. To provide the evaluation of both existing hearing acuity and efficiency of control measures.
4. To detect all employees with hearing loss that might be curable or might be prevented from getting worse.

Melenick (1987) recommended that industrial audiometry helps in detecting the individuals susceptibility tonoise. Industrial audiometry provides an essential safeguard against the failures of HCP (Templezt, 1985).

Equipment and room for hearing testing:

A pure tone audiometer is recommended for hearing testing in industry. An audiometer consists of (1) a electronic osscilator for generating test tones (2) a carefully controlled amplifier - attenuator net work, and (3) earphones to introduce the test tones into the ear canal.

Selecting an audiometer:

Following are the features of an audiometry which should be considered before purchase.

1. It should be simple to operate, with essentials for air conduction threshold measurements.
2. It should have test frequencies including 500, 1000, 2000, 3000, 4000, 6000 and 8000HZ.
3. The tone interruptor should be designed so that tone can be turned on when the switch is pressed. The head bands should have adequate tension to hold the earphones securely against the ears.
4. The earphone cushion should be standard Mx-41/AR type.
5. The audiometer should be puchased from a company which assures of repair services and calibration.

Test environment:

Reliable measures of hearing sensitivity require that ambient background noise levels in test environment be sufficiently low so as not to interfere with measurement of threshold hearing levels.

The most recent federal regulations (U.S.Department of Labor, 1981) stipulate that the background noise levels contained in an out of date ANSI standard, s.3.1-1960 are acceptable. These background noise levels will not permit measurement of threshold of hearing levels designated in National/International standards without the potential contamination of results by masking. If a hearing testing programme requires that it be possible to measure normal hearing threshold sensitivity as specified by National Intemational standard, then the background noise limits should be in agreement with those published in National/International, standard "Criteria for permissible Ambient noise during audiometric testing". These two specifications for allowable background noise levels are contained in table.

Table: Two specifications of acceptable background noise levels for audiometric testing tabulated as actave band sound levels (to the nearest dB).

	Octave band center frequency				
	500	1000	2000	4000	8000
S.3.l-1960(Acceptable to OSHA: U.S.Department of Labor, 1981).	40	40	47	57	62
S.3.1-1977(Necessary for testing ANSI-1969 normal threshold hearing levels	22	30	35	42	42

To obtain a quiet environment, the sound isolating test room is constructed. Equally important in test site selection is its convenience to the personnel conducting hearing tests, personnel to be tested, adequate lighting and ventilation.

Mobile test units are particularly useful when a number of different locations are to be surveyed. At simplest level the mobile facility.

Premanufactured booth:

In some industries where it is not possible to make sound treated rooms due to certain reasons. It may be possible to purchase premanufactured booth. The noise levels within the booth must meet National/International standards. In addition to attenuation characteristics, the following factors should be taken into account.

Room size:

The room in which the booth is placed should be large enough, so that the booth is accommodated without touching walls or ceiling of the room.

Position of booth window and door:

The door which is hung to open from either right or left side, should not interfere with the objects or doors in the room containing booth. The observation window should be on the door opening side.

Position of audiometer and technician:

A shelf attached directly to booth under observation window should be large enough to hold both audiometer and provide desk space for the technician. The space between the booth walls and rooms wall should not be used for storage. These should be ample space on the window side of the booth for a seat for the technician. The booth itself should be equipped with the following: Jack panel for the exterior connections of audiometer to booth and for earphone connections inside the booth, with internal lighting, and a ventilation system. Earphone hanger should be installed in the booth above and behind the chair. The overhead lights ahould not cause reflections on the observation window.

Booth assembly:

Large booths must be assembled on site. Rechecking of noise levels in the booth should be obtained annually.

Testing without a booth:

It includes the very quiet space in the office, an unused vault or a sound treated room or some similar area in which audiometric tests can be satisfactorily conducted. The area must meet all the preresuities tested in "Test environment". The audiometer is placed on the table and subject on opposite side of table.

Modifying an available room for audiometric testing:

The most reliable means of providing noise reduction is massive construction. A room with heavy masonary walls, floors and ceiling will provide noise isolation provided care is taken to prevent leakage paths.

Leakage: Small cracks that might be found around windows, doors* electrical fixtures, pipes etc; provide significant leakage paths that may nullify the benefits of a good noise barrier. Wherever possible, all holes and cracks should be sealed permanently. Openings around an operating door or window should be closed by flexible gaskets.

Radiation: Leakage and re-radiation of noise can occur through thin or light sections such as a single-pane windows and doors. If additional noise reduction is required, double doors or double-pane windows can be used to provide more radiation.

Vibration: Structure borne vibration can be transmitted through heavy walls and reradiated into the air of enclosed space. It noise levels from structure borne sources are high "room within a room" construction may be required and this work should be undertaken only by experienced acoustician.

Interior absorption: Interior noise absorbing materials have little effect on the amount of noise leaking into a room from the outside, or from the subject, from building up. For rooms of moderate size, adequate absorption is provided by a carpet on the floor and full drapes on two walls. If conventional sound-absorbing treatment is used, it should be distributed between the ceilings and two adjoining walls for maximum effectiveness.

Ventilation: Two general principles are normally applied in the design of ventilation system for hearing test rooms. One is to use long inlet and outlet ducts that are heavily lined with noise-absorbing material. The second is to use low air velocities that will minimize noise caused by turbulence.

Audiometer calibration:

The test equipment is the source of possible variation in hearing test results. If the threshold measurement are to be reliable and valid indications of hearing status, the audiometer must be accurately calibrated. An audiometers accuracy or calibrator must be checked daily prior to using the instrument and upon completion of its use for the day. In addition, complete laboratory calibration should be made periodically. An audiometer is in calibration when it produces a specified tone at level and frequency shown on the dial settings. It also produces the tone without unwanted noise in the ear to which it is directed.

The inaccuracy of the audiometer is caused by rough handling of the instrument, heat, dust, high humidity exposure of the audiometer.

Calibration procedure:

The following tests and inspections should be made by the technician at the beginning of each day.

1. All control knobs on audiometer should be checked to be sure that they are tight on their shafts.
2. Earphone cords should be straightened so that there are no sharp bends or knots.
3. Test the earphones cords electrically with dials set at 2000 Hz and 60 dB by listening to earphones while bending the cords along their length. Any scretching noise, intermittency or changes in test tone indicate a need for new cords.
4. Test the operation of tone interruptor with dials set at 2000 Hz and 60 dB by listening to earphones and operating interruptor several times. No audible noise, such as clicks nor changes in test tone quality should be heard when the interruptor switch is used.
5. Check the headband tension by observing the distance between the inner surface of earphone cushions when it is held in a full unmounted condition. While the center of its adjustment range, the distance between cushions should be about one half inch. The band may be sent to reach this adjustment.

Audiometer specifications:

Manual audiometers are manufactured in three basic types.

Wide-range, limited range or narrow range (National/international). The limited range audiometer which is of primary interest is intended for air conduction threshold measurement with tones provided at least 500, 1000, 2000, 3000, 4000 and 6000 Hz with hearing levels from 10 dB to at least 70 dB referenced (National/international standard) threshold levels. Facilities for bone conduction and masking may be obtained.

The other significant factors include -

1. The accuracy of sound pressure levels shall ± 3 dB at test frequencies from 250 to 3000 Hz and ± 4 dB all other frequencies above or below this range.
2. The measured difference between two successive designations of hearing thresholds level shall not differ from dial indicated difference by more than (a) three tenths of dial interval measured in decibels or (b) 1 dB whichever is larger.
3. The accuracy of test tone specifications shall be ± 3 percent of indicated frequency for discrete frequency audiometers.
4. The SPL of any harmonic shall be at least 30 dB below the sound pressure level of the fundamental.

Most manual and automatic audiometers used in hearing conservation programmes are discrete frequency types which are covered by the above specifications. Those few audiometers which supply test tones over a continuous frequency range shall.

meet the above specifications except that frequency accuracy shall be within 5 percent at all indicated test frequencies.

Currently proposed guidelines to the OSHA specifies three types of calibration which are conducted at different intervals of time.

1. Biological calibration
2. Periodic calibration
3. Exhaustive calibration

1. Biological calibration;

As there is no difference in the threshold of sensitivity from day to day in a normal ear, so human ear can be used to check the stability of audiometer in terms of its output. This type of calibration is known as biological calibration. The subjects should not have thresholds poorer than 25 dB. Biological calibration is recommended at least once a month. It may however, be carried out more frequently-perhaps semiweekly, weekly or even daily.

It is important to remember that if the audiometer is found to be out of calibration the last valid audiograms are those that were done upto the previous calibration check.

In addition to recording the thresholds, also record the date and time of calibration check, the serial number and reference standard of audiometer. Maintain all of these records in a separate "calibration folder". Recording time of test is important, especially if change of 10 dB or more is noted. Subsequent tests on other subjects will show, according to time entered, that immediate follow up tests did or did not, substantiate the detected "change".

Each tester should know his or her own thresholds and in an emergency be able to do "self audiogram". It is rather an audiometric check than biological calibration. It is done when there is difficulty with audiometer or when the biological subjects are not immediately available.

Periodic calibration:

The audiometer must be subject to an annual (periodic) calibration check. In some cases it may be subjected to periodic calibration within 30 days of a biological, check tha uncovers threshold changes greater than 5 dB at any frequency, distorted signals, attenuator or tone presenter transients; or other severe operating difficulties. The audiometer must be calibrated with its own set of earphones. The calibration agency must be notified of specific problem observed with the audiometer.

Exhaustive calibration:

Once every 5 years, an exhaustive calibration check of audiometer will be performed. This is a deeper check of calibration and must comply with the national/international standards.

A certificate of calibration and listing of actual audiometer outputs should be obtained for plant records upon completion of this work. Keep all certificates and calibration data with biological calibration log book.

New audiometers or those returned from repair or calibration service, should he immediately subjected to a biological calibration before being placed into service.

Selecting hearing testing equipment:

Industrial audiometry requires following types of audiometer.

1. Manual audiometers
2. Self recording audiometers
3. Computer audiometers.

1. Manual audiometers:

Audiometers used in industry must meet national/international standard specifications for audiometers. For industrial testing purpose the limited range pure tone air conduction audiometer is appropriate. However, audiometers capable of levels greater than 70 dB referenced to standard reference threshold level, and with capability for testing 8000 Hz are essential for otologic diagnosis.

Advantages of Manual audiometers:

Melnick (1987) found that manual audiometer is suitable in hearing testing because of the following advantages.

1. The tester has a greater flexibility regarding the testing procedures and more control over the test situation than the automatic variety.
2. Employees find task due with manual audiometers easier to understand and perform than those done with automatic audiometers.

2. Self Recording audiometers:

Self recording audiometer is actually subject controlled rather than technician controlled.

For "self recording" audiometry the fixed frequency type is preferable in the industrial setting. With this type of instrument, the test frequency is usually presented sequentially in periods of 30 seconds for each test frequency. (Melenick, 1987). The test frequency and test ear are automatically selected by the instrument. The intensity level is controlled by switch manipulated by the person who is being tested in a similar fashion to the Bekesy test procedure. For an automatic test to be valid, the test record should indicate at least six crossing at each test frequency. The threshold is taken to be average of the midpoints of the tracing.

Advantages of self recording audiometry:

Melenick (1987) listed the following advantages of self recording audiometry.

1. It reduces the operator error.

..55)

2. The testing technique is standardized from situation to situation.
3. Self recording audiometry is not completely automatic, it requires the attention of the audiometric technician.
4. In larger industrial situation, self recording audiometry will permit testing of several persons. Simultaneously, the limiting factor being the number of persons, that a technician can visually monitor.

In addition to the above advantages, self recording audiometry permits smaller gradations of intensity, to provide recording of data for medical records.

3. Computer audiometry:

With the evaluation of computer based technology individual microprocessor based audiometers were developed which contained significant advantages over the older, manual instruments. These advantages include complete automatic testing, greater accuracy, easier testing procedures for the test provider and instantly calculated threshold shifts.

The personal computer began to be examined as a logical extension for data management, large bulk storage, and trend analysis.

Advantage of personal computer:

Personal computer was a management tool to help small, mid size or even large health care facility, performs tasks in a minimal amount of time, retrieves large amounts of data, does basic trend analysis by group designation and even directly transferring audiograms to the personal computer were possible.

The creative use of computer by hearing health professionals lead to reduced or down sized budgets and departments, saving time in the more routine tasks necessary to run a hearing health care facility.

Microprocessor based audiometer makes testing to be done automatically with minimal supervision by the test provider, threshold shift calculation, phonetically based calculation and manual testing can be done as well.

Recent development is the evolution of group computerized audiometric system in conjunction with personal computer.

Rather than using multiple individual microprocessor or manual audiometer, the audiometers are built onto a printed circuit board and placed in a chasis about the size of personal computer.

Testing of multiple subjects can be accomplished by one central unit. The number of tests which can be conducted from a single system is limited only by a number of audiometric models placed in the main frame chasis. It lands it-self very well when space is limited. It is time saving also (Schwartz, 1988).

Scheduling for audiograms:

The nurse or audiometric technician and safety engineer must work together to schedule employees for hearing test. So that not much time will be lost from their jobs, and at time when they will be free of temporary hearing loss.

In most instances, hearing tests, should be scheduled so effectively that an employee loses less than fifteen minutes for the initial test which include a history and ear examination. At no time, however should the accuracy of an audiogram be sacrificed for speed. However, a well trained tester who has been certified and experienced should not take more than 5 minutes to get a satisfactory audiogram (Sataloff and Michel, 1973).

Avoiding TTS in audiometry:

It is generally agreed the hearing of employees should be tested when there is no auditory fatigue, that is prior to exposure to industrial noise. This is reason, why the hearing testing is carried out after a week end of rest (such as Monday morning) for the employees who are exposed to noise during the working hours. The other Alternative being to make them to wear EPA during exposures to noise, and test them during other days of the week.

Evaluating auditory fatigue:

It is not practical in large industries to delay hearing tests until each employee has been free of industrial noise of 80 dB and above for 14 hours (EEC, 1982). By conducting minimal pilot experiment, it may be possible for each industry concerned with problem of noise to determine if auditory fatigue is a factor in routine testing, and also to plan audiometry so that resulting thresholds will have more medico legal meaning.

In studies conducted by Sataloff (1973) the following Conclusions were found.

1) In continuous noise levels of 91-92 dBA threshold average shifts were around 10 dB in one or more high frequencies. From this experience we would recommend that employees working in such noise levels have their audiograms done atleast fifteen minutes after leaving their work.
2) In continuous noise levels of 93-95 dBA the TTS becomes very measurable when employees do not were EPD. Audiograms have to be done only after atleast an hour or more absence from noise.

These guidelines in our study can serve as a reasonable guideline for scheduling audiometric tests in industries with noise levels below 100 dB.

By conducting similar pilot studies each industry can establish the best time to do audiogram on individuals employed in noisy areas. As the advancement of EPD has increased both in terms of attenuation and careful instruction in their use, it is found that hearing tests can be done within five or ten minutes after exposure to less than 100 dB of noise.

Who should have hearing test?

Since hearing conservation is a medical problem dedicated not only to prevent noise deafness but to detect and possibly cure all types of hearing loss, every person in the plant should have his/hearing tested and his audiogram evaluated for diagnosis and care. The industrial personal director is right person to take decision in this regard.

Preemployment hearing tests:

In case of pre-employment test, all employment should receive a hearing test. Bryan and Templest (1980) suggested that a questionnaire,including question about prior exposure during employment and elsewhere and any illness, injuries etc. which may have affected hearing, should be administered.

A employees pre-employment audiogram establishes hearing status before he is exposed to noise in his new job. An industrial hearing measurement program should involve pre-employment and periodic follow-up tests. The results of pre-employment test have become known as the baseline audiogram (U.S. Department of Labor, 1981).

The employees who had been previously exposed to noise, the hearing testing should be carried out only after giving them 14 hours rest from hazardous noise to avoid TTS.

The benefits of the baseline audiometry are -

1. It helps to detect the employees who are having hearing loss prior to the job.
2. It helps to compare these thresholds with corresponding audiograms taken at after 6 months or 1 year of noise exposure of employees. This comparison serves to promptly detect any employee who is unusually sensitive to specific noise and to require him to wear more effective EPD or shorten his exposure periods.

Preplacement hearing tests:

There are many situations in some industries where it is impractical or impossible to conduct pre-employment hearing tests. In these situations, employees are hired and hearing tests are delayed untill they have been placed in particular job.

In all situations where the work place noise is greater than 85 dBA or more through out the day the employees of such area should be tested as soon as possible.

How frequently should audiograms be done?

When the noise in the industry is below 90 dBA, the employees should be tested about every two years. The current proposed regulations suggests that annual audiograms should be done for those employees who are working in noisy area when the level of noise in that area is equal to or exceeds 85 dBA(U.S. Department of Labor, 1981).

Comparison is made, of employee's most recent levels of hearing against his first recorded readings. All tests must be baseline tests - i.e. at least 14 hours must have elapsed since the employees last exposure to noise (EEC,1982). Employees can be tested directly after work only if they have worn EPD that will reduce their exposure below 90 dBA. It reduces the scheduling problems.

The frequency of scheduling the employees for follow up test depends on the level of noise,the employee is exposed to and significant threshold shifts of employees. The significant threshold shifts of 10 dB or more from baseline audiogram indicates that routine audiometry should be done at shorter intervals of time (National/International standards).

Routine audiometry helps to monitor effective use of EPD and also to know whether the employee's hearing is being properly protected. In addition to this, the benefit of audiometry is realized in case of an individual whose hearing continues to deteriorate despite the effective use of EPD. An excellent otologist can determine whether the deafness is really due to noise exposure or due to some other cause. Terminal audiograms should be performed in all employees especially of those personnel who have been working in noisy area.

American Association of Otolaryngology Head and Neck Surgery (AAO-HNS., 1982) recommends that a change in threshold of hearing sensitivity be considered significant if the thresholds in either ear worsen by 10 dB or more in the average of the thresholds measured for the puretone 500, 1000, and 2000 Hz or for 4 frequencies 3000, 4000 and 6000Hz.

The AAO-HNS emphasize that there is a distinction between the criteria for medical referral and those for significant threshold shift.

The identification of significant threshold shifts should serve to prompt action within a given program, that is remedy for hazardous noise condition, poor testing technique etc. Medical or more specifically otologic referral should be made for the purpose of diagnostic evaluation and treatment. AAO-HNS defines the criteria for otologic referral as a change in audiometric hearing levels of either ear of (1) more than 15 dB for average of 500, 1000 and 2000 Hz (or) (2) more than 20 dB at 3000 Hz (or) (3) more than 30 dB at 4000 and 6000 Hz.

Record keeping:

Records assume a particular importance in industrial situation, because of potential for compensation and implications for legal actions. The employer will need to keep accurate records of noise exposure measurements. These records should include the specifications on the location, date and time of the measurements, the noise level obtained. The employer may also be required to keep names of the employees and daily noise dose experienced by each of these employees. Certainly there is a need for records specifying the type, model and calibration of the noise measuring equipment (Melenick, 1987).

OSHA recommends the serial type of audiogram for use with manual audiometer. Each audiogram is recorded and kept in sequence. A brief but adequate Otological history is taken and recorded with initial audiogram. Theoretically a record of this type is capable of storing hearing levels covering a 10 year span.

In self recording audiometry the tests are recorded on separate levels. For ease of interpretation, it is recommended that thresholds be transferred to a serial audiogram (Vassallo, 1978).

Basic information on audiogram includes -

Name

Date of test

Audiometer serial number

Calibration date

Signature and certification of tester

Social security number or employer identification number

Time of test

Make, model of audiometer

Noise exposure level of employee

Otologic history.

The length and time that these records need to be retained varies from state to state and from regulation to regulation. OSHA requires that the records of noise exposure measurements should be kept for a period of 2 years, while audiometric tests records shall be retained for the duration of employee's period of employment (U.S.Department of Labor, 1981).

Additional hearing tests:

It is recommended that efforts to be made to conduct hearing tests whenever employees are terminated, return from Lay off, and return from sick leave, or after injuries in or out of work place (Sataloff, and Michel, 1973).

Test personal:

The accuracy of the audiometric measurements depends upon the skill of the tester. Audiologist is an ideal person. But in most of industries the hearing testing is done by industrial nurse or technician. In 1973, the responsibility of quality control of training programs for industries was assumed by the councel for accrediation on occupational hearing conservation (CAOHC). Clinical audiologist have been extremely active in developing and conducting these training programs. Test results produced by certified audiometric technician are legally acceptable.

ADMINISTRATIVE AND ENGINEERING CONTROL

The control of noise in the industry to acceptable noise level can be brought about by different means. These means of control of noise can be divided or grouped into the following categories:

1. Administrative control
2. Engineering Control
3. Control of noise at ear level or use of EPD

1. Administrative control: Berger et al (1983) recommended that the administrative control of noise includes the reduction of employees work schedule, who are exposed to damage causing noise level, limiting the time the machine may work, and other similar administrative options. Administrative controls should include decisions made by management to prohibit the purchase of equipment which will result in an increase in employees noise dose. Purchasing guidelines may be established to prohibit buying equipment which exceeds a selected sound level.

Due to workers skill requirements and union job descriptions, it is very difficult to arrange an individual work pattern so that it consists of activities in significantly different noise level environments. One more complication is difficulty in assessing cost. We would normally expect some loss in productivity when the range of required skill is increased. Presently there appears to be no basis for assessing the cost of this type of noise control level while the work pattern could be arranged to limit exposure.

2. Engineering control: It involves the engineering techniques to decrease the noise level at source or path level.

a) Source_level: Millagan (1978) has given the following procedure to control noise at source level. The procedure involves the controlling of noise by proper design, proper equipment and equipment maintenance. The proper design of equipment to minimize noise generation is rather complex engineering problem requiring strong background in the fundamentals of vibration, fluid mechanics, and machine designs.

In a very general way, some of things that may result from good noise design are:

1. Using shock-absorbing techniques to absorb impact energy (for example the use of nonmetallic gears to reduce noise generated by the metal to metal impact associated with mettalic gears).

2. Using efficient flow techniques to reduce noise associated with high fluid velocities and turbulence (for example, the new quiet hydraulic pumps in which flow paths have been redesigned to give less turbulance).

3. Reducing sound-radiating area.
4. Reducing peak acceleration by utilizing the maximum time to produce required velocity or displacement changes. This is critical in the design of and followers.

5. Significantly separating operating speeds and resonant speeds to a significant extent.

The second primary area is proper operation. All equipment should be operated at the design conditions. Operating equipment at design pressure and speed should result in minimum noise generation.

Several areas relating to proper operation are:

1. If acoustic guards, covers or enclosure are used, make certain that they are in place and that all openings are acoustically sealed.
2. If the equipment is equipped with a muffler system, make sure that it is performing according to design.
3. Install machinery on adequate mountings and foundations to reduce structure borne sound and vibration.
4. Use proper cutting speeds and feed rates to control tool chatter in machining operation.
5. Apply additional sound control devices. Inlet and discharge silences or mufflers can often be added with a small investment. Effective acoustic enclosures are often easy to design and construct.

The important point to be made here is that the manner in which a piece of equipment is operated. Can significantly influence the magnitude of the noise generated.

The third primary area is equipment maintenance. The following list illustrates potential maintenance activities.

1. Maintain good dynamic balance. This decreases rotating forces and normally reduces noise generated by secondary sources such as shaking guards, shell, or vibrating enclosures.

2. When purchasing replacement components such as gears, motors and pumps, do not ignore noise specifications.
3. When installing fluid pipes or lines, use gradual rather than abrupt transitions from one part of a flow passage to another.
4. Improve lubrication.
5. Install bearings correctly
6. Reduce mechanical run out of shafts.

b) Control of the transmission path: Harris (1965)recommended that in this technique noise reduction is that of controlling transmission path so as to reduce energy that is communicated to the receiver. This may be done in a number of ways.

i) Site: In the open air, maximum attenuating should be provided by increasing in so far as possible. The distance between the source and the receiver. Since many noise sources do not radiate uniformly in all directions, by altering the relative orientation of source and receiver a considerable reduction in noise level at the receiver may be possible. For example Orientation of airport runway may be an important consideration in reducing noise in an adjacent community. Where possible, a site should be chosen that will take advantage of the natural terrain to provide additional shielding of the receiver from the source.

ii) Building layout: The careful planning of location Beams within a building, with respect to the relative position of the noise sources and those areas where quiet conditions are desired.

This may result in a considerable economy by reducing the extent of noise control measures that would otherwise be required.

c) Enclosures: Considerable attenuation may be provided by the use of aproperly designed enclosure around a noise source or around the receiver.

d) Absorption: One of the most effective means of attenuating sound in its transmission path is by means of absorption. For example, suppose a number of machines are ain a large office. Most of the noise from these sources that reaches workers on the opposite side of room well have been reflected by ceiling, walls and floor. Therefore the use of sound absorbtion in the form of acoustical materials, or carpet on floor, will provide attenuation in path between the source and receiver.

e) Impedance mismatch: The floor of acoustic energy along the path from source to receiver can be impeded by discontinuties which reflect energy back toward the source (i.e. by an 'impedance mismatch'.

EAR PROTECTIVE DEVICES

Ear protective devices (EPDs) are personnel hearing protective devices which when worn appropriately by an individual provide the most effective means of eliminating a potential hazard to hearing. They are capable of reducing the noise level at the ear by 10 to 45 dB and occasionally to 50 dB depending on their type and sound frequency.

Henry by the above definition it is clear that EPDs are devices placed at the entrance of canal, which cuts off noise from reaching the inner ear. It usually cuts off the noise reaching the inner ear through the acoustic path ie from outer ear to the middle ear to inner ear and does nothing about the bone conduction path.

Is this all an EPDs does. No apart from reducing noise level, it has one more functions. In noisy situations, they not only prevent the impairment of hearing acuity but they may even improve speech communication by cutting down the noise interference level. Speech becomes easier to understand and hence the communication is better. But this advantage is not present in intermittent noise situation.

Is there only one type of EPD? Well, No. The availability of many different types of EPDs makes the task of choosing the EPD difficult. The task is not as simple as taking one EPD and fitting each ear. One should choose the best EPD which is best suited for the worker. And also factors like economy, comfortability are to be taken care off.

Hence, it is important to scan through all the important types available, mainly -

1) Ear plugs
2) Semi-inserts
3) Ear muffs
4) Helmets

Ear plugs and ear muffs dominate the field.

1. Ear plugs: They are devices that are inserted in the earcanal and remain in place without any additional support. They are unabstrusive and must be personally fitted for an individual and for each ear, under medical supervision.

Material: Made of either cotton, paper, wax, glasswool, fiber glass, plastic or expanding single foam etc.

Different types of earplugs have different attenuation characteristics. The mean attenuation afforded by inserts for puretones in the frequency range 100-10,000Hz in between 7.3 to 21.9dB (NAL, 1979).

It should be ensured that the wearer insert it correctly and check the seal from time to time for optimum attenuation.

a) Prefabricated ear plugs: Made of up of soft, flexible material that will fit into many different ear canal shapes. They are available in 3/5 different sizes.

Eg. V51-R is one of the most versatile and efficient type, has asymmetricl shape and single flexible flange, can be fitted to a large number of different earcanal. Bullet-shaped design is most suitable for round and straight ear canal.

Premolded universal design is manufactured with two or more flanges on the stem.

b) Disposible and malleable plugs: They are made up of low cost materials such as cotton, wax, glasswool, sponge rubber etc. They are capable of providing attenuation values similar to prefabricated types.

They can be used whenever necessary by the worker and then throw off. Attenuation range is 15-30 dB depending on frequency. It is a poor choice in dirty areas as clean hands is to be employed for fitting into ear canals.

c) Individually molded ear plugs: They are made by mixing silicone rubber 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.

They fit perfectly to each ear, but are more expensive.

d) super aural (canal caps):Rubber caps suspended by a spring head band 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 of ear plugs:

1. They are small, easier to store and easily carried.
2. Do not interfere with use of personal items.
3. Less expensive when compared to other ear protectors.
4. More comfortable to wear in hot environment, overall plugs are better accepted in all environments.
5. Do not interfere with head movements and convenient to use when the head of the wearer must be in close cramped quarters.
6. Hygiene is maintained.

Disadvantages:

1. Premolded plugs require a tight seal of ear canal in order to be effective.
2. Use of those 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 frequently reseated.

2. semi-inserts: These are generally used for communication system, not for ear protection. They are similar to earplugs but are supported by a head band, which makes it more cumbersome than plugs. It closes off the entrance to the canal (called concha-seated ear protectors) and one size can provide high sound attenuation.

They combine some of the advantages of ear muffs and ear plugs.

Advantages:

1. One size will fit the majority of ears.
2. They are captive and may be reinserted hygienically at any time.

3+ One suitable for industries where the loss of an ear plug must be avoided, eg. food industry.

4. For people who frequently enter noisy environments for short periods or remain in hot environments for long periods.

Disadvantages:

1. They are not as comfortable as other forms.
2. Must be pressed firmly against the ear canal entrance to be effective.

3* Ear muffs: They are in the form of covering for the entire outer ear and ape held against the sides of the head by a spring loaded adjustable band and are sealed to the head with soft circumaural cushion seals. The seals may be either liquid, filled or plastic foam filled, seal. Liquid sealed provide greater attenuation at lesser head band tension. But rough usage may cause leakage. But pad filled seals are almost as good as liquid filled and have an additional advantage of robustness.

The farce with which the cups of muffs are pressed against the side of the head plays an important role in determining the attenuation provided by it. They provide maximum protection when worn on smooth surface. Hence, spectacle, hair, helmets may reduce attenuation.

A volume of air enclosed within the cup is directly related to low frequency attenuation and inside of cup is partially filled with material that absorbs high frequency resonant noises. Usually muffs offer greater protection with frequency greater than 1 KHz.

eg. 20-34 dB with maximum attenuation at 2KHz. A combination of plug and muff provided 34-30 dB at above frequencies with maximum at 3 KHz. NAL-1979 - The mean attenuation values for pure tones (125-8000 Hz) was 8.2 to 29.3 dB.

Advantages:

1. It provided the greatest protection i.e. they are likely to be greater attenuation value than ear plugs and inserts.
2. The variability between individual to individual is less.
3. One size usually fit most people with different size and shape of head.
4. Require very little manipulation. They are easily removed and replaced in a hygienic fashion. Even person with motor problem can use this without difficulty.
5. Eminently suitable for dirty and high levelnoise areas and for people who frequently move in and out of noisy environments.

6. They caa also be worn by people with coppased ear canal people with minor diseases of the external ear canal etc.
7. Can be seen readily at a certain distance away, so the effectiveness of EPD programme can be easily monitored.
8. More comfortable to use so usually more readily accepted by employee than ear plugs.
9. Not as easily misplaced or lost as earplugs.
10. They last longer than ear plugs.

Disadvantages:

1. Bulky and not as easily worn in cramped quarters.
2. In general, more expensive than insert protectors.
3. Unimportable when humidity is high, and they tend to make the ears hot and increases perspirations.
4. Muff protection depends upon the spring force of the head band.
5. Not as easily carried or stored as ear plugs.
6. Not compatible with other personal item like spectacles.
7. Not suitable when lead movement is important to a large extent.

4. Helmets:

i) They are largest and most expensive.

ii) They cover most part of the heads and either through a close fit or through integral earmuffs or other types of built-in-ear pieces provide hearing protection. They are usually designed to safeguard against bump, crash, cold-type injury.

The acoustic impadance of helmet becomes an important factor when sound attenuation at the ear reaches such a high level that transmission through the skull becomes a controlling factor.

Special types of EPDs: They are designed specifically for improved communication and selective attenuation of high level transient noise.

Frequency selective devices: Here usually an acoustic low pass filter is fitted, hence providing a small attenuation below 2 KHz. Hence speech frequencies are permitted. However, only when all the external noise is at a higher frequency, there will be provision for improves speech communication. Hence largly unsuitable for industry.

Amplitude-sensitive devices: They attenuate loud sounds more than quiet ones. Eg. Modified version of V-51R plug. It is possible to here normal speech between high level transient noises, eg. gunfire etc. are attenuated.

Ear muffs with mechanical valves which close when high level gunfire noise in impinging upon them.
Ear muffs with electronic peak limiting devices which is useful in industries where people are exposed to impulse noise or any high level intermittent noise, but wish to communicate easily during the quiet periods between noise bursts.

Disadvantage:

1. It is relatively expensive
2. It requires batteries
3. It must be handled with great care.

We have now examined different types of EPDs and their advantages. It is also equally important to know the attenuation characteristics of EPDs and how to measure it.

Acoustic attenuation: The primary function of an EPD inits capacity to attenuate sounds. The absolute limit of attenuation provided by EPD depends upon the sensitivity of the bone conduction pathway.

According to Waugh (1973) the dBA attenuation of an ear protector is a function of the C-A value of the noise spectrum in which it is used and may vary by more than 20 dB in noises of different C-A values.

There are certain factors which affects the sound attenuation provided by an EPD. They are, -

1. Insertion loss - introduced by the ear protector between the sound source and the eardrum of the literner. It is accmpanied by a change in the sound field (negligible) and transmission loss between outer and inner surfaces of the EPD.

2. Variables such as differences in anatomy of skull, spectacles, and long hair are known to affect attenuation.
3. In earmuffs, bakage between cushion ring and the skin is the most important factor. Small holes may reduce attenuation, mainly between 100-200Hz.

Measurement of inter-subject variability is also an important measurement with respect to EPD, as it provides information regarding EPD, ability to fit different individuals and a measure of the accuracy with which the attenuation determinations are carried out.

Now, let us shift our attention towards standard procedures of measuring EPD attenuation. These are mainly two.

1) **Threshold shift method**: It is most common, simple technique. Almost all manufacturer's data in derived by this method. Basically it measures the minimum level of a sound that a listener can hear without EPD (Open threshold) and with an EPD in place (occluded threshold). The difference in the index of attenuation provided by the EPD.

The standard procedure is given by ANSI 224-22-1957 ANSI-53-10-1974. Testing of ten subjects, 3 times each at nine different frequency is required by both. But both differ in stimuli used and sound field. The I method users pure tone in a directional sound field and hence discarded. The II method user 1/3 octave wide bands of noise, presented in a uniform, non-directional (diffuse) sound field, which approximates industrial noise exposure conditions.

2. **Single number rating**: The attenuation values obtained as explained above do not facilitate direct determination of the total effectiveness of one device as compared to another. Hence need for a single number rating which will provide a simple and effective means of choosing EPDs and assessing their utility for particular applications. Such a rating is found to provide a successful compromise between under protecting a minority and over protecting a majority of wearers.

Noise reduction rating is the correct EPD (Environmental protection Agency) proposed single number descriptor. It is a dB noise reduction value that must be subtracted from the measure dB C sound level in work place.

Effective exposure (dBA)=Noise level (dBC) - NRR.

It uses "C-A concept" first proposed by Botsford in 1973. The attenuation values used in calculation are the measured lab attenuation values minus 2 S.D. which accounts for wearer's misuse/abuse.

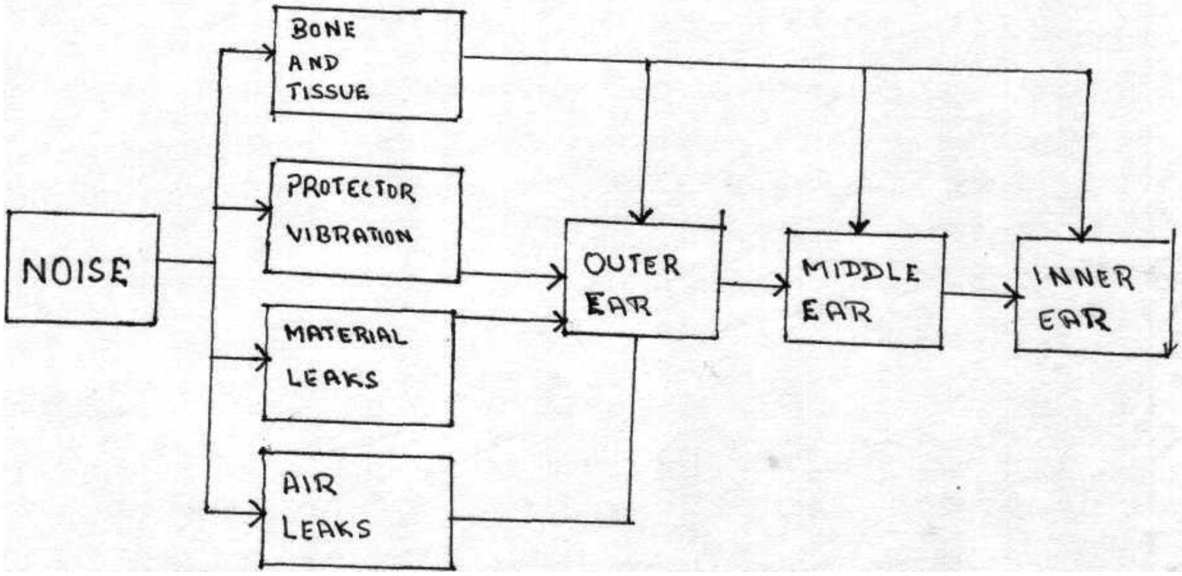
The highest NRR ever measured on an EPD in 35.

Does this lab measured value provide accurate picture of attenuation that a worker is getting in his workplace?

No, because there is considerable variation in the EPD performance in lab and in actual set up. This fact can be examined by analyzing how a correctly worn EPD operates and how misuse, misfitting abuse affects is effectiveness.

Sound transmission through the unoccluded ear is mainly by 2 ways - air conduction and bone conduction. If the AC path were totally blocked by EPD, the total attenuation offered is only 60 dB.

That is EPD cannot stop completely sound from entering inner ear. The other path by which noise enter the inner ear is illustrated below:



Ref: (Sataloff and Michael, 1973).

1. Air leaks: For maximum protection, the devices like, EPD should actually fit the contours of the ear canal and ear-muff cushions must accuratly fit the areas surrounding the external ear pinna.

   Air leaks can typically reduce attenuation by 5-15 dB over a broad frequency range.

2. Vibration of EPD: Due to the flexibility of the ear canal, earplugs can vibrate in a piston, like manner within the carnal. This limits their low frequency attenuation of ear-muffs are attached to the head in a totally rigid manner, the caps will vibrate against the head as a mass/spring system, with an effective stiffness governed by the flexibility of

of the muff cushion and the flesh surrounding the ear, as well as the air volume entrapped under the cup. For earmuffs, premolded inserts and foam inserts these limits of attenuation at 125 Hz are approximately 25 dB, 30 dB, 40dB respectively.

3. Transmission through the material of the EPD: For most inserts this is generally not significant, although with lower attenuation devices such as cotton, or glass dain. This path is a factor to be considered. Because of the much larger Surfaces areas involved with ear muffs, sound transmission to cups material and through the ear muff cushion is significant, and can limit the achievable attenuation at certain frequencies.

4. Bone conduction: EPD is designed to effectively reduce the AC path. When ear is occluded, the BC path in enhanced relatively for frequencies below 2 KHz.

Real world attenuation: In lab situation path 2,3,4 are the primary sound transmission paths, where as path 1 in minimum. But in real world path 1 often in the dominent factor.

Some of the causes of poor EPD sealing are -

1. Comfort: For proper sealing, EPDs must be tightly fitted. But this is not comfortable for many. Hence many EPD must be selected and employee should be encouraged to select final EPD.

2. Utilization: Due to factors like, poor comfort, poor motivation or poor hearing etc. earplugs are improperly inserted and earmuffs improperly adjusted.

3. Fit: All EPDs must be properly fitted when they are initially dispensed. The companies should have stock of all available sizes and should be willing to use 2 different sizes for 2 ears of an employee.

4. Compatibility: Not all EPDs will suite all ear canal and head shapes. Certain head contours cannot be fitted by any available muffs and some ear canals cannot be fitted properly. Eyeglasses, or bushy hair underneath cushions may reduce attenuation of ear muffs.

5. Readjustment:Certain activities like eating, talking, moving about bumping, jumping etc. may result in jaw motion. This may cause improper sealing of EPDs. Custom moulded and expandable foam plugs tend to maintain their position in the ear canal than premolded plugs.

6. Deterioration: EPDs wear out few as fast as 3 weeks like shrinking of earplugs etc. Hence permanent EPDs must be checked regularly 2-12 times/year depending on the EPDs used.

7. Abuse: Employees often deform EPDs for comfort, eg. springing earmuff head bands to reduce the tension, drilling holes the plugs or muffs etc.

Employee should also wear EPD for extended period of time. Hence neither low attenuation nor low comfort devices are suitable for industrial use. Comfortable, user acceptable EPDs, with real world NRR, suitable for the prevailing environmental sound levels will be necessary to protect employee's hearing.

Practical consideration and selection of ear protectors:

Each ear protector, all types, must fulfill the following requirements.

1) sound attenuation (2) comfort (3) absence of advance effect on the skin (4) speech communication noninterference (5) ease of use and handling (6) hygiene (7) durability (8) cost.

1. Sound attenuation: (a) The primary function of an ear protector in its capacity to attenuate sound. The greater the sound attenuation capacity of an ear protector, the greater the ability to provide hearing protection against harmful noise.

b) The amount of sound attenuation required, depends on the sound pressure, the kind of noise, and duration of exposure.

c) Each ear protector has its own characteristic attenuation pattern. Even the best EPDs will not give more than 25-35 dB attenuation of the average.

d) EPDs are more effctive at high frequencies.

e) Threshold shift is used to measure the annuation characteristics of EPDs.

f) Earplugs are better suppressors of low frequency sounds, helmets are good high frequency suppressors.

g) The attenuation capabilities of ear plugs, earmuffs are sufficient for industrial use, the combination is still better.

2. Comfort: This is the 2nd most important factor, as these are meant to do worn for long periods they should not exerrt undue

pressure or lead to any discomfort. There are instances where people preferred to work without EPDs, at the risk of considerable amount of hearing loss.

The EPD should be able to reduce the total pressure applied on the skin or distribute the applied force over a large area eg. earplugs are available in various sizes and has a soft, pliable outer layers. The sealing cushions of earmuss which make contact with a fairly large area of skin, one composed of soft material. This large surface area may cause overheating of skin particularly in hot environment.

3. <u>Speech communication non-interference</u>: The design of EPD should also take into consideration the speech communication aspect. It should interfere minimally with the speech communition in the noise situation. EPD with flat frequency characteristic will ensure intelligible speech communication in continuous noise.

At high noise levels EPDs faciticate speech communication also, as attenuation reduces overloading of auditory system and the consequent distorion. But if the masking noise is less than 75 dB EPDs tend to reduce speech intelligibility.

For intermittent noise condition, special devices are developed, such as

- earmuffs with parts that can be opened or closed dpending upon the need.

- earplugs with diaphragms and values that will transmit sound unattenuated to the ear provided that it is below a certain intensity level.

4. **Absence of adverse effect on the skin**: The inflammatory condition of the skin due to wearing an EPD, is curable only by discontinuing its use. Hence chemically neutral materials are used in its manufacture. Other than this it should be soft to wear and should be able to withstand all weather conditions.

5. **Hygiene**: Maintaining the hygiene of EPDs, especially of earplugs is important as it may cause irritation in the external ear canal. Hence earplugs should be kept clean, and free from chemicals, oil or grease or it should be changed more frequently.

6. **Ease of use and handling**: Improper usage results in poorer performance. Hence EPDs, especially earplugs have to be issued by a trained personnel and proper counselling should be done to all. EPDs should be designed to stand some rough handling and also should be convenient to carry from one place to another.

7. **Durability**: Devices which last longer are more economical in the long run. Reusable earmuffs aRe composed of materials which can resist most of the aging factors like humidity, earwax, perspiration etc, and can last for 2 or more years without any objectionable changes. Most of the soft,

resistent materials, however show a tendency to contract or harden with time or to expand and become soft.

8. **Cost:** It is an important factor when EPDs are purchase in large quantities. The cost involved may be categorized into:

a) expenditure due to initial purchase.

b) expenditure including cost of supplying spare parts and replacements.

c) expenditure involving cost of time, spent in administering the ear protectors.

The replacement and administration costs are often the largest factors involved.

Motivating employees to wear hearing protection devices:

Review of literature suggests that the pivotal characteristics of a successful HCP are support of management, enforcement, education, motivation, comfortable and effective EPDs.

Support of management is crucial as employees get a feeling that HCP is an important part of overall safety program. Also management should be responsive to employee problems and complaints.

Enforcement must be firm and consistent. Disciplinary procedure involving:

1) Verbal warning (2) written warning (3) brief suspension, no pay (4) termination.

posted
All personnel/in hearing protection are as should wear EPDs, be it visitors, managers etc. Enforcement alone may cause resentment among employees. Hence it should be combined with motivation and education programms.

Short films and posters may be used to educate on topics such as function of ear, damage to it by noise, training on use of EPDs. Education alone is of little value unless it is integrated into the employees daily experiences.

Motivational techniques:

The best motivational resource is the person/s in the HCP who are responsible for direct employee contact, those who fit HPDs, and administer monitoring audiograms. The audiometric evaluation session could be utilized to check the employees EPD for proper fitting cleanliness and signs of deterioration/abuse. Audiogram should be shown to the individual and the results should be explained. Significant threshold shift due to improper EPD should be explained and demonstrated. Reminder on importance of EPD should be given at this time.

Zohar et al used a successful behavioral modification approach. Workers underwent audiometric testing at 500, 2000, 4000 and 6000Hz. Testing occured on randomly selected dates, at the beginning and end of regular shifts. Significant threshold shifts if present at second test, should be explained as temporary hearing loss due to noise. Employees participated in these tests on separate days, wearing hearing protection device one day and none on the other. Audiometric results were also pasted on the department bulletin board. This information feedback procedure demonstrated to the employees the effect of noise on their hearing. The feedback lasted only one month. But successfully modified employees behavior.

Schmidt et al reported a significant observation that provides additional support for their results. They studied employee audiometric record for 10 years. The analysis indicated that females were wearing their EPDs, more effectively and receiving better protection than were the males. Hence proved the link between EPD usage and rate of industrial injuries.

EPD and speech communication and warning signals:

This is an important relation to be considered. EPD provided to cut off noise may also cut off the speech signals. There is a concept on the part of the EPD users that communication is adversely affected. But researchers have something else to say. They report -

1) At moderate levels of noise like 80 dBA, EPDs do not have any effect on speech discrimination.
2) At high noise levels 85 dBA EPDs improve speech discrimination for normal hearing listeners.
3) At low sound noise levels, EPD, with high attenuation values would decrease speech discrimination, both earplug and earmuffs.

But with respect to warning signals, it is found that EPDs have an adverse effect.

Weehinn and Martin (1987) found that wearing of an EPD would disturb the perception of warning sounds, which are of vital importance in certain industrial settings. Hence alternative means of communicating the warning, or the alternative methods of reducing noise exposures are to be thought off.

The amplitude sensitive and frequency sensitive EPDs find their importance in such conditions. However effective an EPD may be, motivation of a worker is equally important for effective protection.

Public awareness and EPD:

Many researchers have suggested an increase in awareness of harmful effects of noise and use of EPD among American public.

Gasaway (1989) reported that EPDs are now available in different hardwares stores, gun shops. The number of manufacturer and designs of EPD have increased.

Some employees, made devices available for home use by employees as well as family members.

Goldstein et al (1987) found young child exposed to loud music played through a personal radio and stereo developed NIHL (Dip at 6 KHz). This study suggested the carrying out of hearing screening in schools and EPD usage among children.

Lass, Woodford et al (1981) - there are differences in high school students knowledge about normal hearing mechanism and hearing loss and about the effect on hearing by over exposure to noise.

Hence HCP should also include educating programmes for high school children, which includes -

1. The normal auditory mechanism
2. Types of hearing loss and their causes
3. Noise and its effects on hearing
4. The warning signs of NIHL
5. Specific recommendations for prevention of NIHL.

MISCONCEPTIONS IN HEARING CONSERVATION PROGRAMMES

Royster and Berger (1988) have talked about possible misconception in a HCP.

1. All audiometric test excepting baline audlometry should be done during workers daily activities. The recommend the use of audiometric data base analysis (ADBA) which helps in identifying the effectiveness of HCP. Here the presence of TTS will not affect the result as it is used to the predict the effectiveness of HCP.

2. The second common misconception largely seen in professional: is that level below 85 dBA can cause NIHL. But studies such as epidemiological data suggest no such presence of hearing loss which can be accountable only by noise. Even the international standard ISO/DIS 1999.22 estimates that regular exposure to 85 dBA for 8 hours per day over a 40 year period causes no NIPTS below 1 KHz, and only 9dB at the most sensitive frequency (i.e. 4 KHz and this is also only in most sensitive portion of population. Therefore, the belief that noise below 85 dBA can cause NIHL baseless.

3. The management over emphasis the importance HPD and NRR but effective protection can only be achieved by taking into consideration other factors such as proper wearing Of EPD etc.

There are studies which indicates that NRR is a poor indicator of HPDs absolute performance, hence for effective HCP more importance should be given for subjective variables such as comfort and economy of EPD which if taken care of increases the employees motivation to use EPD.

4. There is a general tendency among professionals semi-professionals and non-professionals to take HCP as only as a simple SLM measurement and annual hearing measurements. This will lead to poor HCP. An effective HCP should not only gather data but use it for the benefit of employee, specification should include not just a program but a quality programme.

SUMMARY

This study is aimed at viewing the HCP as a whole.

The HCP through it is various steps is aimed at protecting workers in industry from developing NIHL. The programme prevents the management from unjustified claims for compensation. As stated earlier the effective HCP can only be brought about by the cooperation among team members.

As you know HCP is primarily aimed at controlling the noise. It is preferable if the noise can be controlled at source or path level. The various engineering methods are employed for the same purpose. Apart from this even administrative controls can effectively reduce the noise exposure for employees. In both of these cost effectiveness plays an important role.

The audiologist has a major role in the selection of EPD and industrial audiometry. In recent yegrs computers are used for hearing testing in industry to increase efficiency of work and time.

BIBLIOGRAPHY

Aarni, J.D., and Red Field, N.P., (1974), "Attenuation characteristics of recreational helmets", Ann.Otol. Rhinol.Laryngol. 83(1), 119-124.

Action, W.S., (1977), "Problems associated with use of hearing protection", Ann.Occup.Hyg.20(3), 229-246.

Alberti, P.W., (1987), "Hearing conservation past, present, ad Future", Sound Vib. 21(1), 46-49.

American Hearing Health Habits Attitudes (1984 survey). Hearing J. Vol.37, 12, 13-19.

Axelsson, k., Axelsson, A., and Johnson, A (1978), "Aspects on Personal noise protection", Scand.Audiol.7(4), 247-253.

Bebout, J.M., (1987), "OSHA, BLS officials adress NHCA annual meeting", Hearing J.Vol.40, No.6, 30-32.

Bergstrom, B., and Nystrom, B., (1986), "Development of hearing loss during long term exposure to occupational noise", Scand Audiol. 15(4), 227-234.

Botsford, J., (1972), "Ear protectors-their characteristics and uses", Sound and Vibration, 6(24).

Cerale, J.G., Lam, S.T., and Epps, B.W.,(1987), "Rating and ranking methods for hearing protector wearability", Sound Vib.21(12) 10-18.

Cohen, S., Psychol.Today, October, 1981, 38-49.

Council for acreditation in occupational hearing conservation (1978) CAOHC manual. Edited by M.H.Miller, Fischler Printing, Cherry Hill, N.J.

Course material: (1984) - Training programme on industrial hearing conservation: A national model centre for occupational health services", A government of India, (BHEL/UNDP/ILO/Project, Trichirapalli.

Croushore, G.C.Jr. (l977), "An industrial hearing conservation Programm", Hearing instrument, Vol.28, 8-10.

Delgado Paredes, G.A., and Goldstein, D.P., (1987), Noise induced hearing loss in children", The Hearing J. Vol.40, No.2, 33-34.

Eckel, A., (1982),"Industrial hearing conservation standard: Guidelines for meeting new Government requirements" Hearing Instruments, 33: 20-28.

Erlandsson, B., Hakansson, H., Ivarsson, A., and Nilsson, P., (1979),"Comparison between stationery and personal noise dose measuring systems", Acta. Otolaryngol, Suppl. 360, 105-108.

Erlandsson, B., Hakonson, H., Irarsson, A., and Nilsson, P., (1980), "The difference in protection efficiency between earplugs and earmuffs", Scan.Audiol. 9(4), 215-221.

Fishbein, G., (1989) "Records accuracy, access hindered by poor understanding and attitudes". Noise regulation report, Vol.16, 55.

Foltner, K.A., (1984), The case for otoscopic screenings in Industrial hearing conservation", Hearing J. 37(6), 27-30.

Glorig,A., (1982), "Hearing conservation or compliance", Sound and Vib. 5.

Glorig, A., (1980), "Noise: past, present, and future" EAR and hear 1(1), 9-18.

Harris (1957), " C M . (Ed.) Handbook of Noise control, 2nd Ed. McGraw-Hill Book Company, N.Y.

Howell, K., and Martin, A.M., (1975), "An investigation of effects of hearing protectors on vocal communication in noise", J.Sound Vib. 41(2), 181-196.

Imbus, H.R., (1972) "Hearing conservation programmes", Inter-Noise 72, 8-11.

Ivarsson, A., (1980), "Advances in measurement of noise and hearing", Acta Oto-laryngol. Suppl.366, 112

Klockhoff, I., Dsetlner, B., Hagelin, K.W., and Lindholm, L., (1973), A method for computerized classification of pure tone screening audiometry in results in noise exposed group", Actaotolaryngology, 75, 339-340.

Lipscomb, D.M., (1973), Reasons behind the conservation of hearing in industry". Hearing Aid. J.26.

Lass, N.J., Woodword, C M ., Lundern, C., Lundern, D.J., Everly-Myers, D., (1987), "A study of high school students knowledge and wareness of hearing, hearing loss and hearing health". The Hearing J. 40(6), 15-19.

Lipscomb, D.M., Taylor, A.C., (Ed), (1978), "Noise control". Handbook of principles and practices. Van Nostrand Reinhold Company, N.Y.

Lipscomb, D., (Ed), Noise and Audiology, Baltimore, Univ.Park press, 1978, 476.

Lipscomb, M.D., (1980), "Noise and occupational hearing impairment", E.N.T. J., 59(6), 243-250.

Mass,R.B., (1972), Industrial noise and hearing conservation in Handbook of Clinical Audiology, edited by J.Katz, William and Wilkins, Co., Baltimore, M.D.

May,D.N. (Ed), (1978), "Handbook of Noise Assessment", N.Y. Van Nostrand Reinhold Co., 400.

Miller, M.H., (1981) "Occupational hearing conservation". Monographs in Contemporary Audiol. 3(1),

Muller, M.H., (1975), Piffalls and problems of industrial audiometry", Maico Audiol. Lab series, XV, Report 3.

Nilsson, P., (1980), The difference in protection efficiency between ear plugs and earmuffs, Sound Audiol. 9,(41) 215-221

Noise regulation report (1989) Vol.16 (6&7).

Organ, D.L., (1983), "Hearing conservation to be sertomes new project", Hearing Instr. Vol.34(3), 16.

Oyiborhoro, J.M.A., (1983), "Noise induced hearing loss physiologic basis and management", The hearing J., 36(8), 27-30.

Plomp,R., (1963), Soesterberg, Netherlands, Graven DEEL, D.W., and Mimpen, A.M., Relation of hearing loss to noise spectrum, J.Acoust.Soc.Amer, 35, 1234-1240.

Radclyffe, D., (1983), "Preview of OSHA regs sparks", 7th NHCA annual conference. Hearing J. 36(3), 23-26.

Rink, T.L., (1978) Industrial hearing conservation" A medically managed programme, Hearing instruments. 3.

Rink,T.L., (1982), "Industrial hearing conservation of the art", Hearing instruments, 3, 10-51.

Rohe (R.T.A., (1983), Reliability and validity of industrial audiometry", Laryngoscope, 93, 906-927.

Royster, R.M., (1979), Effectiveness of three different types of ear protectors in preventing TTS, J.Acoustc. Soc.Amer. Vol. 66.

Royster L.M., and Royster, J.D., (1980),"Industrial hearing conservation - new consideration". Hearing Instruments, 31: 4-5

Schwartz, H.M., (1988) "Computerized audiometric systems for hearing conservation program". Hearing Instrument, 39(8), 10-12.

Shield, B.M., (1980), "A computer model for the prediction of factory noise", Appl.Acoust.l3(6), 471-486.

Smith, C.R., Wilmoth, J.N., and Boston,T.E., (1980), "Custom molded earplug performance", Aretrospective study, Scand Audiol. 9(2), 113-117.

S/V News Royster, L.H., and Berger, E.H., (1988), "Misconceptions in hearing conservation", Sound Vib. 22: 8-15.

Thomas, S.M., (1976), "An effective hearing conservation programme in industry today",. Inter-noise 76, 161-16

Timplest, W.(Ed) (198S), "The noise handbook". Academic Press Inc, London,

Timoth, L., and Rink, L., (1982), "Industrial hearing Conservation: State of Art", Hear-Instrum.33:10-12.

Thunder, T.D., and Lanford, J.E., (1985), "An easy to use diagram of OSHA noise exposure regulation", sound Vib. 19:24-28.

Waugh, R, (1973), "8BA attenuation of ear protectors", J.Acoust. Soc.Amer.53(2), 440-447.

Wilkins, P., and Martin, A.M., (1987), "Hearing protection and wqrning sounds in industry - A review", Appt. Acoustics, 21(4), 267-293.

Williams, H.N., (1981) " A short history of occupational safety and health legislation", Audiol.Hear.Educ. 6:11-1!

Willoughby, P.J., Mettler, P.C., Conbey, H.D., Mcspaden, J.B., and Johnson, C.E.,(1979) "Hearing loss in forest products industries", Sear Instrum.30(3), 24-25.

Woodford, C.M., (1980) "Notes on audiology in public schools". Hearing Aud.J. 5-9.

Zwislachi, J.,(1957) "Ear protectors" in Harris, CM., (Ed), "Handbook of noise control", N.Y. McGraw-Hill Book Company.